DEDICATED

TO

MY BELOVED PARENTS, TEACHERS AND FRIENDS

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

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SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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BY

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CERTIFICATE

This is to certify that thesis entitled, "CHARACTERIZATION AND VARIABILITY ANALYSIS OF SOME ADVANCED LINES OF FINE GRAIN 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 Genetics and Plant Breeding, embodies the result of a piece of bona fide research work carried out by Bidyut Prava Deb Sharma, Registration No. 18-09104 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: December, 2020

Prof. Dr. Md. Sarowar Hossain

Supervisor

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LIST OF CONTENTS

LIST OF CONTENTS (CONT'D)

LIST OF TABLES

LIST OF TABLES (CONT'D)

LIST OF TABLES (CONT'D)

LIST OF FIGURES

LIST OF FIGURES (CONT'D)

LIST OF FIGURES (CONT'D)

LIST OF PLATES

LIST OF APPENDICES

SOME COMMONLY USED ABBREVIATIONS

Full Name	Abbreviations
Agricultural	*Agril.*
Agriculture	*Agric.*
Agro-Ecological Zone	AEZ
At the rate	@
And others	*et al.*
Bangladesh	BD
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Bangladesh Rice	BR
Bangladesh Rice Research Institute	BRRI
Biological	*Biol.*
International Rice Research Institute	IRRI
Biodiversity International	WARDA
Seed Certification Agency	SCA
Centimeter	Cm
Days After Transplanting	DAT
Department of Agricultural Extension	DAE
Etcetera	etc
Food and Agricultural Organization	FAO
Lines	L
Genetics	Genet.
Gram	g

SOME COMMONLY USED ABBREVIATIONS (CONT'D)

Full Name	**Abbreviations**
High Yielding Variety	HYV
Journal	*J.*
Kilogram	Kg
Meter	m
Ministry of Agriculture	MoA
Muriate Potash	MP
Percent	%
Randomized Complete Block Design	RCBD
Sher-e-Bangla Agricultural University	SAU
Square meter	m^2
Science	Sci.
Ton	t
Triple Super Phosphate	TSP

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

BY

BIDYUT PRAVA DEB SHARMA

ABSTRACT

The experiment was conducted to characterize some advanced lines of fine grain boro rice and to determine the variability among these lines during the period of boro season (2018-2019) at the experimental field of Sher-e-Bangla Agricultural University, Dhaka. These advanced lines of fine grain boro rice were characterized for 15 quantitative and 17 qualitative traits. Variability study was carried out on 15 parameters to select the best lines for further trial. Among the qualitative characteristics, variation was observed in leaf color, leaf sheath: anthocyanin color, flag leaf: attitude of the blade, lemma and palea: anthocyanin color, stem: anthocyanin coloration of internodes, spikelet: color of the tip of lemma, panicle: awns in the spikelet, panicle exertion, grain color and culm habit. Among the quantitative characteristics- time of heading, stem: culm diameter, days to maturity, grain length, decorticated grain length showed difference for all the lines. In case of variability study all the characters showed significant result. Phenotypic variance was higher than the genotypic variance for all the characters indicating environmental effect presence on these characters. High phenotypic and genotypic coefficient of variation was found in unfilled grain/plant and days to 80% maturity. High heritability coupled with high genetic advance and genetic advance in percentage of mean was found in primary branch/panicle, spikelet/panicle, filled grain/plant and unfilled grain/plant which indicated that additive gene expression on this character. Character association analysis indicating that yield/plant had highest significant positive correlation with thousand seed weight (g) in both genotypic and phenotypic level indicating the importance of these trait in selection for increasing yield. Most of the lines showed higher no. of effective tillers, long panicles with higher no. of grains/panicle which would be the agronomic superiority. The average panicle length was 24.83 cm and mean total no. grain was 179.31 per panicle which contributed to an average yield of 36.97 g per plant. Five lines viz. L1, L2, L3, L6 and L7 showed extra-long fine rice grain character. The highest yield was observed in L10 (7.70 t/ha), L8 (7.50 t/ha) and L5 (7.40 t/ha) comparing with the check varieties. So, the best lines viz. L5, L8 and L10 which could be used for further trial in future to follow the release procedure in respect of time and yield.

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is a plant belonging to the family of grasses, Gramineae (Poaceae). The genus *Oryza* L. belongs under the tribe *Oryzeae*, subfamily *Oryzoideae* in the family*Poaceae*(*Gramineae*).This genus is divided into four species complexes, including the *Oryza sativa*, *Oryzaofficialis*, *Oryzaridelyi* and *Oryzagranulata* species complexes**.** The *Oryza sativa* complex is divided into cultivated species and wild species. *Oryza sativa* L. and *Oryzaglaberrima* are two cultivated species, whereas *Oryzarufipogon*, *Oryzanivara*, *Oryzabarthii*, *Oryzalongistaminata*, *Oryzameridionalis* and *Oryzaglumaepatula* are wild species. Both cultivated species are diploid and share the AA genome (2n=24).

