CHARACTERIZATION OF ADVANCED LINES OF BORO RICE (*Oryza sativa* L.)

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CHARACTERIZATION OFADVANCED LINES OF BORO RICE (*Oryza sativa* L.)

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CERTIFICATE

*This is to certify that thesis entitled, "CHARACTERIZATION OF 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 Samia Sharmin Shethee, Registration No. 10-03824under 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.

Dated: June, 2016

Prof. Dr. Md. Sarowar Hossain
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ABSTRACT

The investigation was carried out under field conditions to characterize nine genotypes of advanced lines of Boro rice during the period of Boro season (2015-2016) at the experimental field of Sher-e-Bangla Agricultural University, Dhaka. These nine advanced lines of Boro rice were characterized for 15 qualitative and 20 quantitative traits. All the genotypes were characterized and categorized as per the descriptors developed by Bioversity International, IRRI and WARDA. Among the qualitative characteristics no variation was observed in case of basal leaf sheath color, leaf blade pubescence, ligule shape, culm habit and caryopsis scent and all the genotypes were green, pubescent, 2-cleft type, lodging resistant and non-scented respectively. Only two types of ligule and auricle color viz. whitish and yellowish green were found. Among the nine genotypes, five genotypes viz. G01, G02, G07, G08 and G09 were found having well exerted type panicle. Only two genotypes had awns specifically G02 showed partly awned and G06 showed fully awned character. Among the quantitative characteristics no variation was observed in case of seedling height (30DAS), flag leaf width, leaf senescence and branching of panicle and all the genotypes were short with broad type flag leaf showing late and slow leaf senescence and clustered type panicle. Most of the genotypes showed higher no. of effective tillers, long panicles with higher no. of grains per panicle which would be the agronomic superiority. The average panicle length was 27.59 cm and mean total no. of grain was 218.80 per panicle which contributed to an average yield of 31.35 g per plant. Three genotypes viz. G03, G04 and G05 showed extra long fine rice grain character. All the genotypes except G07 were very high yielding and for maturing time they were late to very late type rice genotypes.

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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	^oC	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.*		

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple food crops of Asia, Africa, and South America, and serves as a primary source of food for more than half of the world population (Khush, 2005). It is belong to the family Poaceae and subfamily Oryzoidea and occupies almost one-fifth of the total land area covered by cereals. It is grown under different climatic conditions and over wide geographical range. Most of the world's rice is cultivated and consumed in Asia which constitutes more than half of the global population. It provides 75% of the calories consumed by more than three billion Asians. Approximately 11% of the world's arable land is under rice cultivation and it ranks next to wheat (Chakravarthi and Naravaneni, 2006).

Asia is said as 'Rice Basket' of the world, as more than 90 percent of the rice is produced and consumed in Asia, a region with high population density. World rice production area was 160.8 million hectares and production was 496.0 million tons (FAO, 2016). Bangladesh is the fourth largest producer of rice in the world with the annual production of 344.95 lac metric tons (BBS, 2016).

According to the BBS report 2015-16, the total area under boro crop has been estimated 1,17,93,512 acres (47,72,576 hectares). Total boro production of Financial Year 2015-16 has been estimated at1,89,37,581 metric tons and average yield rate has been estimated 3.968 metric tons husked rice per hectare, where local, HYV and hybrid variety cultivated area was 0.473 lac hectares, 40.44 lac hectares and 6.82 lac hectares respectively and production was 0.883 lac metric tons, 156.09 lac metric tons and 32.389 lac metric tons respectively.

There are thousands of rice varieties, genotypes, land races and wild species which differ with respect to plant and grain characteristics like plant type, height, nature of leaves, grain size, texture, glutinous nature, aroma, cooking and nutritive quality. Selection of the right type of cultivar is most important factor for optimizing rice production. Although, morphological traits have a number of limitations including low polymorphism, low heritability, late expression and vulnerability to environmental influences then morphological characterization is the first step in the classification and evaluation of the germplasm (Smith *et al.*, 1991; Smith and Smith. 1989).

Agro-morphological characterization of germplasm accessions is fundamental in order to provide information for plant breeding programs (Lin, 1991). Several researchers reported the use of agro-morphological markers in the characterization and study of rice (*Oryza sativa* L.) germplasm diversity. Li *et al.* (2000) obtained consistent results analyzing the correlation between genetic and morphological differentiation in 111 accessions of rice from the Japonica and Indica groups. Yawen *et al.* (2003) studied the genetic diversity on 5285 accessions of indigenous rice in China and found considerable morphological variation among accessions. In India, Patra and Dhua (2003) analyzed the agro-morphological diversity of upland rice and in Vietnam, Fukuoka *et al.* (2006) assessed the variability in agronomic characters among landraces of aromatic rice populations.

Tillering, plant height and panicle morphology are very important agronomic traits that determine grain production of rice. The total number of tillers includes both productive and non-productive tillers. The number of productive tillers determines the number of panicles that eventually affects the yield and total production of the crop. Plant height is mainly determined by the pattern of internode and panicle elongation and it is dependent on cultivars and the environment. For rice plant, upper internodes start successive elongation, while the rest of the lower internodes remain as unelongated during panicle formation in early maturing rice cultivars but in the late maturing cultivars, the internode elongation precedes panicle formation. Therefore, exploring the relationship between internode elongation and the number of internodes is necessary in each of the cultivars (Takeda, 1977).

Qualitative characters are important for plant description (Kurlovich, 1998) and are influenced by consumer preference, socio-economic scenario and natural selection. Several morphological characters are the major determining factors of rice grain yield. Genetic diversity probably serves as an insurance against crop failure (Subba *et al.,* 2001). The understanding of the genetic variability of varieties will provide farmers the opportunity to choose the appropriate variety which may fulfill their need. By definition, genetic diversity is an inherited variation among and between populations, created, activated and maintained by evolution (Demol, 2001). It is a fundamental characteristics without which breeders are very limited and powerless in plants breeding. The study of genetic diversity reposes on adapted and appropriate techniques. Techniques such as plant characterization have been successfully used in recent years to help in identifying elite individuals. It is an indispensable tool for selecting varieties or lines based on agronomical, morphological, genetic or physiological characters (Ndour, 1998). Characterization is the technique used to evaluate the phenotypic diversity through agro-morphological traits (Bajracharya *et al.,* 2006). Many studies on genetic diversity using agro-morphological characterization have been conducted and it led to the identification of the phenotypic variability in rice (Barry *et al.,* 2007; Bajracharya *et al*., 2006 and Ogunbayo *et al*., 2005).

Bangladesh Rice Research Institute (BRRI) developed 82 rice varieties including modern and hybrid varieties. Aromatic and fine rice are high in demand. Rice of Boro season takes long life cycle though its yield is higher than other seasons rice varieties. However, now we should be more concentrated on quality of rice like nutrition, aroma etc. as we are almost self-sufficient in rice production. The major limitations of these seasons rice are the photosensitivity, long term dormancy, long life cycle, susceptibility to disease and pest and ultimate low yield.

For development of high yielding rice variety, the crossing between two cultivar having specific desirable characters produces numerous individuals. The superior type individuals are then sorted and cultivated as advanced lines. Characterization and evaluation of these advanced lines is the prerequisite to develop new rice variety. It will pave the ways for further breeding programs. Thus the present investigation was undertaken with the following objectives:

1. To characterize rice germplasms as per descriptors used for rice.
2. To find out fine rice genotypes with their different growth parameters and yield contributing characters for release as new variety.
3. To find out the genotypes which have potential traits for using in further breeding programs as parent material.

CHAPTER II

REVIEW OF LITERATURE

The literature relevant to the present investigation entitled “Characterization of advanced lines of boro rice (*Oryza sativa L.*)” through morphological characters has been reviewed in this section under the following subheads:

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 a non-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.

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 2015 to May 2016. 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

Nine rice genotypes were used in the study. The seeds of 9 genotypes were collected from germplasm centre of Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University. Descriptions of the genotypes are given in Table l.

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 9 plots where genotypes were randomly assigned. The experimental field size was 26m x 16mwhere

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 9 genotypes were distributed to each plot within each block randomly.

Table 1. List of the genotypes used for the experiment

Genotype No.	Accession No.
G01	(21)AL-42
G02	(28)AL-18
G03	(38)Special from AL-29
G04	(39)AL-33
G05	(43)Special from-129
G06	(48)Special from 179(III)B
G07	(54)Special from AL-36
G08	(57)AL-29
G09	(58)AL-36

G=Genotype

3.5 Raising of seedling

Seeds of all collected rice genotypes were sown on 14 December, 2015 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 14 January 2016 in separate strip of experimental field. Water level was maintained properly after transplanting.

3.9 Intercultural operation and after care

Necessary gap filling was done within 7 days of transplanting. The crop was kept weed free throughout the growing period. Hand weeding was done at 20 and 35 days after transplanting. Flood irrigation was given to the field regularly.

3.10 Plant protection measure

Adequate control measures were taken against rice stem borer during tillering and heading stage of rice. Furadan 5G @ 1 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.

3.11 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. Fourteen qualitative and seventeen quantitative traits were recorded using the descriptors developed by Bioversity International, IRRI and WARDA, 2007. The descriptors are appended at the appendix IV. 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 regularly in every day and required data were collected as per schedule. An appropriate data record book was used for keeping records of data related to identification of the genotypes. Rice Descriptors developed by the Bioversity International, IRRI and WARDA, 2007. Appendix II were used for data collection and recording. The photographs of specific trait were taken from the experimental field at appropriate times for different traits to compare the distinctness among the rice genotypes. Photographs and data related to distinctness in morphological traits were taken on each of the 9 rice genotypes. This was done particularly to find out the expression of the qualitative traits of the genotypes when grown under constant environment.

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 and 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 and Dark green-7.

3.11.1.3 Leaf blade attitude

Leaf blade attitude refers the position of the tip of the blade relative to its base, scored on the leaf below the flag leaf at late vegetative (prior to heading) stage and rice genotypes were classified into three groups with codes according to guided descriptors as Erect-1, Horizontal-5 and Drooping-7.

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 andPubescent-3.

3.11.1.5 Ligule shape

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 and two-cleft-3 which are also shown hypothetically in Figure 1.

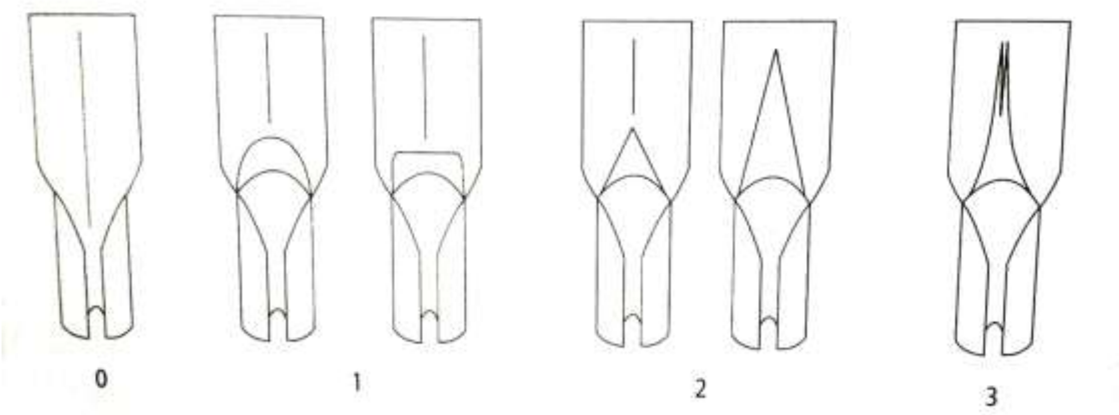

Figure 1. Ligule shape

3.11.1.6 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 and Purple lines-5.