Rice (*Oryza sativa* L.) is one of the major food crops in the world and particularly important in Asia where approximately 90% of world's rice is produced and consumed (Khush, 2004; Zeigler and Barclay,2008). Rice is the world's most important crop and the food security in Asia has been traditionally defined as having stable prices for rice in the major urban markets of a country. Rice is the stable food for more than 50% of the population in Asia and for South Asia alone, the figure is around 70% (Bishwajit*et al*., 2013). Asia can be considered as 'Rice Basket' of the world, as more than 90% of the rice is produced and consumed in Asia. World paddy production area was163.3 million hectares and production was 749.7 million tons (FAO, 2016).

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

Agro-morphological characterization of germplasm accessions is fundamental to provide information in plant breeding programs (Lin, 1991). The use of agro-morphological markers in the characterization and study of rice (*Oryza sativa* L.) germplasm diversity is reported by several researchers. Li *et al.* (2000) found consistent results analyzing the correlation between genetic and morphological differentiation in 111 accessions of rice from the Japonica and Indica groups. 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 seed 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 rice. 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 unelongatedduring 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 condition and natural selection. Several morphological characters act as the major determining factors of rice grain yield.Genetic diversity may be defined as 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 selecting elite individuals. It is an important tool for selecting varieties or lines based on agronomical, morphological, genetic or physiological characters (Ndour, 1998). Characterization is an fundamental technique which is used to evaluate the phenotypic diversity through agro-morphological traits (Bajracharya*etal.,* 2006). Many studieshave been conducted on genetic diversity using agro-morphologicalcharacterization 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 100rice varieties including modern and hybrid varieties. Aromatic and fine rice are high in demand. 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 boro rice are the photosensivity, 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 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 of fine grain boro rice lines as per descriptors used for rice.
2. to select best advanced lines with their different growth parameters and yield contributing characters.
3. to find out the variability among the rice lines.

CHAPTER II

REVIEW OF LITERATURE

The literature relevant to the present investigation entitled “Characterization and variability analysis of ten advanced lines of fine grain 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. The breeders have been applying morphological markers for genetic diversity estimation and a number of morphological descriptors for characterization purpose (Rana and Bhat, 2004). Some morphological characters of seeds such as seed coat color, seed shape, seed length, seed width, kernel length, kernel breadth, presence of awn, 1000 seed weight etc. and traits of plants such as stem length, heading of time, time of maturity, number of primary branches, number of secondary branches, panicle length, numbers of effective tillers per hill, grains per panicle etc. can be usedinvariably in characterization of rice genotypes.

Sarma *et al.* (1990) studied the grain characteristics of 13 traditional aromatic rice varieties of Assam and reported wide variation in grain length, breadth,L/B ratio and thousand seed weight. Obviously some of the collections had extra ordinarily high grain length and could be used as donors in breeding programs.

Tian (1991) observed that male sterility usually creates barriers for cross-pollination of the female parent which prevents access to about 20% of the spikelets and the failure of about 20% of spikelet to open at all.

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

Mohapatra *et al*. (1993) evaluated 13 agro-morphological characters of 34 mutant lines for the magnitude of genetic divergence. The population was categorized into seven clusters. Plant height (24.6%) and thousand seed weight (18.3%) contributed considerable result accounting for 43% of total divergence.

Vivekzuradanand Subramanian (l993) studied 28 rice genotypes for the magnitude of genetic divergence. The population was categorized into five clusters. Plant height and grain yield contributed considerable result accounting for 85% of total divergence.

Virmani (1994) stated that being a self-pollinated crop, commercial production of hybrid seed plays key role in successful implementation of hybrid rice. Anther dehiscence and flowering in rice occur more or less simultaneously. So male sterility has to be adopted to the female which prevents self-pollination and secure cross-pollination.

Miyagawa and Nakamura (1984) studied 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.

Ali *et al.* (1995) observed that the use of male sterility is a pre-requisite for commercial exploitation of heterosis in case of self-pollinating crop. One of the possible alternatives is the two line breeding system, which is obtained using environmental sensitive genic male sterility (EGMS).

Khush and Peng (1996) found that one important approach is to find a new plant type with large panicles,ideal morphology, high photosynthetic efficiency strong lodging resistance.

Considerable genetic variability was recorded by Awasthi and Sharma (1996) for morphological traits in fifteen high quality aromatic rice genotypes grown at Faisabad. Color of leaves and magnitude of aroma also varied greatly with genotypes.

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 categorized into five clusters and found that plant height, tiller number per hill, earliness, grain size and grain yield contributed considerably to total divergence.

Clifford *et al.* (1987) found that the establishment of the lemma or palea morphology might play a pivotal biological role in grass. Based on genetics analysis some researches refer to the palea and lemma as seeds or prophylls.

Jeschke and Hartung (2000) observed that the nutrient circulation model coordinating these transport processes within a whole plant has been described particularly for N and K/Na based on an analysis of the xylem sap and phloem exudates.

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 hill, panicle length, number of grains/panicle, 1000 seed weight, grain length, grain breadth, grain L/B ratio, kernel length, kernel breadth, kernel L/B ratio and grain yield per plant.