3.11.1.7 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 and Purple-3.

3.11.1.8 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 and Descending-7which are also shown hypothetically in Figure 2.

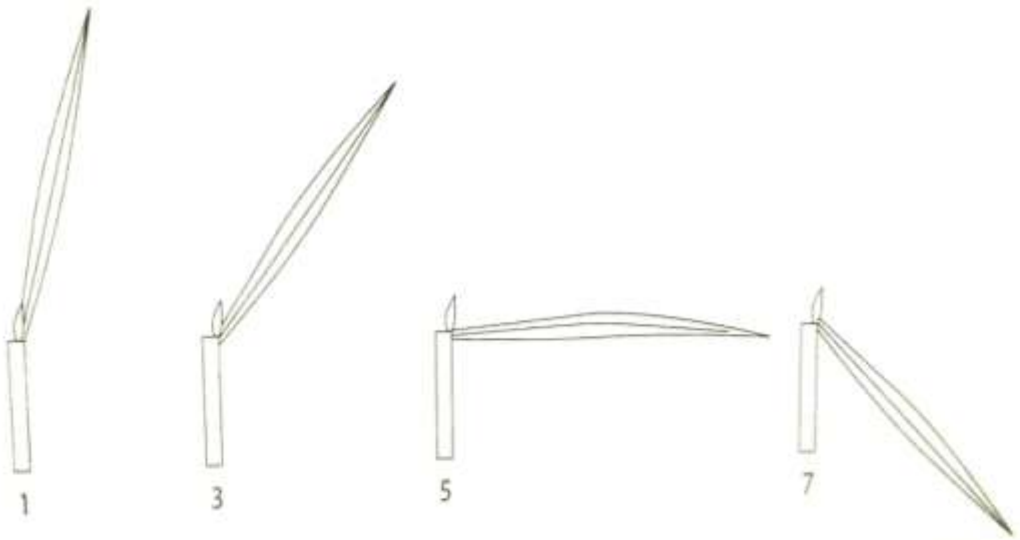

Figure 2. Flag leaf attitude

3.11.1.9 Culm habit

Culm habit indicate the average angle of inclination of the base of the main culm from vertical. 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 and Procumbent (culm or its lower part rests on ground surface)-9 which are shown in Figure 3.

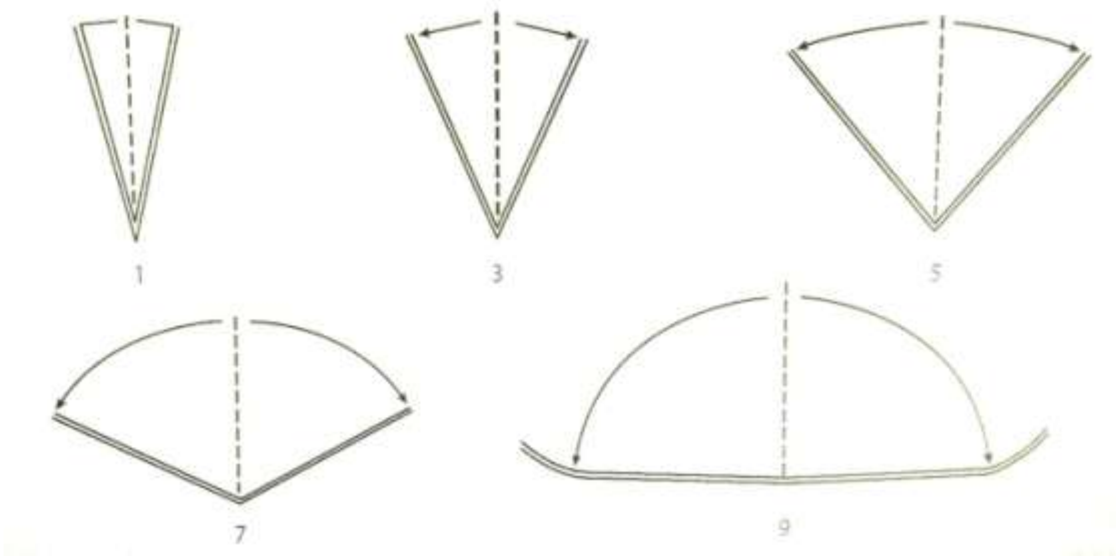

Figure 3. Culm habit

3.11.1.10 Culm: lodging resistance

It was observed at maturity stage and based on the degree of lodging it was categorized into five groups as Very weak -1 (all plants flat), Weak-3 (most plants nearly flat), Intermediate-5 (most plants leaning about 45°), Strong- 7 (most plants leaning about 20° from vertical) and Very strong-9 (all plants vertical).

3.11.1.11 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 and Drooping-9 which are shown in Figure 4.

Figure 4. Attitude of panicle branches

3.11.1.12 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 and Well Exerted-9.

3.11.1.13 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 and Black-5.

3.11.1.14 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 and Scented-2.

3.11.1.15 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 and Fully awned-2.

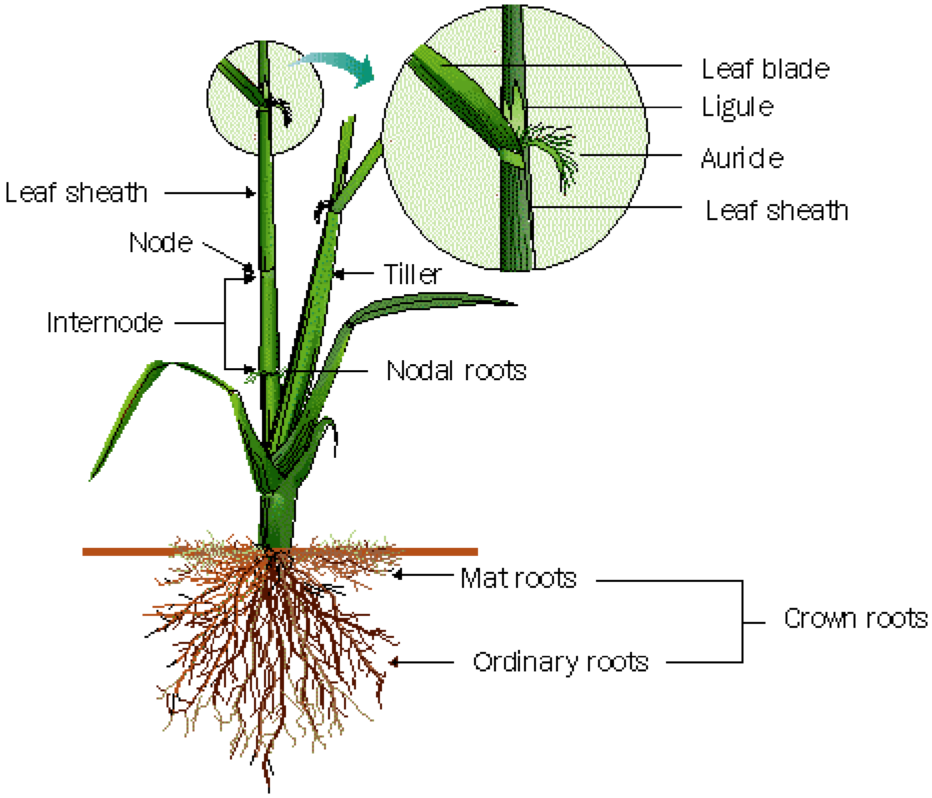

Figure 5. Morphology of a rice plant (vegetative stage)

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, Lightpurple-3, Purple-4
2	Green color intensity of leaf blade	No green-0, Light green-3, Medium green-5, Dark green-7
3	Leaf blade attitude	Erect-1, Horizontal-5, Drooping-7
4	Leaf blade pubescence	Glabrous-1, Intermediate-2, Pubescent-3
5	Ligule shape	Absent-0, Truncate-1, Acute to acuminate-2, two-cleft-3
6	Ligule color	Absent (ligule less)-0, Whitish-1, Yellowishgreen-2, Purple-3, Light purple-4, Purplelines-5
7	Auricle color	Absent (no auricles)-0, Whitish-1, Yellowish green-2, Purple-3
8	Flag leaf attitude	Erect-1, Semi-erect (intermediate)-3,Horizontal-5, Descending-7
9	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
10	Culm: lodging resistance	Very weak -1, Weak-3 , Intermediate-5, Strong-7,Very strong-9
11	Panicle: attitude of branches	Erect (compact panicle)-1,Semi-erect (semi-compact panicle)-3, Spreading (open panicle)-5, Horizontal-7 Drooping-9
12	Panicle: exertion	Enclosed-1, Partly exerted-3, Just Exerted-5, Moderately Exerted-7, Well Exerted-9
13	Lemma and palea color (grain color)	Straw-1, Golden-2, Purple-4, Black-5
14	Caryopsis scent	Non-scented-0, Lightly scented-1, Scented-2
15	Presence of awns	Absent-0,Partly awned-1, Fully awned-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 Seedling height (30 DAS)

The average height of the 5 plants from the plant base to the tip of the leaf was calculated in centimeters at 30 days after sowing (30DAS). According to their length, the observed genotypes depending on their length were classified into three different categories as 3 -Short (<30 cm), 5- Intermediate (31-40 cm) and 7- Tall (>60 cm).

3.11.2.2 Flag leaf length

The flag length was measured in centimeter scale from the jointing point of flag leaf and panicle to the tip point of flag leaf after panicle initiation and categorized as 1-Very short (<21 cm), 3-Short (21-30 cm), 5-Intermediate (31-50 cm), 7-Long (51-80 cm) and 9-Very long (>80 cm).

3.11.2.3 Flag leaf width

Flag leaf width was measured in cm scale at the middle of flag leaf after panicle initiation and categorized as 3-Narrow (<1 cm), 5-Intermediate (1-1.5cm) and 7-Broad (>2 cm).

3.11.2.4 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) and 9-Very long (>180 cm).

From figure-6, we can see the way to measure the culm length of a rice plant.

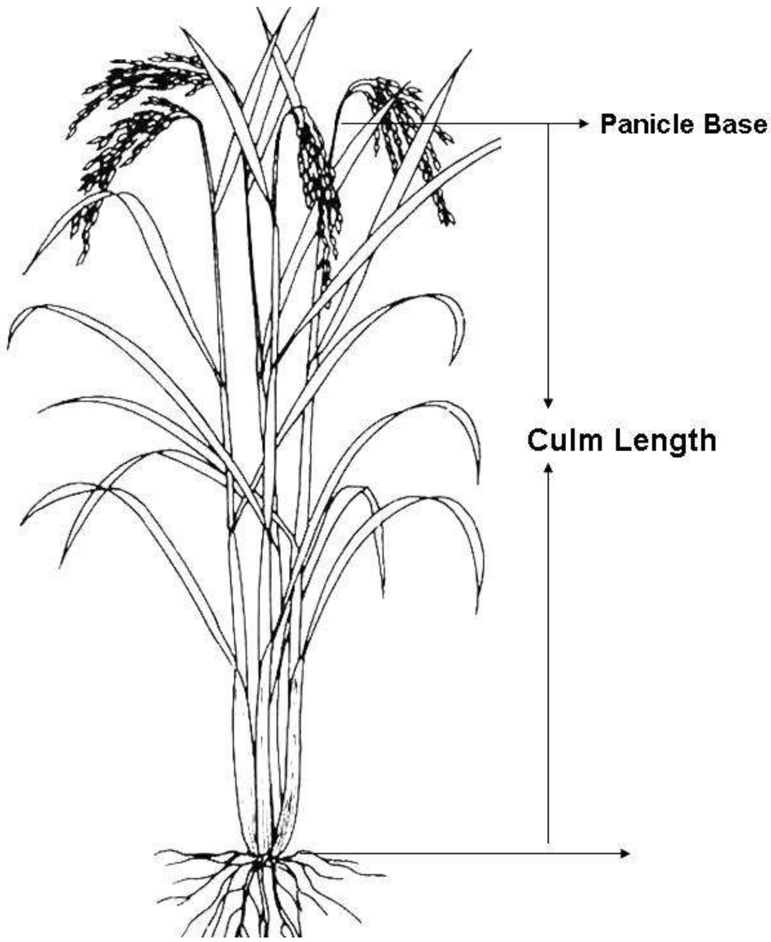

Figure 6. Culm length

3.11.2.5 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) and 7- Very Large (>7.0 mm).