Itani (2002) evaluated the agronomic characteristics of aromatic rice collected from all over Japan, 71 randomly selected cultivars were cultivated along with 21 foreign aromatic cultivars from 7 countries and l8 Japanese non-aromatic cultivars.

Basher (2002) studied genetic divergence among 36 genotypes by using D_2 statistics for 15 characters related to yield and its contributing characters. The results revealed that the harvest index had the highest contribution followed by tillers per hill, panicle length, 1000 seed 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 andbreadth. They concluded that these traits play a major role in the enhancement of production of grain yield and serve as important criteria for screening germplasm 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 panicle and plant height..

Mishra *et al*. (2003) studied 16 rice cultivars and their 72 F_1 hybrids for genetic diversity and grouped in twelve clusters using Mahalanobis'sD^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 hill, and number of filled grains per panicle. 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. 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 panicle 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 panicle 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.

Abede et al. (2004) found that lemma and palea are unique character found only in Poaceae, familywhere they are responsible for protecting the florets and kernels from pathogen and insect attack besides supplying carbohydrates to developing seeds.

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.

Naheela *et al.* (2004) evaluated 124 landrace genotypes of rice for seven quantitative and eight qualitative characters. Most of the traits showed significant amount of genetic variation.For all the characters, the coefficient of variation was more than 10% 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).

Rudall and Bateman (2004) stated that the grass inflorescence contains a number of spikelets and each spikelet has several florets subtended by a pair of glumes. Each grass floret consists of three types of organs i.e. a pistil, one or two whorls of three stamens and two to three lodicules subtended by an inner bract called the palea and the outer bract called lemma.

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.

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.

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.

Chen *et al.* (2005) and Xu *et al.* (2005) found that morphological characteristics such as stem thickness, leaf angle,leaf size, neck stem vascular bundle abundance, and plant height during the heading stage are important indices in super rice breeding.

Hossain *et al.* (2005) conducted a experiment to investigate the relationship between grain yield with the morphological parameters of five local and three modern aromatic rice varieties. The Chinigura showed highest plant height which was statistically similar to Kataribhog. The highest number of effective tillers per hill was found 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.

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

Sharief *et al.* (2005) studied 4 rice cultivars for morphological characteristics. 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, panicle weight, presence of awn, number of tillers, filled grain per panicle, thousand grain weight and grain color.

Virmani (2006) stated that in the tropics the cytoplasmic genetic male sterility (CGMS) and the thermo sensitive genic male sterility (TGMS) are the two male sterility systems that can be used in the tropics.

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. Medium gel consistency, intermediate amylose content and cooking quality which are characteristics of typical U.S. long grain non-aromatic rice.

Hirose *et al.* (2006) found that improving lodging resistance a thick culm may also act as a carbohydrate store for high yield in rice.

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.

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.

Hien *et al.* (2007) conducted an experiment to determine relationship among 36 aromatic rice cultivars and the extent of diversitycollected from Asia. Characterization for 23 morphological characters with 102 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, culm strength, plant height and secondary branching contributed the highest mean diversity indices.

Zanis (2007) and Rudall (2005) stated that evolutionary changes in the organization and structure of inflorescence and flower resulted in their distinct morphology in grasses diverging from those of higher eudicots and even other monocots.

Bisne and Sarawgi (2008) studied thirty two aromatic rice accessions of Badshahbhog group from IGKV germplasm, Raipur, Chhattisgar for characterization. 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, 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.

Sarhadi *et al.* (2008) studied in 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.

Vcasey *et al*. (2008) characterized the genetic variability among species and populations of South American wild rice, eleven populations of *Oryzaglumeapatula*, 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 *Oryzaglumeapatula* 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 *Oryzaglumeapatula* followed by *O. latifolia*.

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.

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.

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 discriminate function analysis (DFA) function 1 alone absorbed 6l.7% of the total variance.

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.

Oakawa *et al*. (2010) and Chen et al. (2005) stated that morphological characteristics such as culm thickness, leaf size, leaf angle, and plant height at the heading stage have been considered important traits in breeding both super rice and bioenergy crops.

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 ofthe Asian aromatic rice varieties.

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

Tanchotikul and Thomas (1991) extracted parts per billion 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.

CHAPTER III

MATERIALS AND METHODS

3.1 Experimental Site

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

3.2 Soil and climate

The research site was situated in the sub-tropical zone. The soil of the research site lies in Agro-ecological zone of "Madhupur Tract" (AEZ 28). Its top soil was clay loam in texture and olive gray with common fine to medium with distinct dark yellowish brown mottles. The pH was 4.47 to 5.63 and organic carbon content was 0.82%. The record of air temperature, humidity and rainfall during the period of research work were noted from mini weather center of Sher-e-Bangla Agricultural University.

3.3 Planting materials

Tenadvanced lines of fine grain boro rice and five check varieties were used in this research work. The seeds of 10 lines were collected from germplasm centre of Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University and 5 check varieties viz. BRRI dhan28, BRRI dhan50, BRRI dhan60, BRRI dhan63,and BRRI dhan81 were collected from Bangladesh Rice Research Institute, Joydebpur, Gazipur (Table 1).