3.11.2.6 Tillers per hill

The total number of tillers was counted from each of the sample plants or hills and the average was taken. Based on this character, all the genotypes were grouped as 3- Low (<10 culms), 5-Intermediate (11-15 culms) and 7-High (>20 culms).

3.11.2.7 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) and 7- High (>15 culms).

3.11.2.8 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) and 9- Very long (>35cm).

3.11.2.9 Branching of panicle

The number of total primary branches per particle was counted and recorded at maturity and then total number of secondary branches per panicle was also counted and recorded. Branching of panicle indicates the ratio of secondary branches to primary branches per panicle and all the genotypes were grouped into three groups as 0-Absent, 1-Sparse (~1 secondary branch per primary branch), 2- Dense (~2-3 secondary branches per primary branch) and 3-Clustered (~3-4 secondary branches per primary branch) which are shown in figure-7.

3.11.2.10 Number of filled grains per panicle

The number of filled grains of five randomly selected panicles of main tillers from five hills was recorded and then averaged. According to number of filled grain, the observed genotypes were classified into four different categories as 1- Few (<150), 3-Medium (151-200), 5- Many (201-300) and 7- So Many (>301). From figure-7, we can see the branching of panicle of a rice plant.

Figure 7. Branching of panicle

3.11.2.11 Number of unfilled grains per panicle

The number of unfilled grains of five randomly selected panicles of main tillers from five hills was recorded and then averaged. The observed genotypes were classified into three different categories as 1-Few (<30), 3-Medium (31-50) and 5-Many (>51).

3.11.2.12 Total number of grains per panicle

Total number of grain was measured by adding the total number filled and unfilled grains per panicle and the observed genotypes were classified into three different categories as 1-Few (<200), 3-Medium (201-300), 5-Many (301-350) and 7-So Many (>351).

3.11.2.13 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) and 7-High (24-27g).

3.11.2.14 Days to main heading (80%)

The number of days from date of sowing to the 80% plants with heading in the plots was recorded on each individual plot and replication and the genotypes were classified as 1-Early (<80 Days), 3-Medium (81-100 Days), 5-Late (101-125 Days) and 7-Very Late (>125 Days).

3.11.2.15 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-Early (<95 Days), 3-Medium (96-120 Days), 5-Late (121-140 Days) and 7-Very Late (9>4 Days).

3.11.2.16 Leaf senescence

Penultimate leaves are observed at the time of harvest and observed whether any leaves were retained green color or not. Here our observed genotypes were grouped into three categories as 1-Late and slow (2 or more leaves retain green color at maturity), 5-Intermediate (1-2 leaves retain green color at maturity) and 9-Early and fast (all leaves are dried at maturity).

3.11.2.17 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) and 7-Extra Long (>7.51 mm).

3.11.2.18 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) and 5-Coarse (>3 mm).

3.11.2.19 Yield per plant

Panicles of randomly selected plants per replication were threshed, seeds were sun dried for two days and weighed and then averaged. Seed yield was adjusted at 12% moisture content. The genotypes were categorized into three different groups based on seed yield per plant as 1-Low (<20g), 3-Medium (20-27g) and 5-High (>27).

3.11.2.20 Yield per square meter area

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) and 5-High (>650g).

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Table 3. Descriptors with codes for quantitative characteristics

SL. No.	Characteristics	Descriptors with codes
1	Seedling height (30 DAS)	3-Short (<30 cm), 5- Intermediate (~45 cm),7- Tall (>60 cm)
2	Flag leaf length	1- Very short (<21 cm), 3- Short (~30 cm), 5- Intermediate (~50 cm), 7- Long (~70 cm), 9-Very long (>80 cm)
3	Flag leaf breath	3- Narrow (<1 cm), 5- Intermediate,7- Broad (>2 cm)
4	Culm length	1-Very short (<50 cm), 2-Very short to short (51-70 cm), 3-Short (71-90cm), 4- Short to intermediate (91-105cm), 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)
5	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)
6	Tillers per hill	3- Low (<10 culms), 5 -Intermediate (~15culms), 7 -High (>20 culms)
7	Effective tillers per hill	3 -Low (<7 culms), 5- Intermediate (~10culms), 7- High (>15 culms)
8	Panicle length	1- Very short (<11 cm), 3- Short (~15 cm), 5-Medium (~25 cm), 7- Long (~35 cm), 9- Very long (>40 cm)
9	Branching of panicle	0- Absent, 1-Sparse (~1 secondary branch per primary branch), 2- Dense (~2-3 secondary branches per primary branch), 3-Clustered (~3-4 secondary branches per primary branch)
10	No. of filled grains per panicle	1-Few (<150), 3-Medium (151-200), 5-Many (201-300), 7-So Many (>301)
11	No. unfilled grains per panicle	1-Few (<30), 3-Medium (31-50), 5-Many (>50)
12	Total no. of grains per panicle	1-Few (<200), 3-Medium (201-300), 5-Many (301-350), 7-So Many (>351)
13	Thousand seed weight(dry)	1-Very low (<15g), 3-Low (16-19g), 5-Medium (20-23g), 7-High (24-27g)
14	Days to main heading (80%)	1-Early (<80), 3-Medium (81-100), 5-Late (101-125), 7-Very Late (>125)
15	Days to maturity	1-Early (<95), 3-Medium (96-120), 5- Late (121-140), 7-Very Late (>141)
16	Leaf senescence	1-Late and slow (>2 leaves), 5- Intermediate (1-2 leaves), 9-Early and fast (0 green leaf)

Table 3. (cont'd)

17	Grain length (mm)	1- Short (<5.50), 3- Medium (5.51-6.5), 5- Long (6.51-7.5), 7- Extra Long (>7.51)
18	Grain width (mm)	1-Fine (<2.5), 3-Medium (2.51-3), 5- Coarse (>3)
19	Yield per plant	1-Low (<20g), 3-Medium (20-27g), 5- High (>27)
20	Yield per square meter area	1-Low (<450 g), 3-Medium (450-600 g), 5-High (>600 g)

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

3.11.3 Statistical application

The qualitative and quantitative data in relation to morphological traits are just presented in tabular form for easier description according to the descriptors developed by Bioversity International, IRRI and WARDA, 2007. The data were arranged as per IBPGR-IRRI formulation with the help of Microsoft-XL program and were not needed to statistical analysis

CHAPTER IV

RESULTS AND DISCUSSION

The study was conducted with a view to characterizing and evaluating nine advanced lines of boro rice as per the guided descriptors developed by Bioversity International, IRRI and WARDA, 2007. Twenty quantitative and fifteen qualitative characters were observed. Results have been compiled in tabular form according to descriptors and described by qualitative and quantitative characteristics.

4.1 Qualitative characteristics evaluation

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 as presented in Table 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 3 genotypes (G07, G08 and G09) were shown medium green color and 6 genotypes (G01, G02, G03, G04, G05 and G07) were shown dark green color of leaf blade. No green and light green color type leaf blade were found (Table 5).

4.1.3 Leaf blade attitude

Based on leaf blade attitude our observed genotypes were categorized into 3 groups as Erect-1, Horizontal-5 and Drooping-7 nature (Table 6). Here no drooping types of leaf blade were found. Here six genotypes (G01, G02, G05, G07, G08 and G09) were

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
Green with purple lines	2	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	G07 G08 G09
Dark green	7	G01 G02 G03 G04 G05 G06

Table 6. Categorization and grouping based on leaf blade attitude

Types	Code	Genotypes
Erect	1	G01 G02 G05 G07 G08 G09
Horizontal	5	G03 G04 G06
Drooping	7	Nil

erect type and three genotypes (G03, G04 and G06) were horizontal type in nature presented in Table 6.

4.1.4 Leaf blade pubescence

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

4.1.5 Ligule shape

On the basis of ligule shape, rice genotypes were classified as Absent-0, Truncate-1, Acute to acuminate-2 and two cleft-3. But our all genotypes were 2-cleft type that means there was no significant difference among the genotypes (Table 8). According to IRRI most of the cultivated rice have 2-cleft type ligule shape and wild type genotypes may show other types. From our observation the 2-ceft type ligule were found (Plate 2).

4.1.6 Ligule color

According to Bioversity International, IRRI and WARDA, 2007, 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. whitish (Plate 3) and yellowish green (Plate 4) were found among our nine genotypes. Six genotypes (G01, G02, G03, G05, G08 and G09) had whitish type and three genotypes (G04, G06 and G07) had yellowish green type ligule (Table 9).

4.1.7 Auricle color

According to Bioversity International, IRRI and WARDA, 2007, descriptors for wild and cultivated rice, cultivated rice were categorized into 4 groups as- Absent (ligule

Table 7. Categorization and grouping based on leaf blade pubescence

Types	**Code**	**Genotypes**
Glabrous	1	Nil
Intermediate	2	Nil
Pubescent	3	G01 G02 G03 G04 G05 G06 G07 G08 G09

Table 8. Categorization and grouping based on ligule shape

Types	**Code**	**Genotypes**
Absent	0	Nil
Truncate	3	Nil
Acute to acuminate	5	Nil
2-Cleft	7	G01 G02 G03 G04 G05 G06 G07 G08 G09

Table 9. Categorization and grouping based on ligule color

Types	**Code**	**Genotypes**
Absent	0	Nil
Whitish	1	G01 G02 G03 G05 G08 G09
Yellowish green	2	G04 G06 G07
Purple	3	Nil
Light Purple	4	Nil

Plate 1. Pubescent type leaf blade

Plate 2. Real view of 2-cleft type Ligule

Plate 3. Whitish color ligule

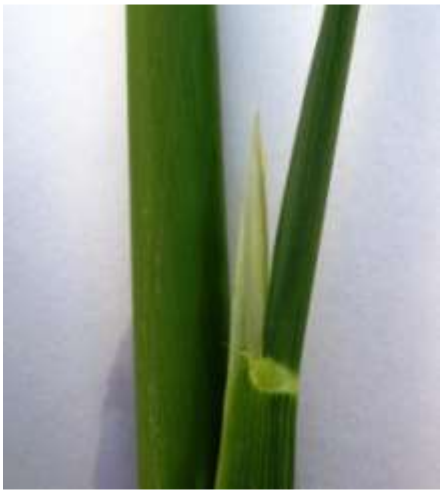

Plate 4. Yellowish green color ligule

less)-0, Whitish-1, Yellowish green-2, and Purple-3. Here only 2 types of auricle color viz. whitish and yellowish green were found among our nine genotypes. Six genotypes (G01, G02, G03, G05, G08 and G09) had whitish type and three genotypes (G04, G06 and G07) had yellowish green type auricle (Table 10). From Plate-5 and Plate-6 we can see yellowish green color and whitish color auricle respectively.

4.1.8 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 7 genotypes (G01, G02, G05, G06, G07, G08 and G09) had erect type flag leaf, 2 genotypes (G03 and G04) had semi-erect type flag leaf (Table 11).

4.1.9 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 (G01, G05, G06, G08 and G09) showed erect type and 4 genotypes (G02, G03, G04 and G07) showed semi-erect type in nature but open, spreading and procumbent type culm were not found in any genotypes (Table 12). From Plate-7 and Plate-8 we can see erect and semi-erect type of culm habit respectively.

4.1.10 Culm: lodging resistance

It was scored at maturity based on the observed degree of lodging. Based on culm lodging resistance the observed genotypes were categorized into 5 groups as Very weak -1, Weak-3, Intermediate-5, strong-7 and Very strong-9 type. Here all the genotypes were lodging resistant and grouped under very strong category (Table 13).

Table 10. Categorization and grouping based on auricle color

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

Table 11. Categorization and grouping based on flag leaf attitude

Types	Code	Genotypes
Erect	1	G01 G02 G05 G06 G07 G08 G09
Semi-erect	3	G03 G04
Horizontal	5	Nil
Horizontal	7	Nil

Table 12. Categorization and grouping based on culm habit

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

Table 13. Categorization and grouping based on lodging resistance

Types	Code	Genotypes
Very weak	1	Nil
Weak	3	Nil
Intermediate	5	Nil
Strong	7	Nil
Very strong	9	G01 G02 G03 G04 G05 G06 G07 G08 G09

Plate 5. Yellowish green color auricle

Plate 6. Whitish color auricle

Plate 7. Erect type culm habit

Plate 8. Semi-erect type culm habit

4.1.11 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 one genotype (G07) showed spreading type, one genotype (G06) showed horizontal type panicle and rest 7 genotypes (G01, G02, G03, G04, G05, G08 and G09) showed drooping type panicle. Erect and semi-erect type panicles were not found among the genotypes (Table 14)**.** Plate-9 and Plate-10 shows horizontal type and drooping type panicle respectively.

4.1.12 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 two genotypes (G03 and G05) were found just exerted, two genotypes (G04 and G06) were moderately exerted and five genotypes (G01, G02, G07, G08 and G09) were well exerted (Table 15). From Plate-11, Plate-12 and Plate-13 we can see the Just exerted, Moderately exerted and Well exerted panicle respectively.

4.1.13 Lemma and palea color (grain 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 case among our observed genotypes, four genotypes (G02, G03, G04 and G06) were straw type, and five genotypes (G01, G05, G07, G08 and G09) were golden type seed coat color (Table16).

Table 14. Categorization and grouping based on panicle attitude of branches

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

Table 15. Categorization and grouping based on panicle exertion

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

Table 16. Categorization and grouping based on grain color

Types	Code	Genotypes
Straw	1	G02 G03 G04 G06
Golden	2	G01 G05 G07 G08 G09
Purple	4	Nil
Black	5	Nil

Plate 9. Horizontal type panicle

Plate 10. Drooping type panicle

Plate 11. Just exerted panicle

Plate 12. Moderately exerted panicle

Plate 13. Well exerted panicle

From Plate-14 and Plate-15 we can see the straw type and golden type of grain color respectively and from Plate-16 we can see the grain color of 9 genotypes at a glance.

4.1.14 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. However details aroma detecting method has been described in materials and method part of this thesis. 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 non-scented type (Table 17).

4.1.15 Presence of Awns

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 one genotype (G06) was fully awned, one genotype (G02) was partly awned and rest seven genotypes (G01, G03, G04, G05, G07, G08 and G09) had no awns (Table 18). From Plate-17 and Plate-18 we can see the fully awned and partly awned genotypes respectively.

4.2 Quantitative Characteristics Evaluation

4.2.1 Seedling height (30 DAS)

Seedling height was measured from the base of the shoot to the tip of the tallest leaf blade at 4-5 leaf stage 30 days after sowing (30 DAS). Seedling height of observed genotypes ranged from 20.53 cm (G07) to 23.58 cm (G04) with a mean value of 22.41 cm (Table-19 and Appendix-II). On the basis of this character, the genotypes were categorized into three groups as Short (<30 cm), Intermediate (31-40 cm) and Tall

Table 17. Categorization and grouping based on caryopsis scent

Types	Code	Genotypes
Non-scented	0	G01 G02 G03 G04 G05 G06 G07 G08 G09
Lightly scented	1	Nil
Scented	2	Nil

Table 18. Categorization and grouping based on presence of awns

Types	Code	Genotypes
Absent	0	G01 G03 G04 G05 G07 G08 G09
Partly awned	1	G02
Fully awned	2	G06

Table 19. Categorization and grouping based on seedling height (30DAS)

Groups	Scale	Code	Genotypes
Short	<30 cm	3	G01 G02 G03 G04 G05 G06 G07 G08 G09
Intermediate	31-40 cm	5	Nil
Tall	>40 cm	7	Nil
Range	(G07) 20.53 cm - (G04) 23.58 cm		
Average	22.41 cm		

Plate 14. Straw color grain

Plate 15. Golden color grain

Plate 16. Seed coat (grain) color observed in 9 genotypes

Plate 17. Fully awned grain

Plate 18. Partly awned grain

(>40 cm) and has been presented in Table 18. Here all the genotypes were short type (Table 19).

4.2.2 Flag leaf length

Flag leaf length was measured from the jointing point of panicle and flag leaf to tip of flag leaf. Flag leaf length of observed genotypes ranged from 28.91 cm (G07) to 46.24 cm (G04) with a mean value of 41.32 cm (Appendix-II). On the basis of this character, the genotypes were categorized into 5 groups as Very short (<21 cm), Short (21-30 cm), Intermediate (31-50 cm), Long (51-70 cm) and Very long (>70 cm) as the guided descriptors. Here only one genotype (G07) was short type, and rest 8 genotypes (G01, G02, G03, G04, G05, G06, G08 and G09) were intermediate type (Table 20). From the Plate-19 we can see a short type flag leaf.

4.2.3 Flag leaf width

Flag leaf width of observed genotypes ranged from 1.67 cm (G07) to 2.77 cm (G02) with a mean value of 2.22 cm (Appendix-II). On the basis of this character, the genotypes were categorized into three groups as Narrow (<1 cm), Intermediate (1-1.5 cm) and Broad (>1.5 cm) as the guided descriptors where all the genotypes were broad types (Table 21). From the Plate-20 we can see a broad type flag leaf.

4.2.4 Culm length

Culm length means the length of a stem from ground level to panicle base. Culm lengths of observed genotypes ranged from 54.37 cm (G07) to 74.23 cm (G04) with a mean value of 66.61 cm (Table 22 and Appendix-II). 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

Table 20. Categorization and grouping based on flag leaf length

Groups	Scale	Code	Genotypes
Very short	<21 cm	1	Nil
Short	21-30 cm	3	G07
Intermediate	31-50 cm	5	G01 G02 G03 G04 G05 G06 G08 G09
Long	51-70 cm	7	Nil
Very long	>70 cm	9	Nil
Range	(G07) 28.91 cm - (G04) 46.24 cm		
Average	41.32 cm		

Table 21. Categorization and grouping based on flag leaf width

Groups	Scale	Code	Genotypes
Narrow	<1 cm	3	Nil
Intermediate	1-1.5 cm	5	Nil
Broad	>1.5 cm	7	G01 G02 G03 G04 G05 G06 G07 G08 G09
Range	(G07) 1.67 cm- (G02) 2.77 cm		
Average	2.22 cm		

Table 22. 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	G01 G02 G03 G06 G07 G09
Short	71-90cm	3	G04 G05 G08
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	(G07) 54.37 cm - (G04) 74.23 cm		
Average	66.61 cm		

Plate 19. Short type flag leaf

Plate 20. Broad type flag leaf

were six genotypes (G01, G02, G03, G06, G07 and G09) belongs to very short to short category and three genotypes (G04, G05 and G08) belongs to short category presented in table-22. From the figure-8, 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.

4.2.5 Culm diameter

Culm diameter was measured from mother tillers in the lowest internode. From our observed genotypes, it was ranged from 4.15 mm (G07) to 6.54 mm (G02) with a mean value of 5.88 mm (Appendix-II). 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 five genotypes (G02, G03, G05, G08 and G09) belongs to large category, three genotypes (G01, G04 and G06) belongs to medium category and only one genotype (G07) belongs to small category (Table 23).

4.2.6 Total number of tillers per hill

The total number of tillers per plant of 9 genotypes ranged from 13.92 (G06) to 28.87 (G05) with a mean value of 21.29 (Appendix-II). Based on this character, the observed genotypes were identified as few (<10), medium (11-15) and high (>15) number of tillers per plant. From our observed genotypes we can see that two genotypes (G06 and G09) belongs to intermediate category and rest seven genotypes (G01, G02, G03, G04, G05, G07 and G08) belongs to high category (Table 24).

4.2.7 Effective tillers per hill

The number of effective tillers per plant of the observed genotypes ranged from 11.77 (G06) to 25.13 (G05) with a mean value of 18.81 (Table 25 and Appendix-II) and considering this character, the observed genotypes were categorized as low (<7), intermediate (8- 12) and high (>12) effective tillers per plant. From the observed

Table 23. Categorization and grouping based on culm diameter

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

Table 24. Categorization and grouping based on total number of tillers per hill

Groups	Scale	Code	Genotypes
Low	<10 culms	3	Nil
Intermediate	11-15 culms	5	G06 G09
High	>15 culms	7	G01 G02 G03 G04 G05 G07 G08
Range	(G06) 13.92 - (G05) 28.87 culms		
Average	21.29 culms		

Table 25. Categorization and grouping based on effective tillers per hill

Groups	Scale	Code	Genotypes
Low	<7 culms	3	Nil
Intermediate	8-12 culms	5	G06 G09
High	>12 culms	7	G01 G02 G03 G04 G05 G07 G08
Range	(G06) 11.77 - (G05) 25.13 culms		
Average	18.81 culms		

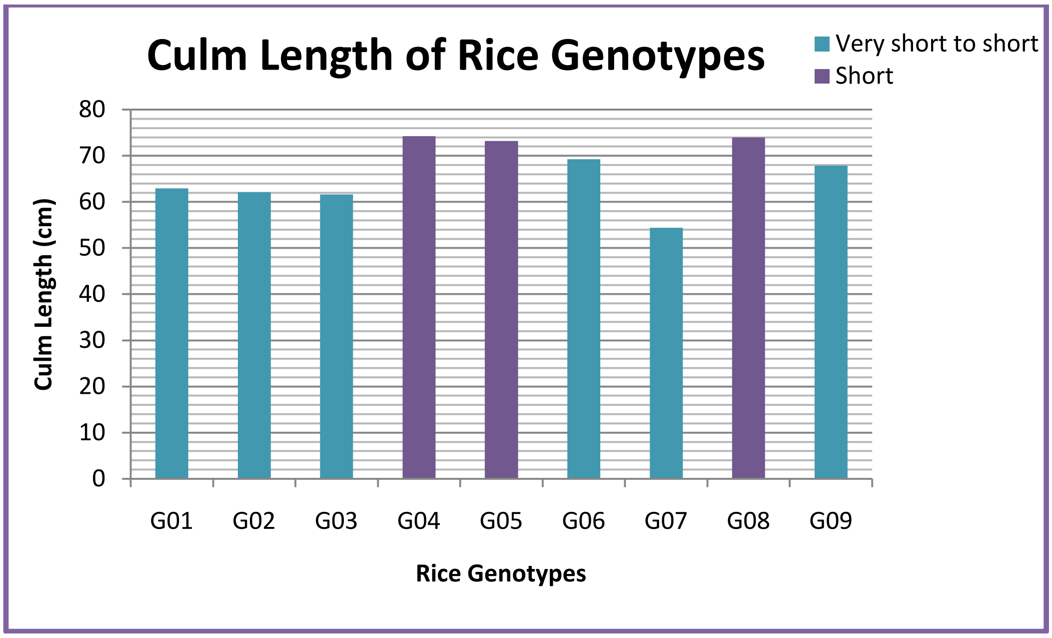

Figure 8. Grouping of observed genotypes based on culm length

genotypes we can see that two genotypes (G06 and G09) belongs to intermediate category and rest seven genotypes (G01, G02, G03, G04, G05, G07 and G08) belongs to high category (Table 25).