Table 1. List of the materials used for the research work

Lines	Accession No.	Sources
L1	AL-44 (I) (Basmoti type)	SAU, Dhaka
L2	S1 (Basmoti type)	SAU, Dhaka
L3	S2 (Basmoti type)	SAU, Dhaka
L4	AL-18	SAU, Dhaka
L5	AL-17 (III) B (Fine grain)	SAU, Dhaka
L6	Special form AL-29 (Fine grain)	SAU, Dhaka
L7	AL-33 (II) (Fine grain)	SAU, Dhaka
L8	Special form AL-36 (Early)	SAU, Dhaka
L9	Special form AL-36 (Fine grain)	SAU, Dhaka
L10	Special form AL-36	SAU, Dhaka
L11	BRRI dhan28	BRRI, Gazipur
L12	BRRI dhan50 (Basmoti type)	BRRI, Gazipur
L13	BRRI dhan60	BRRI, Gazipur
L14	BRRI dhan63	BRRI, Gazipur
L15	BRRI dhan81	BRRI, Gazipur

L=Lines

3.4 Design and layout

The experiment was set out in randomized complete block design (RCBD). The field was divided into three blocks; the blocks were sub-divided into 15 plots where lines were randomly assigned. The experimental field size was 25.8m x 14.5mwhere1.25m boarder was maintained surrounding the field and every block. The experimental field was designed such a way where row to row distance was 25cm and plant to plant distance was 20cm. The 15 lines were distributed to each plot within each block randomly.

3.5 Raising of seedling

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

3.6 Preparation of main field

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

3.7 Application of fertilizers

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

3.8 Transplanting of seedling

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

3.9 Intercultural operation and after care

After 7 days of transplanting necessary gap filling was done and the field was kept weed free during the growing season. Hand weeding was done at 25 and 40 days after transplanting. Flood irrigation was given to the field properly.

3.10 Plant protection measure

Adequate control measures were taken against rice stem borer during tillering and heading stage of rice. Furadan 5G @ l kg per square meter was applied during active tillering stage and panicle initiation stage of rice for controlling rice yellow stem borer.

A) Seed soaking

B) Transplanting

C) Spraying of insecticide

Plate 1. Experimental work from soaking to transplanting and intercultural operation

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. To avoid border effect, the plants were selected from middle of each plot.The mean was estimated from each plot. Seventeen qualitative and fifteen quantitative traits were recorded using the descriptors developed by Biodiversity International, IRRI and WARDA, 2007. The observed lines 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 lines. The photographs of specific trait were taken from the experimental field at appropriate times for different traits to compare the distinctness among the rice lines. Photographs and data related to distinctness in morphological traits were taken on each of the fifteen rice lines. This was done particularly to find out the expression of the qualitative traits of the lines when grown under constant environment.

3.11.1.1 Leafsheath: Anthocyanin color

Data of basal leaf sheath color was collected at late vegetative stage and the rice genotypes were classified into two groups with codes according to guided descriptors absent-1 and present-2 (Table 2).

3.11.1.2 Leaf colour

Green coloration of leaf at late vegetative stage the rice lines were grouped into seven groups with codes according to guided descriptors as pale green-1, green-2, dark green-3, purple tip-4, purple margins-5, purple blotch-6 and purple-7 (Table 2). The leaf colour chart in Figure 1 showing different colors (green, dark green and pale green).

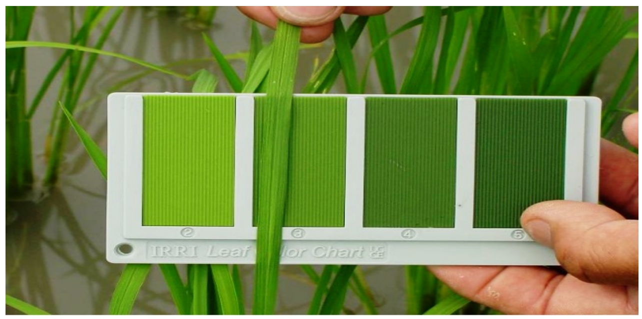

Figure 1. IRRI Leaf Color Chart

3.11.1.3 Penultimate leaf : shape of the ligule

Shape of the penultimate leaf ligule was observed and the genotypes were categorized into four groups as absent-0, truncate-1, acute to acuminate-2 and two-cleft-3 (Table 2) which are also shown hypothetically in Figure 2.