4.2.8 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 23.12 cm (G07) to 31.70 cm (G05) with a mean value of 27.59 cm (Appendix-II) 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 two genotypes (G01 and G07) were under Medium group and rest seven genotypes (G02, G03, G04, G05, G06, G08 and G09) were under Long group and other types of panicle were not found (Table 26).From the figure-9 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.

4.2.9 Branching of panicle

This character indicates primary and secondary branching of the panicle and based on primary and secondary branching our observed genotypes were classified into 4 groups (Table 27) where every genotypes showed primary branching and grouping were followed actually by secondary branching as absent, dense, clustered sparse type. All the genotypes were clustered type and average secondary branches per primary branch was 4.24 where G05 showed highest (4.38) secondary branching and G01 showed lowest (3.99) secondary branching (Appendix-II).

Table 26. 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 G07
Long	26-35 cm	7	G02 G03 G04 G05 G06 G08 G09
Very long	>35 cm	9	Nil
Range	(G07) 23.12 cm - (G05) 31.70 cm		
Average	27.59 cm		

Table 27. Categorization and grouping based on branching of panicle

Groups	Scale	Code	Genotypes
Absent	0	0	Nil
Sparse	1	1	Nil
Dense	2-3	2	Nil
Clustered	>3	3	G01 G02 G03 G04 G05 G06 G07 G08 G09
Range	(G01) 3.99 - (G05) 4.38		
Average	4.24		

4.2.10 Number of filled grains per panicle

The number of filled grains per panicle ranged from 101.43 (G1) to 280.77 (G05) with a mean value of 180.78 (Appendix-II). On the basis of this character, the genotypes were grouped as few (<150), medium (150-200), many (201-300) and so many (>301) where three genotypes (G01, G02 and G07) were recorded as Few, three genotypes (G04, G06 and G08) as Medium and three genotypes (G03, G05 and G09) as Many category (Table 28).

4.2.11 Number of unfilled grains per panicle

The number of unfilled grains per panicle ranged from 24.6 (G09) to 65.3 (G05) with a mean value of 38.01 (Appendix-II). On the basis of this character, the genotypes were grouped as few (<30), medium (31-50) and many (>51) number of unfilled grain per panicle. Here four genotypes (G01, G02, G07 and G09) belong to Few, three genotypes (G04, G06 and G08) belongs to Medium and two genotypes (G03 and G05) belongs to Many category (Table 29).

4.2.12 Total number of grains per panicle

The total number of grains per panicle ranged from 130.13 (G01) to 346.07 (G05) with a mean value of 218.80 (Appendix-II). On the basis of this character, the genotypes were grouped as few (<200), medium (201-300), many (301-350) and so many (>351) where three genotypes (G01, G02 and G07) were under few group, five genotypes (G03, G04, G06, G08 and G09) were under medium group and only one genotype (G05) was under many group (Table 30). From the figure-10 we can distinguish different groups of observed genotypes based on total no. of grains per panicle where genotypes and grain numbers has been presented in horizontal and vertical axis respectively

Table 28. Categorization and grouping based on no. of filled grains per panicle

Groups	Scale	Code	Genotypes
Few	<150	1	G01 G02 G07
Medium	151-200	3	G04 G06 G08
Many	201-300	5	G03 G05 G09
So many	>300	7	Nil
Range	(G01) 101.43 - (G05) 280.77		
Average	180.78		

Table 29. Categorization and grouping based on no. of unfilled grains per panicle

Groups	Scale	Code	Genotypes
Few	<30	1	G01 G02 G07 G09
Medium	31-50	3	G04 G06 G08
Many	>51	5	G03 G05
Range	(G09) 24.6 - (G05) 65.3		
Average	38.01		

Table 30. Categorization and grouping based on total no. of grains per panicle

Groups	Scale	Code	Genotypes
Few	<200	1	G01 G02 G07
Medium	201-300	3	G03 G04 G06 G08 G09
Many	301-350	5	G05
So many	>351	7	Nil
Range	(G01) 130.13 - (G05) 346.07		
Average	218.80		

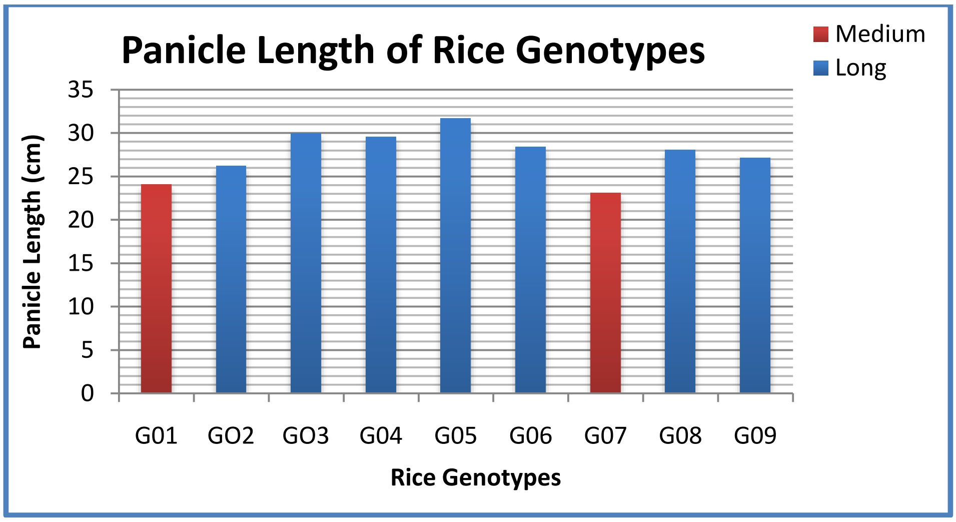

Figure 9. Grouping of observed genotypes based on panicle length

4.2.13 Days to main heading (80%)

Date on which 80% of the plants were in heading stage and it is specified as the number of days from seed sowing date to main heading date. Time of 80% heading of the observed genotypes ranged from 90 (G07) days to 120 (G05) days with a mean value of 103 days (Appendix-II). On the basis of time of 80% heading, aromatic rice genotypes were classified into 4 groups viz. early (<80 days), medium (81- 100days), late (101-125) and very late (>125). Here four genotypes (G02, G04, G07 and G08) were recorded as medium, five genotypes (G01, G03, G05, G06 and G09) as late group (Table 31).

4.2.14 Days to maturity

Time of maturity was calculated as days required from sowing to maturity. Time of maturity of the observed genotypes ranged from 130 days (G07) to 160 days (G05) with a mean value of 143 days (Appendix-II) and on the basis of this character, all the genotypes were classified into 4 groups as early (<95 days), medium (96-120 days), late (121-140) and very late (>141 days). Here only one genotype (G07) was recorded as Medium, six genotypes (G01, GO2, G04, G06, G08 and G09) as late and two genotypes (G03 and G05) as very late group (Table 32).This grouping based on days to maturity is also shown in bar graph for more easy perception by the following figure-11, where genotypes had been shown in vertical axis and days to maturity along the horizontal axis.

4.2.15 Leaf senescence

Penultimate leaves are observed at the time of harvest and observed whether any leaves were retained green color or not. Here our observed genotypes ranged from 2.20 (G02) to 2.80 (G08) with a mean value of 2.56 (Table 33 and Appendix-II). These characteristics were grouped into three categories as Late and slow (2 or more

Table 31. Categorization and grouping based on days to main heading

Groups	Scale (days)	Code	Genotypes
Early	<80	1	Nil
Medium	81-100	3	G02 G04 G07 G08
Late	101-125	5	G01 G03 G05 G06 G09
Very late	>125	7	Nil
Range	(G07) 90 - (G05) 120		
Average	103		

Table 32. Categorization and grouping based on days to maturity

Groups	Scale (days)	Code	Genotypes
Very early	<100	1	Nil
Early	101-115	3	Nil
Medium	116-135	5	G07
Late	136-150	7	G01 G02 G04 G06 G08 G09
Very late	>150	9	G03 G05
Range	(G07) 130 - (G05) 160 days		
Average	143 days		

Table 33. Categorization and grouping based on leaf senescence

Group	Scale (leaves retained green color)	Code	Genotypes
Late and slow	>2	1	G01 G02 G03 G04 G05 G06 G07 G08 G09
Intermediate	1-2	5	Nil
Early and fast	0	9	Nil
Range	(G02) 2.20 - (G08) 2.80		
Average	2.56		

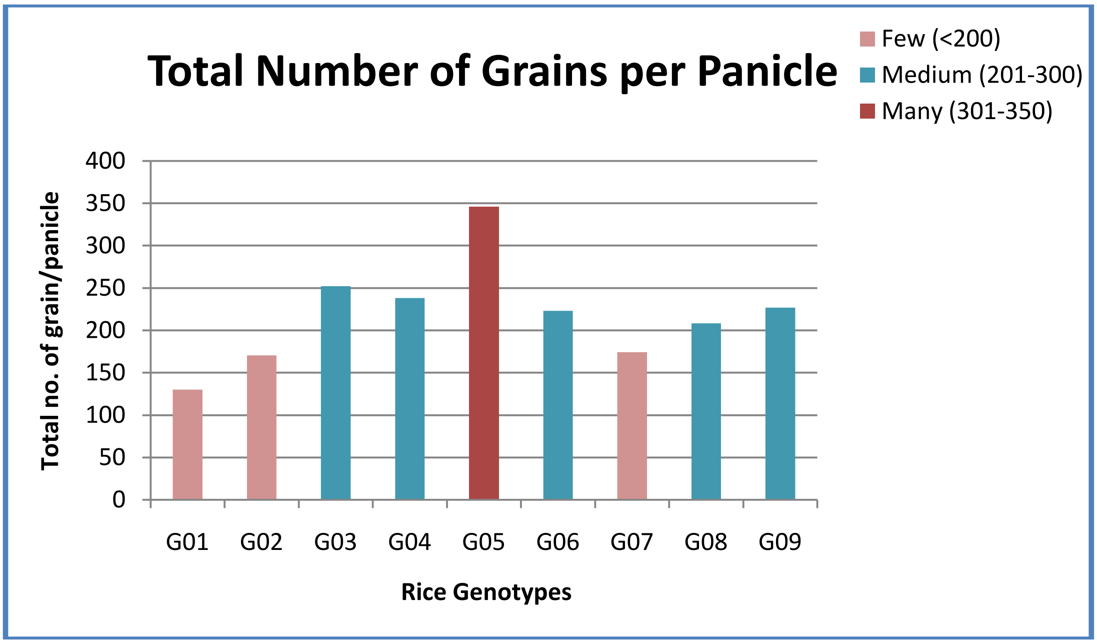

Figure 10. Grouping of observed genotypes based on total no. of grain per panicle

leaves retain green color at maturity), Intermediate and Early and fast (leaves are dried at maturity). Here all the genotypes were under late and slow groups (Table 33).