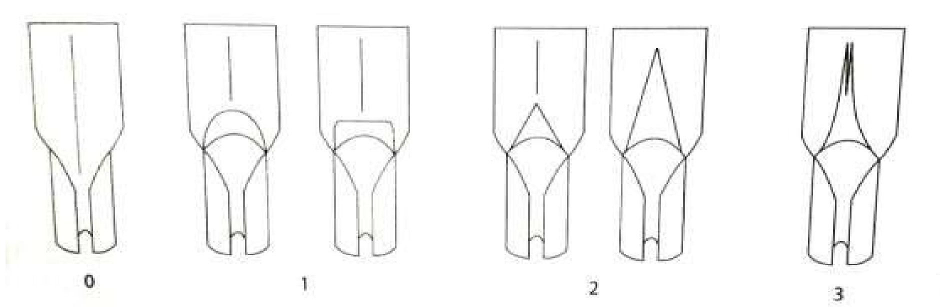

Figure 2. Shape of the ligule

3.11.1.4 Flag leaf: attitude of the blade

Leaf blade attitude may be defined as the position of the tip of the blade relative to its base, scored on the leaf below the flag leaf at the late vegetative stage and rice genotypes were classified into three groups with codes according to guided descriptors as erect-1, horizontal-5 and drooping-7 (Table 2).

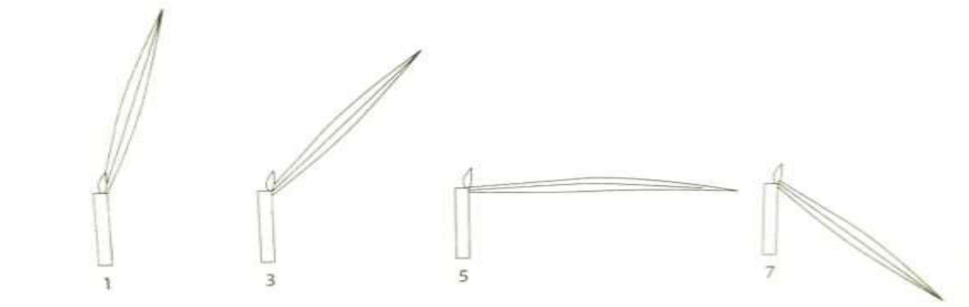

Figure 3. Flag leaf attitude

3.11.1.5 Male sterility

The observation of male sterility were classified into six groups with codes according to guided descriptors as absent-0, CMS-3, TGMS-3, PGMS-7 and P(T)GMS-9 (Table 2).

3.11.1.6 Lemma and palea: anthocyanin coloration

The anthocyanin coloration of lemma and palea was observed under the four categories according to guided descriptors as absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9 (Table 2).

3.11.1.7 Stem: Anthocyanin coloration of nodes

The anthocyanin coloration of nodes of the stem was observed under the two categories according to guided descriptors as absent -1 and present-9 (Table 2).

3.11.1.8 Stem:Anthocyanin coloration of internodes

The anthocyanin coloration of internodes was observed under the four categories according to guided descriptors as absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9 (Table 2).

3.11.1.9 Stem: Intensity of anthocyanin coloration of nodes

The intensity of anthocyanin coloration of nodes was observed under the four categories according to guided descriptors as weak-3, medium-5, strong-7 and very strong-9 (Table 2).

3.11.1.10 Spikelet: Color of the tip of lemma

The color of the tip of lemma was observed under five groups according to guided descriptors as white-1, yellowish-2, brownish-3, red-4, purple-5 and black-6 (Table 2).

3.11.1.11 Panicle: Awns in the spikelet

The observation of awns in the spikelet was categorized into two groups according to guided descriptors as absent-1 and present-9 (Table 2).

3.11.1.12 Panicle: attitude of branches

The attitude of branches were observed by the compactness of panicle. It was categorized according to its mode of branching, angle of primary branches, and spikelet density. It was categorized into five category as erect-1, semi-erect-3, spreading-5, horizontal-7 and dropping-9 (Table 2) which are shown in figure 4.

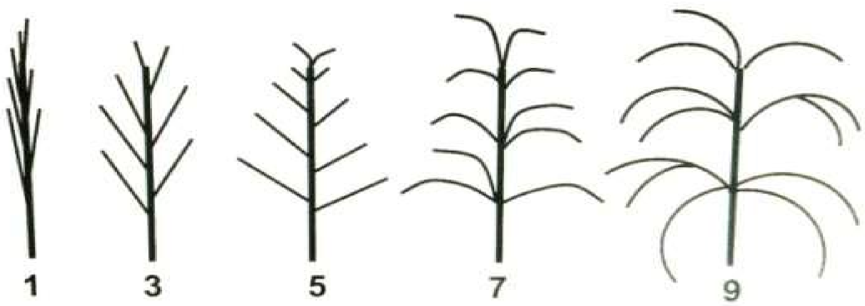

Figure 4. Attitude of panicle branches

3.11.1.13 Panicle exertion

Panicle exertion was observed at near maturity stage of the lines. IT was classified into five groups as enclosed-1, partly exerted-3, just exerted-5, moderately exerted-7 and well exerted-9 (Table 2).

3.11.1.14 Caryopsis scent

Different techniques were used to detect aroma 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. 5 ml of 1.7% (0.3035N) solution of KOH was added to each petridish immediately after crushing and the petridish were covered. By smelling one hour after crushing aroma was determined. The tested genotypes were grouped as non-scented-0, lightly scented-1 and scented-2 (Table 2).

3.11.1.15 Panicle: Length of the longest awn

The length of the longest awn was observed at the mature stage of rice plant under five categories as very short -1, short-3, medium-5, long-7 and very long-9 (Table 2).