4.2.16 Thousand seed weight (dry)

Thousand grain weight of the observed genotypes ranged from 23.13 g (G03) to 34.13 g (06) with a mean value of 28.69 g (Appendix-II) and considering this character, the genotypes were grouped as very low (<l5 g), low (l6-19 g), medium (20-23 g) and high (24-27 g). Here only one genotype (G03) was recorded as medium, four genotypes (G05, G07, G08 and G09) as high and four genotypes (G01, G02, G04 and G06) as very high group (Table 34).

4.2.17 Grain length (mm)

Grain length of rice genotypes ranged from 7.45 mm (G07) to 12.02 mm (G04) with a mean value of 9.22 mm (Appendix-II). On the basis of grain length, the observed genotypes were grouped as short (<5.50 mm), medium (5.51-6.5 mm), long (6.51-7.5 mm) and extra-long (>7.51 mm) where two genotypes (G07 and G08) were recorded as long and seven genotypes (G01, G02, G03, G04, G05, G06 and G09) as extra long group (Table 35). From plate-23 and plate-24 we can see long and extra long rice grain respectively.

4.2.18 Grain width (mm)

Grain width of our observed genotypes ranged from 2.02 mm (G03) to 3.02 mm (G01) with a mean value of 2.50 mm (Table 36 and Appendix-II). On the basis of grain width, our observed genotypes were categorized as fine (<2.5 mm), medium (2.51-3 mm) and coarse (>3 mm). Here four genotypes (G03, G04, G05 and G07) were recorded as fine, four genotypes (G01, G06, G08, and G09) as medium and one genotype (G02) as coarse group (Table 36).

Table 34. Categorization and grouping based on thousand seed weight (dry)

Groups	Scale	Code	Genotypes
Very low	<15 g	1	Nil
Low	16-19 g	3	Nil
Medium	20-23 g	5	G03
High	24-27 g	7	G05 G07 G08 G09
Very high	>27 g	9	G01 G02 G04 G06
Range	(G03) 23.13 g - (G06) 34.13 g		
Average	28.69 g		

Table 35. 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	G07 G08
Extra long	>7.51 mm	7	G01 G02 G03 G04 G05 G06 G09
Range	(G07) 7.45 mm - (G04) 12.02 mm		
Average	9.22 mm		

Table 36. Categorization and grouping based on grain width

Groups	Scale	Code	Genotypes
Fine	<2.5 mm	3	G03 G04 G05 G07
Medium	2.51-3 mm	5	G01 G06 G08 G09
Coarse	>3 mm	7	G02
Range	(G03) 2.02 mm - (G02) 3.02 mm		
Average	2.50 mm		

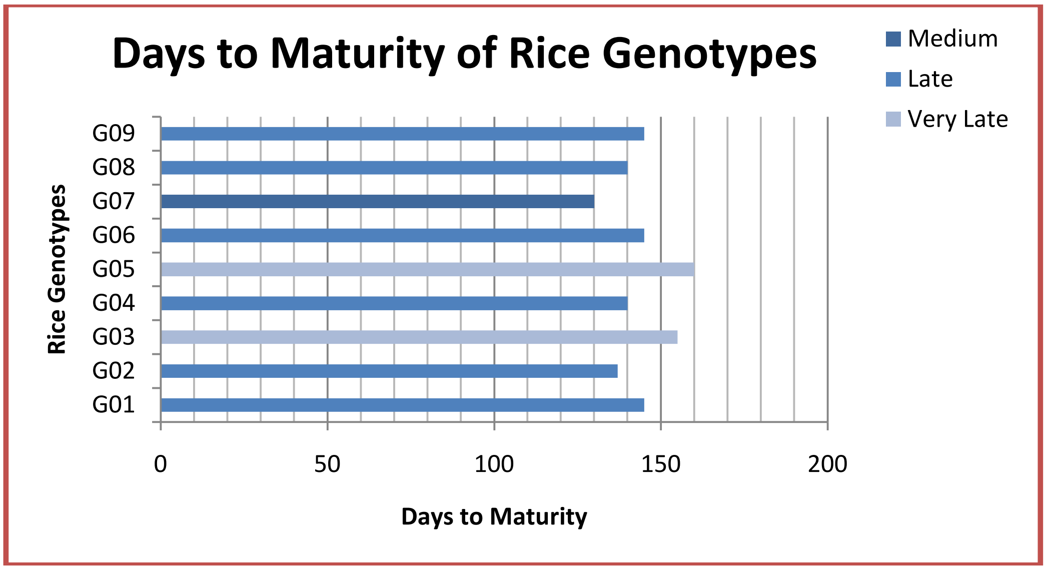

Figure 11. Grouping of observed genotypes based on days to maturity

Plate 21. Long rice grain

Plate 22. Extra long rice grain

The grouping based on grain width is also shown in graph for more easy perception by the following figure-12, where genotypes had been shown horizontal axis and grain width along the vertical axis. From Plate-25, plate-26 and plate-27 we can see Fine, Medium and Coarse type rice grain respectively.

4.2.19 Yield per Plant

Yield per plant ranged from 26.23 g (G07) to 35.42 g (G06) with a mean value of 31.35 g (Appendix II). On the basis of seed yield per plant, the observed genotypes were grouped as Low (<20gm), Medium (20-27gm) and High (>27gm) seed yielder where only one genotype (G07) was recorded as medium category and rest eight genotypes (G01, G02, G03, G04, G05, G06, G08 and G09) were as high category (Table 37).

4.2.20 Yield per square meter area

Yield per plant ranged from 629.52 g (G07) to 850.02 g (G06) with a mean value of 752.34 g (Appendix II). On the basis of seed yield per plant the observed genotypes were grouped as low (<20gm), medium (20-27gm) and high (>27gm) seed yielder where only one genotype (G07) was recorded as medium category and rest eight genotypes (G01, G02, G03, G04, G05, G06, G08 and G09) were as high category (Table 38).

This grouping based on yield per square meter area is also shown in graph for more easy understanding by the following figure-13, where genotypes have been shown horizontal axis and yield per square meter area along the vertical axis. The blue color columns are indicating high yielding genotypes and pink color column indicating medium yielding genotypes

Table 37. Categorization and grouping based on yield per plant

Groups	Scale	Code	Genotypes
Low	<20 g	1	Nil
Medium	20-27 g	3	G07
High	>27 g	5	G01 G02 G03 G04 G05 G06 G08 G09
Range	(G07) 26.23 g - (G06) 35.42 g		
Average	31.35 g		

Table 38. Categorization and grouping based on yield per square meter area

Groups	Scale	Code	Genotypes
Low	<450	1	Nil
Medium	450-650	3	G07
High	>650	5	G01 G02 G03 G04 G05 G06 G08 G09
Range	(G07) 629.52 g - (G06) 850.02 g		
Average	752.34 g		

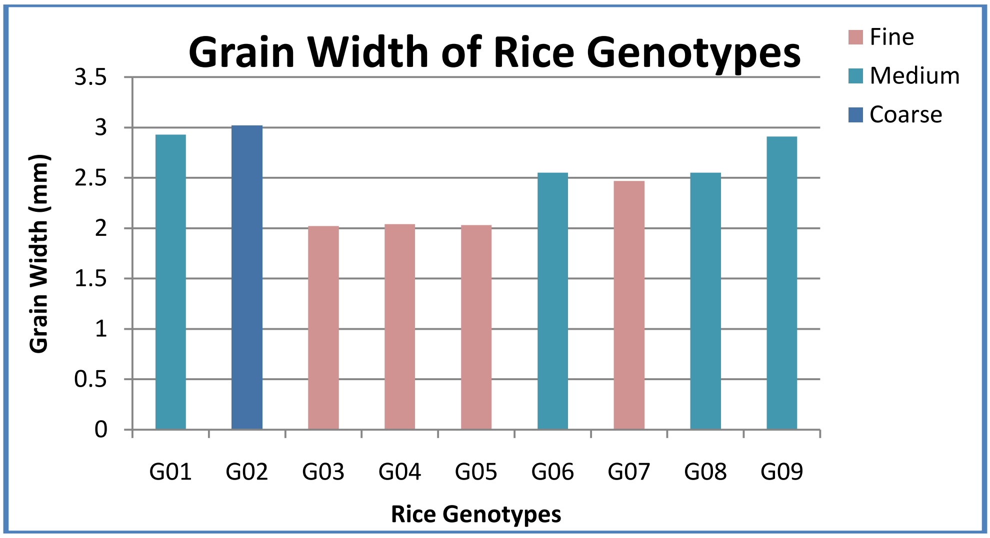

Figure 12. Grouping of observed genotypes based on grain width

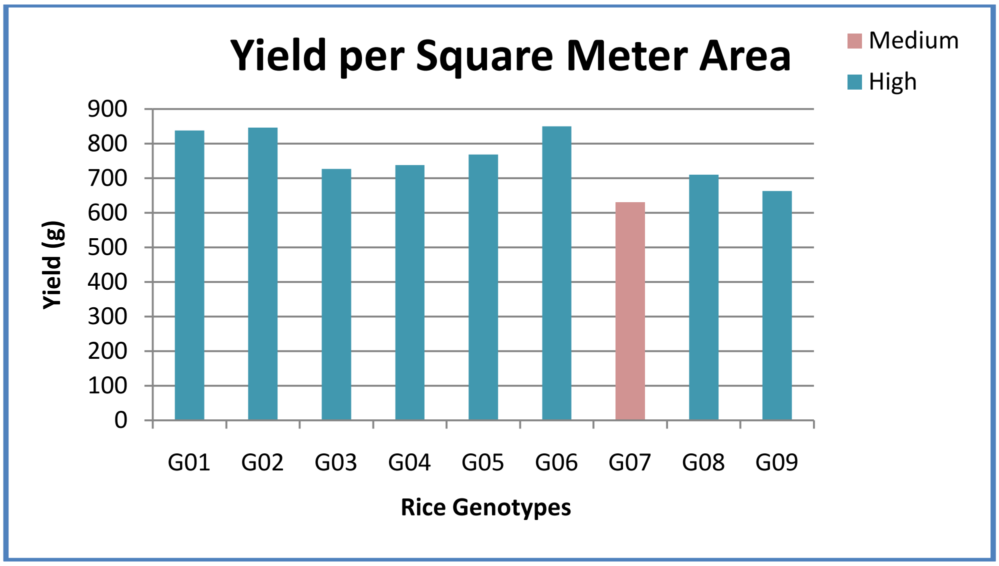

Figure 13. Grouping of observed genotypes based on yield per square meter area

Plate 23. Fine rice grain

Plate 24. Medium type Rice grain

Plate 25. Coarse type rice grain

CHAPTER V

SUMMARY AND CONCLUSION

Rice is the most important field crop and primary source of food for more than half of the world population. It grows in three seasons in Bangladesh where Boro is the most important and single largest crop in Bangladesh in respect of volume of production. Along with the higher production of Boro rice, nowadays the quality of grain and duration of growing season is the main concern to release a variety for Boro season. Considering these above points, an investigation entitled "Characterization of advanced lines of boro rice (*Oryza sativa L.*)" was conducted with nine advanced lines of Boro rice genotypes through a field experiment during the period of Boro season of 2015-16 at Sher-e-Bangla Agricultural University, Dhaka.

Nine advanced lines of rice genotypes were evaluated for fifteen qualitative and twenty quantitative traits of morphological characters to identify the best genotypes. Qualitative and quantitative characters both were coded for specific scales. For some characters higher value of those code indicates superiority such as dark green color (coded as 7) of leaf blade showed the superiority. On the other hand, some characters had lower value of those codes which were indicated as the superiority such as erect leaf blade (coded as 1) showed the superiority.