3.11.1.16 Lemma and palea color (grain color)

Lemma and palea 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 (Table 2).

3.11.1.17 Culm habit

Culm habit refers as the average angle of inclination of the base of the main culm from vertical. It was observed visually. Culm habit was categorized into five category 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 (Table 2) which are shown in Figure 5.

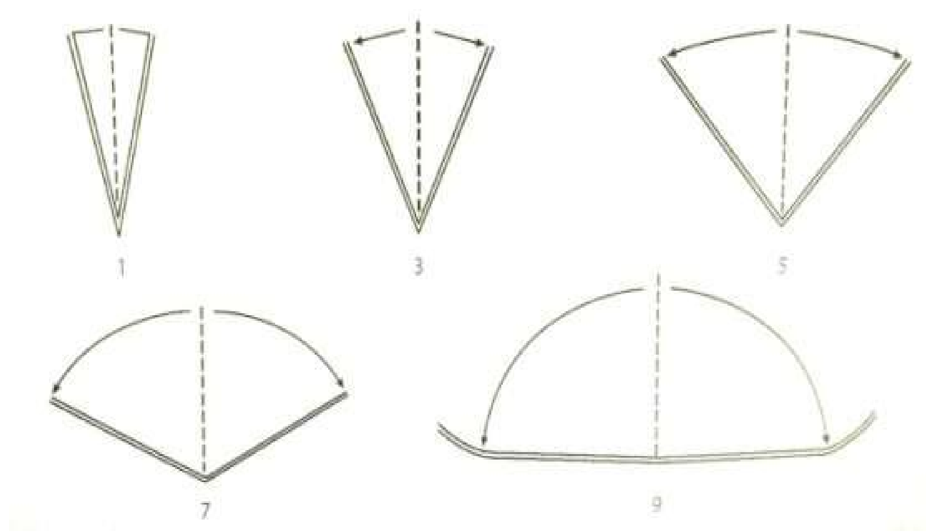

Figure 5. Culm habit

Table 2. Descriptors with the codes for qualitative characteristics

SL. No.	Characteristics	Descriptors with codes
1	Leaf sheath: Anthocyanin color	Absent-1 and present-2
2	Leaf color	Pale green-1, green-2, dark green-3, purple tip-4, purple margins-5, purple blotch-6, and purple-7
3	Penultimate leaf : shape of the ligule	Truncate-1, acute to acuminate-2 and split or two cleft-3
4	Flag leaf: Attitude of the blade	Erect-1, semi erect-3, horizontal-5 and reflexed-7
5	Male sterility	Absent-1, CMS-3, TLMS-5, PLMS-7 and P(T)LMS
6	Lemma and palea : Anthocyanin coloration	Absent or very weak-1, weak-3, medium-5, strong-7, and very strong-9
7	Stem: Anthocyanin coloration of nodes	Absent -1 and Present-9
8	Stem: Anthocyanin coloration of internodes	Absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9
9	Stem: Intensity of anthocyanin coloration of nodes	Weak-3, medium-5, strong-7and very strong-9
10	Spikelet: Color of the tip of lemma	White-1, yellowish-2, brownish-3, red-4, purple-5, and black-6
11	Panicle: Awns in the spikelet	Absent-1 and present-9

SL. No.	Characteristics	Descriptors with codes
12	Panicle: attitude of branches	Erect-1, semi-erect-3, spreading-5, horizontal-7 and drooping- 9
13	Panicle: exertion	Enclosed-1, partly exerted-3, just exerted-5, moderately exerted-7 and well exerted-9
14	Caryopsis scent	Non-scented-0, lightly scented-1, and scented-2
15	Panicle: Length of the longest awn	Very short (<2 mm)-1, short (2-5mm), medium 5-10mm), long(11-20mm), and very long(>20mm)
16	Lemma and palea color (grain color)	Straw-1, golden-2, purple-4 and black-5
17	Culm habit	Erect (<15°)-1, semi-erect (intermediate) (~20°)-3, open (~40°)-5, spreading (60-80°)-7 and procumbent -9

3.11.2 Quantitative traits evaluation methods

3.11.2.1 Time of heading (50 %)

The number of days from date of sowing to the 50% plants with heading in the plots was recorded on each individual plot and replication and the lines were classified as very early (<70 Days)-1, early (70-80 days)-3, medium (86-105 days)-5, late (106-120 days) and very late (>120 days)-9 (Table 3).

3.11.2.2 Flag leaf length (cm)

The flag leaf 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 grouped as very short-1 (<21 cm), short-3 (21-30 cm), intermediate-5 (31-50 cm), long-7 (51-80 cm) and very long-9 (>80 cm) (Table 3).

3.11.2.3 Flag leaf width (cm)

Flag leaf width was measured in centimeter scale at the middle of flag leaf after panicle initiation and classified as narrow-3 (<1 cm), intermediate-5 (1-1.5cm) and broad-7 (>2 cm) (Table 3).

3.11.2.4 Culm length (cm)

Culm length was measured from ground level to the base of the panicle at maturity stage and categorized as very short-1 (<50 cm), very short to short-2 (51-70 cm), short-3(71-90 cm), short to intermediate-4 (91-105 cm), intermediate-5 (106-120 cm), intermediate to long-6 (121-140 cm), long-7 (141-155 cm), 8- long to very long (156-180 cm) and very long-9 (>180 cm) (Table 3).

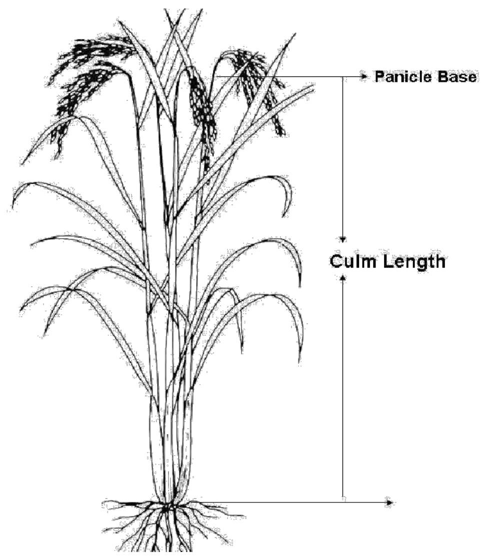

Figure 6. Culm length

3.11.2.5 Culm diameter (mm)

Culm diameter was measured from mother tillers at the lowest internode. Based on this character, the observed genotypes were classified as small-1 (<5.0 mm), medium-3 (5.1-6.0 mm), large-5 (6.1-7.0 mm) and very large-7 (>7.0 mm) (Table 3).

3.11.2.6 Total number of 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 lines were grouped as low-3 (<10 culms), intermediate-5 (11-15 culms) and high-7 (>20 culms) (Table 3).

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 lines were grouped into three groups as low-3 (<7 culms), 5-intermediate (8- 12culms) and high-7 (>15 culms) (Table 3).

3.11.2.8 Panicle length (cm)

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 very short-1 (<11 cm), short-3 (12-15 cm), medium - 5(16-25 cm), long-7 (26-35 cm) and very long-9 (>35cm) (Table 3).

3.11.2.9 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) (Table 3). From figure-7, we can see the branching of panicle of a rice plant.

3.11.2.10 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). (Table 3).

3.11.2.11 Thousand seed weight (dry)

Thousand seed weight (g) was weighed after threshing and recording the net yield 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) (Table 3).

3.11.2.12 Days to maturity (80%)

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) (Table 3).

3.11.2.13 Grain length (without dehulling)

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).

3.11.2.14 Grain length (after dehulling)

Grain length was measured in mm and stereo-microscope was used for clear visualization. Five grains from each lines were measured and the mean value was recorded. The lines were classified as short (<5.5 mm)-1, medium (5.51-6.5 mm)-3, long (6.51-7.5 mm)-5 and very long (> 7.51 mm)-7 (Table-3).

3.11.2.15 Yield per plant

Panicles were 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) (Table 3).

Table 3. Descriptors with codes for quantitative characteristics

SL. No.	Characteristics	Descriptors with codes
1	Time of heading (50%)	1-Very early (<70 days), 3-early (70-85 days), 5-medium (86-105 days), 7-late (106-120 days) and 9-very late (>120 days
2	Flag leaf length	1-Very short (<21 cm), 3-short (21-30 cm), 5-intermediate (31-50 cm), 7-long (51-70 cm) and 9-very long (>70 cm)
3	Flag leaf width	3-Narrow (<1 cm), 5-intermediate (1-1.5 cm) and 7-broad (>1.5 cm)
4	Culm length	1-Very short (<50 cm), 2-very short to short (51-70 cm), 3-short (71-90 cm), 4-short to intermediate (91-105 cm), 5-intermediate (106-120 cm), 6-intermediate to long (121-140 cm, 7-long (141-155 cm), 8- long to very long (156-180 cm) and 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) and 7-very large (>7.0 mm)
6	Total number of tillers per hill	3-Few (<10), 5-medium (11-15) and 7-high (>15)
7	Effective tillers per hill	3-Low (<7), 5-intermediate (8- 12) and 7-high (>12)

SL. No.	Characteristics	Descriptors with codes
8	Panicle length	1-Very short (<11 cm), 3-short (12-15 cm), 5-medium (16-25 cm), 7-long (26-35 cm) and 9-very long (>35 cm)
9	Number of filled grains per panicle	1-Few (<150), 3-medium (150-200), 5-many (201-300) and 7-so many (>301)
10	Number of unfilled grains per panicle	1-Few (<30), 3-medium (31-50) and 5-many (>51)
11	Thousand seed weight (dry)	1-Very low (<l5 g), 3-low (l6-19 g), 5-medium (20-23 g) and 7-high (24-27 g)
12	Days to maturity	1-Early (<95 days), 3-medium (96-120 days), 7-late (121-140) and 9-very late (>141 days)
13	Grain length (without dehulling)	1-Very short (<6.0 mm), 3-short (6.1-7.0 mm), 5-medium (7.1-8.0 mm), 7-long (8.1 – 9.0 mm) and 9-very long (>9.00 mm)
14	Decorticated grain : Length (after dehulling)	1-Short (<5.5 mm), 3-medium (5.6-6.5mm), 5-long (6.6-7.5 mm) and 7-very long (>7.5 mm)
15	Yield per Plant	1-Low (<20gm), 3-medium (20-27gm) and 5-high (>27gm)

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

3.12 Statistical Application

Statistical analysis was done by the help of Stratrix 10 software.