Some qualitative characters like presence of awns could not be suitable for cultivated rice. This character was partly observed in G02 genotype and fully observed in G06 genotype. Although presence of this undesirable character, both G02 and G06 genotypes showed high yielding performance. Here in experiment, all our nine genotypes showed the 2-cleft ligule and high lodging resistance which were the most desirable agronomic character. In case of panicle exertion, well exerted panicle could be most desirable for easy threshing and G01, G02, G07, G08 and G09showed the well exerted panicle character.

The higher value of the code of some quantitative characters like total no. of tillers per hill, panicle length, branching of panicle, total no. filled grain, grain length, yield per plant and yield per square meter area were indicated as the best agronomic characters. Genotypes like G01, G02, G03, G04, G05, G07 and G08 showed the higher tiller number as well as higher effective tillers per hill which is the most desirable agronomic character. Short culm length having long panicle length was considered best for cultivated rice genotypes. The genotypes like G02, G03, G06 and G09 showed these characters. Clustered type panicle with higher filled grain was seen in G03, G05 and G09 genotypes and these were the high yielding characters.

The lower value of the code of some quantitative characters like culm length, no. of unfilled grains per panicle, thousand seed weight, days to main heading, days to maturity, leaf senescence and grain width were indicated as the superiority. The genotype G07showed much less days required to maturity compared to other eight genotypes and grouped under medium (116-135 days) category. Genotype G01, G02, G04, G06, G08 and G09 were grouped under late (136-150 days) category and G03 and G05 were under very late (>150 days) category. In case of thousand seed weight, the higher weight indicated the higher yield but it was less in quality. Most of the higher thousand seed weight was considered as coarse grain category which was considered as less quality grain in case of consumption purpose. The genotype G04 was under the medium category in case of thousand seed weight and fine rice category in case of grain quality. Genotype G04, G05 and G07 were also under the fine rice category.

In case of yield per plant and yield per square meter area, genotype G07 was under the medium yielding category and rest eight genotypes i.e. G01, G02, G03, G04, G05, G06, G08 and G09 were under the high yielding category. Therefore, above observed nine advanced lines of rice genotypes have a lot of potentiality for various agronomic traits and could be used for further characterization, crossing program, improvement and incorporation of some desired traits.

Based on the research findings, some recommendation could be made as- firstly, the G06, G02 and G01genotypes could be selected as new variety for considering their higher yield performance. Secondly, the G05, G04 and G03genotypes could be selected as new variety for considering their fine rice grain quality and finally, the G07 genotype could be selected as new variety for its short life cycle.

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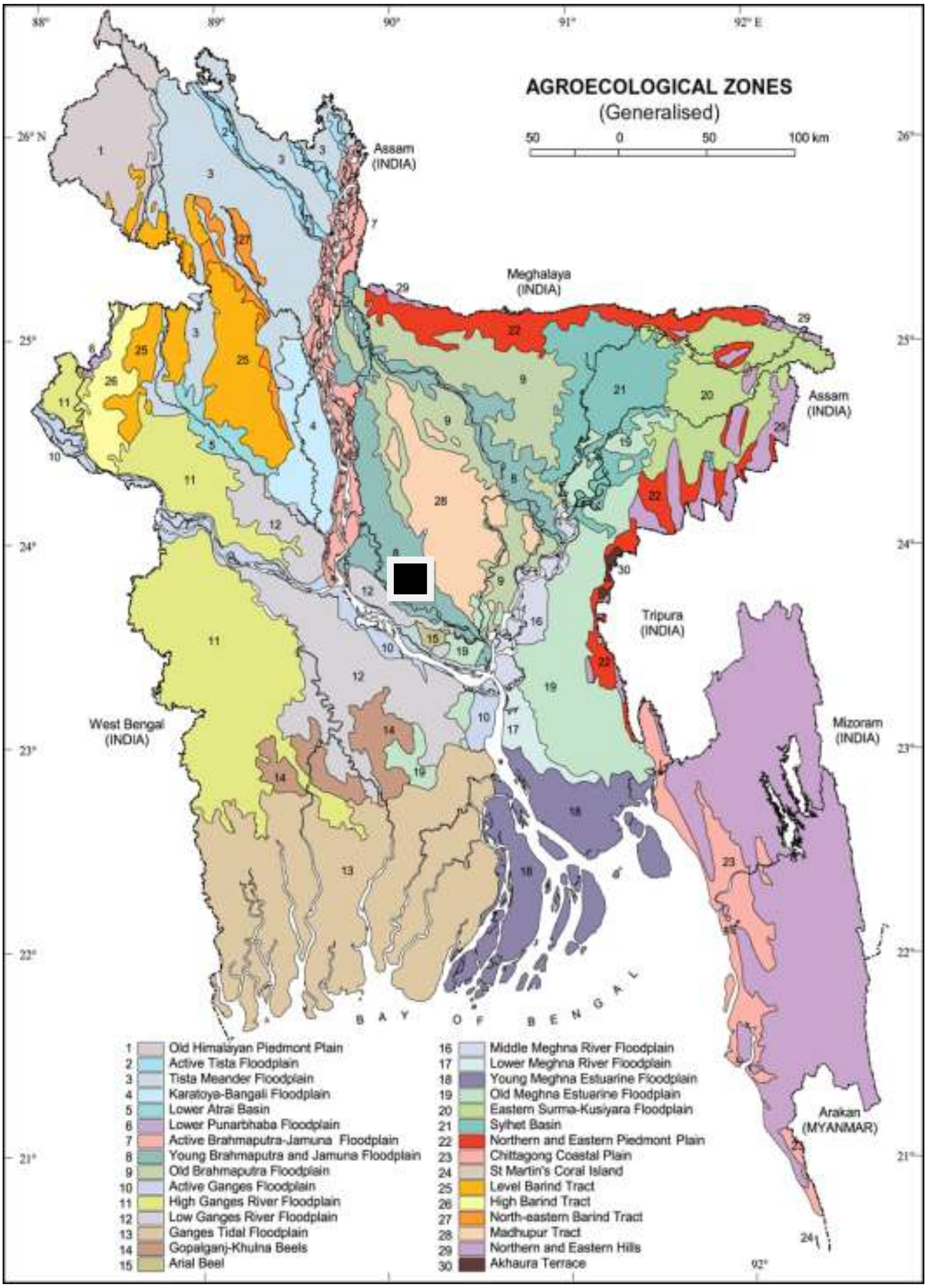
APPENDICES

Appendix I. Map showing the experimental site



-The experimental site under study

Appendix II. Mean performance of quantitative characters of nine genotypes

Genotypes	SD LH	FL L	FL W	CL	CD M	TN T	ETN	PL	NP B	NS B	TSW
G01	21.89	34.87	2.51	62.91	5.81	24.02	21.52	24.07	12.32	49.12	32.57
G02	21.07	39.33	2.77	62.13	6.54	23.13	22.33	26.25	12.67	54.17	32.33
G03	22.73	45.72	2.33	61.64	6.21	25.52	23.29	29.97	13.35	57.86	23.13
G04	23.58	46.24	2.29	74.23	5.79	21.89	18.97	29.55	13.11	54.29	28.23
G05	22.72	43.13	2.41	73.17	6.23	28.87	25.13	31.70	13.63	59.65	26.92
G06	22.97	44.13	2.35	69.23	5.95	13.92	11.77	28.41	13.49	58.37	34.13
G07	20.53	28.91	1.67	54.37	4.15	20.57	18.11	23.12	11.43	47.29	26.83
G08	23.31	44.37	1.75	73.93	6.11	18.73	16.23	28.06	13.27	56.77	26.93
G09	22.87	45.18	1.87	67.84	6.17	14.95	11.95	27.18	13.34	57.17	27.13
Mean	22.41	41.32	2.22	66.61	5.88	21.29	18.81	27.59	12.96	54.97	28.69
Minimum	20.53	28.91	1.67	54.37	4.15	13.92	11.77	23.12	11.43	47.29	23.13
Maximum	23.58	46.24	2.77	74.23	6.54	28.87	25.13	31.70	13.63	59.65	34.13

SDLH: Seedling Height (30 DAS), FLL: Flag Leaf Length, FLW: Flag Leaf Width, CL: Culm Length, CDM: Culm Diameter, TNT: Total No. of Tiller per Hill, ETN: Effective Tiller No. per Hill, PL: Panicle Length, NPB: No. of Primary Branch per panicle, NSB: No. of Secondary Branch per Panicle, TSW: Weight of Thousand Seed.

Appendix II . (cont'd).

Genotypes	NFG	NUG	TNG	DMH	MD	LS	GL	GW	YPP	Y/m^2
G01	101.43	28.7	130.13	105	145	2.47	8.51	2.93	34.93	838.23
G02	141.83	28.5	170.33	097	137	2.20	9.06	3.02	35.26	846.32
G03	201.87	50.2	252.07	110	155	2.27	11.52	2.02	30.27	726.43
G04	199.47	38.7	238.17	100	140	2.67	12.02	2.04	30.76	738.29
G05	280.77	65.3	346.07	120	160	2.47	8.27	2.03	32.03	768.67
G06	185.13	37.8	222.93	105	145	2.67	9.93	2.55	35.42	850.02
G07	147.33	26.9	174.23	090	130	2.73	7.45	2.47	26.23	629.52
G08	167.0	41.4	208.40	100	140	2.80	7.49	2.55	29.59	710.23
G09	202.23	24.6	226.83	105	145	2.73	8.73	2.91	27.64	663.33
Mean	180.78	38.01	218.80	103	143	2.56	9.22	2.50	31.35	752.34
Minimum	101.43	24.6	130.13	90	130	2.20	7.45	2.02	26.23	629.52
Maximum	280.77	65.3	346.07	120	160	2.80	12.02	3.02	35.42	850.02

NFG: No. of Filled Grain per Panicle, NUG: No. of Unfilled Grain per Panicle, TNG: Total No. of Grain per Panicle, DMH: Days to Main Heading, DM: Days to Maturity, LS: Leaf Senescence, GL: Grain Length, GW: Grain Width, YPP: Yield per Plant, Y/m^2: Yield per Square Meter Area.

Appendix III. Code of quantitative characters of nine genotypes

Genotypes	SDLH	FLL	FLW	CL	CDM	TNT	ETN	PL	BP	NFG	NUG	TNG	TSW	DMH	DM	LS	GL	GW	YPP	Y/m^2
G01	3	5	7	2	3	7	7	5	3	1	1	1	9	5	7	1	7	5	5	5
G02	3	5	7	2	5	7	7	7	3	1	1	1	9	3	7	1	7	7	5	5
G03	3	5	7	2	5	7	7	7	3	5	5	3	5	5	9	1	7	3	5	5
G04	3	5	7	3	3	7	7	7	3	3	3	3	9	3	7	1	7	3	5	5
G05	3	5	7	3	5	7	7	7	3	5	5	5	7	5	9	1	7	3	5	5
G06	3	5	7	2	3	5	5	7	3	3	3	3	9	5	7	1	7	5	5	5
G07	3	3	7	2	1	7	7	5	3	1	1	1	7	3	5	1	5	3	3	3
G08	3	5	7	3	5	7	7	7	3	3	3	3	7	3	7	1	5	5	5	5
G09	3	5	7	2	5	5	5	7	3	5	1	3	7	5	7	1	7	5	5	5

SDLH: Seedling Height (30 DAS), FLL: Flag Leaf Length, FLW: Flag Leaf Width, CL: Culm Length, CDM: Culm Diameter, TNT: Total No. of Tiller per Hill, ETN: Effective Tiller No. per Hill, PL: Panicle Length, NPB: No. of Primary Branch per panicle, NSB: No. of Secondary Branch per Panicle, TSW: Weight of Thousand Seed, NFG: No. of Filled Grain per Panicle, NUG: No. of Unfilled Grain per Panicle, TNG: Total No. of Grain per Panicle, DMH: Days to Main Heading, DM: Days to Maturity, LS: Leaf Senescence, GL: Grain Length, GW: Grain Width, YPP: Yield per Plant, Y/m^2: Yield per Square Meter Area.

Appendix IV. Overall characterization of nine genotype based on quantitative character

Genotypes	SDLH	FLL	FLW	CL	CDM	TNT	ETN	PL	BP	NFG	NUG	TNG	TSW	DMH	DM	LS	GL	GW	YPP	Y/m^2
G01	short	intermediate	broad	Very short to short	medium	High	High	medium	clustered	few	few	few	low	late	late	Late and slow	Extra long	coarse	high	high
G02	short	intermediate	broad	Very short to short	large	High	High	long	clustered	few	few	few	low	medium	late	Late and slow	Extra long	medium	high	high
G03	short	intermediate	broad	Very short to short	large	High	High	long	clustered	many	many	medium	medium	late	Very late	Late and slow	Extra long	medium	high	high
G04	short	intermediate	broad	short	medium	High	High	long	clustered	medium	medium	medium	low	medium	late	Late and slow	Extra long	medium	high	high
G05	short	intermediate	broad	short	large	High	High	long	clustered	many	many	many	high	late	Very late	Late and slow	Extra long	medium	high	high
G06	short	intermediate	broad	Very short to short	medium	intermediate	intermediat	long	clustered	medium	medium	medium	low	late	late	Late and slow	Extra long	coarse	high	high

Appendix IV. (cont'd)

Genotypes	SDLH	FLL	FLW	CL	CDM	TNT	ETN	PL	BP	NFG	NUG	TNG	TSW	DMH	DM	LS	GL	GW	YPP	Y/m^2
G07	short	short	broad	Very short to short	small	High	High	medium	clustered	few	few	few	high	medium	medium	Late and slow	long	medium	medium	medium
G08	short	intermediate	broad	short	large	High	High	long	clustered	medium	medium	medium	high	medium	late	Late and slow	long	coarse	high	high
G09	short	intermediate	broad	Very short to short	large	intermediate	intermediat	long	clustered	many	few	medium	high	late	late	Late and slow	Extra long	coarse	high	high

Appendix V. Code of qualitative characters of nine genotypes

Genotype	BLSC	GCILB	LBA	LBP	LS	LC	AC	FLA	CH	CLR	PAB	PE	GC	CS	PA
G01	1	7	1	3	7	1	1	1	1	9	9	9	2	0	0
G02	1	7	1	3	7	1	1	1	3	9	9	9	1	0	1
G03	1	7	5	3	7	1	1	3	3	9	9	5	1	0	0
G04	1	7	5	3	7	2	2	3	3	9	9	7	1	0	0
G05	1	7	1	3	7	1	1	1	1	9	9	5	2	0	0
G06	1	7	5	3	7	2	2	1	1	9	7	7	1	0	2
G07	1	5	1	3	7	2	2	1	3	9	5	9	2	0	0
G08	1	5	1	3	7	1	1	1	1	9	9	9	2	0	0
G09	1	5	1	3	7	1	1	1	1	9	9	9	2	0	0

BLSC: Basal Leaf Sheath Color, GCILB: Green Color Intensity of Leaf Blade, LBA: Leaf Blade Attitude, LBP: Leaf Blade Pubescence, LS: Ligule Shape, LC: Ligule Color, AC: Auricle Color, FLA: Flag Leaf Attitude, CH: culm Habit, CLR: Culm Lodging Resistance, PAB: Panicle- Attitude of Branches, PE: Panicle Exertion, GC: Grain Color CS: Caryopsis Scent, PA: Presence of Awns.

Appendix VI. Overall characterization of nine genotype based on qualitative character

Genotype	BLSC	GCILB	LBA	LBP	LS	LC	AC	FLA	CH	CLR	PAB	PE	GC	CS	PA
G01	Green	Dark green	Erect	Pubescent	Cleft	Whitish	Whitish	Erect	Erect	Very strong	Dropping	Well exerted	Golden	No scented	Absent
G02	Green	Dark green	Erect	Pubescent	Cleft	Whitish	Whitish	Erect	Semi-erect	Very strong	Dropping	Well exerted	Straw	No scented	Partly awned
G03	Green	Dark green	Horizontal	Pubescent	Cleft	Whitish	Whitish	Semi-erect	Semi-erect	Very strong	Dropping	Just exerted	Straw	No scented	Absent
G04	Green	Dark green	Horizontal	Pubescent	Cleft	Yellowish green	Yellowish green	Semi-erect	Semi-erect	Very strong	Dropping	Moderately exerted	Straw	No scented	Absent
G05	Green	Dark green	erect	Pubescent	Cleft	Whitish	Whitish	Erect	Erect	Very strong	Dropping	Just exerted	Golden	No scented	Absent
G06	Green	Dark green	Horizontal	Pubescent	Cleft	Yellowish green	Yellowish green	Erect	Erect	Very strong	Horizontal	Moderately exerted	Straw	No scented	Fully Awned
G07	Green	Medium green	Erect	Pubescent	Cleft	Yellowish green	Yellowish green	Erect	Semi-erect	Very strong	Spreading	Well exerted	Golden	No scented	Absent
G08	Green	Medium green	Erect	Pubescent	Cleft	Whitish	Whitish	Erect	Erect	Very strong	Dropping	Well exerted	Golden	No scented	Absent
G09	Green	Medium green	Erect	Pubescent	Cleft	Whitish	Whitish	Erect	Erect	Very strong	Dropping	Well exerted	Golden	No scented	Absent

Appendix VII. 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-0, Light green-3, Medium green-5, Dark green-7
3	Leaf blade attitude	Erect-1, Horizontal-5, Drooping-7
4	Leaf blade pubescence	Glabrous-1, Intermediate-2, Pubescent-3
5	Ligule shape	Absent-0, Truncate-1, Acute to acuminate-2, 2-cleft-3
6	Ligule color	Absent (ligule less)-0, Whitish-1, Yellowish green-2, Purple-3, Light purple-4, Purple lines-5
7	Auricle color	Absent (no auricles)-0, Whitish-1, Yellowish green-2, Purple-3
8	Flag leaf attitude	Erect-1, Semi-erect (intermediate)-3, Horizontal-5, Descending-7
9	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
10	Culm: lodging resistance	Very weak -1, Weak-3 , Intermediate-5, Strong- 7, Very strong-9
11	Panicle: attitude of branches	Erect (compact panicle)-1, Semi-erect (semi-compact panicle)-3, Spreading (open panicle)-5, Horizontal-7, Drooping-9
12	Panicle: exertion	Enclosed-1, Partly exerted-3, Just Exerted-5, Moderately Exerted-7, Well Exerted-9
13	Lemma and palea color (grain color)	Straw-1, Golden-2, Purple-4, Black-5
14	Caryopsis scent	Non-scented-0, Lightly scented-1, Scented-2
15	Presence of awns	Absent-0, Partly awned-1, Fully awned-2

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

Appendix VIII. Descriptors with codes for quantitative characteristics

SL. No.	Characteristics	Descriptors with codes
1	Seedling height (30 DAS)	3- Short (<30 cm), 5- Intermediate (~45 cm), 7- Tall (>60 cm)
2	Flag leaf length	1- Very short (<21 cm), 3- Short (~30 cm), 5- Intermediate (~50 cm), 7- Long (~70 cm), 9- Very long (>80 cm)
3	Flag leaf breath	3- Narrow (<1 cm), 5- Intermediate, 7- Broad (>2 cm)
4	Culm length	1- Very short (<50 cm), 2- Very short to short (51-70 cm), 3- Short (71-90cm), 4- Short to intermediate (91-105cm), 5- Intermediate (106-120 cm), 6- Inter mediate to long (121-140 cm), 7- Long (141-155 cm), 8- Long to very long (156-180 cm), 9-Very long (>180 cm)
5	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)
6	Tillers per hill	3- Low (<10 culms), 5 -Intermediate (~15culms), 7 -High (>20 culms)
7	Effective tillers per hill	3 -Low (<7 culms), 5- Intermediate (~10culms), 7- High (>15 culms)
8	Panicle length	1- Very short (<11 cm), 3- Short (~15 cm), 5-Medium (~25 cm), 7- Long (~35 cm), 9- Very long (>40 cm)
9	Branching of panicle	0- Absent, 1- Sparse (~1 secondary branch per primary branch), 2- Dense (~2-3 secondary branches per primary branch), 3- Clustered (~3-4 secondary branches per primary branch)
10	No. of filled grains per panicle	1- Few (<150), 3- Medium (151-200), 5- Many (201-300), 7- So Many (>301)
11	No. unfilled grains per panicle	1- Few (<30), 3- Medium (31-50), 5- Many (>50)
12	Total no. of grains per panicle	1- Few (<200), 3- Medium (201-300), 5- Many (301-350), 7- So Many (>351)
13	Thousand seed weight(dry)	1-Very low(<15g), 3-Low(16-19g), 5-Medium(20-23g), 7-High(24-27g)
14	Days to main heading (80%)	1- Early (<80), 3- Medium (81-100), 5- Late (101-125), 7- Very Late (>125)
15	Days to maturity	1- Early (<95), 3- Medium (96-120), 5- Late (121-140), 7- Very Late (>141)
16	Leaf senescence	1- Late and slow (>2 leaves), 5- Intermediate (1-2 leaves), 9- Early and fast (0 green leaf)

Appendix VIII. (cont'd)

17	Grain length (mm)	1- Short (<5.50), 3- Medium (5.51-6.5), 5- Long (6.51-7.5), 7- Extra Long (>7.51)
18	Grain width (mm)	1- Fine (<2.5), 3- Medium (2.51-3), 5- Coarse (>3)
19	Yield per plant	1- Low (<20g), 3- Medium (20-27g), 5- High (>27)
20	Yield per square meter area	1- Low (<450 g), 3- Medium (450-600 g), 5- High (>600 g)

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

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

A. Physical composition of the soil

Soil separates	Percentage	Methods employed
Sand	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, Dhaka.

B. Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.82	Walkley and Black, 1947
2	Total N (kg/ha)	1790.00	Bremner and Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lanester, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner, 1965

B. (cont'd)

6	Available P (kg/ha)	69.00	Olsen and Dean, 1965
7	Exchangeable K (kg/ha)	89.50	Pratt, 1965
8	Available S (ppm)	16.00	Hunter, 1984
9	pH (1:2.5 soil to water)	5.55	Jackson, 1958
10	CEC	11.23	Chapman, 1965

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

Appendix X. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from December, 2015 to May, 2016

Month	Air temperature (°c)		Relative Humidity (%)	Rainfall (mm)
	Maximum	Minimum		
December, 2015	22.4	13.5	78	10
January, 2016	24.5	11.5	74	00
February, 2016	27.1	16.7	68	30
March, 2016	31.4	19.6	67	43
April, 2016	36.0	21.2	65	86
May, 2016	36.1	22.5	62	95

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

Appendix XI. A visit to the experimental site of my Supervisor with the Dean of Post Graduate Studies, SAU, Dhaka and data collection of the genotypes at maturity stage