3.13 Data collection for estimation of variability

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

3.13.1 Days to 80% maturity

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

3.13.2 Plant height (cm)

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

3.13.3 Number of total tillers per hill

The number of total tillers per hill were counted from each of the sample plants and average was taken.

3.13.4 Number of effective tillers per hill

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

3.13.5 Panicle length (cm)

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

3.13.6 Number of primary branches per panicle

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

3.13.7 Number of secondary branches per panicle

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

3.13.8 Total number of spikelets per panicle

The total number of spikelet per panicle were counted from the five randomly selected plants of each plot and then averaged.

3.13.9 Number of filled grains per panicle

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

3.13.10 Number of unfilled grains per panicle

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

3.13.11 Thousand seed weight (g)

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

3.13.12 Yield per plant (g)

Five plants from each plot collected randomly then their grains harvested and sun dried. The dried yield was weighted separately and averaged.

3.13.13 Yield per hectare (t)

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

3.13.14 Stem length up to neck (cm)

Five plants from each plot collected randomly then their length from grouped to neck measured separately and averaged.

3.14 Estimation of variability

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

3.14.1 Analysis of variance (ANOVA)

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

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

Where,

r = Number of replications

l = Number of lines

D.F. = Degree of freedom

M.S. = Mean sum of square

EMS = Expected values of M.S.

3.14.2 Estimation of genetic parameters

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

3.14.2.1 Estimation of variance components

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

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

Where,

MSL = Mean sum of square for lines

MSE = Mean sum of square for error and

r = Number of replication

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

Where,

$\sigma^2 g$ = Genotypic variance

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

3.14.2.2 Estimation of co-efficient of variation

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

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

Where,

$\sigma^2 g$ = Genotypic variance

$\overline{x}$ = Population mean

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

Where,

$\sigma^2 p$ = Phenotypic variance

$\overline{x}$ = Population mean

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

3.4.10.3.3 Estimation of heritability in broad sense:

Singh and Chaudhary (1985) suggested a formula to estimate broad sense heritability which is given below:

$$h_b^2(\%) = \frac{\delta_g^2}{\delta_p^2} \times 100$$

Where, h_b^2=Heritability in broad sense

σ_g^2= Genotypic variance

σ_p^2= Phenotypic variance

Robinson *et al.* (1966) suggested the following categories for heritability estimates in cultivated plants:

Categories: Low: 0-30%

Moderate: 30-60%

High: >60%

3.4.10.3.4 Estimation of genetic advance:

Allard (1960) suggested the following formula which was used to estimate the expected genetic advance for different characters under selection:

$$GA = \frac{\sigma_g^2}{\sigma_p^2} . K . \sigma_p$$

Where,

GA = Genetic advance

σ_g^2 = Genotypic variance

σ_p^2 = Phenotypic variance

σ_p= Phenotypic standard deviation

K= Standard selection differential which is 2.06 at 5% selection intensity.

Categories: Low (<10%)

Moderate (10-20%)

High (>20%)

3.4.10.3.5 Estimation of genetic advance in percentageof mean:

Following formula was given by Comstock and Robinson (1952) to compute genetic advance in percentage of mean:

$$\text{GA in percent of mean} = \frac{\text{GA}}{\text{Grand mean}} \times 100$$

Johnson *et al.* (1955) suggested that genetic advance in percent of mean was categorized into following groups:

Categories:

Less than 10% - Low

10-20% -Moderate

More than 20% -High

3.15 Correlation coefficient analysis:

To determine the level of relationship of characters with yield and furthermore among the yield parts, the correlation coefficients were computed. Both genotypic and phenotypic correlationcoefficients between two characters were determined by utilizing the variance and covariance components as suggested by Al-Jibouri*et al.* (1958).

$$r_{gxy} = \frac{Cov_{gxy}}{\sqrt{\sigma^2_{gx}}.\sqrt{\sigma^2_{gy}}}$$

$$r_{pxy} = \frac{Cov_{pxy}}{\sqrt{\sigma^2_{px}}.\sqrt{\sigma^2_{py}}}$$

Where,

$r_g(xy), r_p(xy)$ the genotypic and phenotypic correlation coefficients of x and y, respectively.

Cov_{gxy}, Cov_{pxy} are the genotypic and phenotypic covariance of x and y, respectively.

σ^2_{gx}= Genotypic variance of the trait x and σ^2_{gy} = Genotypic variance of the trait y.

σ^2_{px}= Phenotypic variance of the trait x and σ^2_{py}= Phenotypic variance of the trait y.

The calculated value of 'r' was compared with table 'r' value with n-2 degrees of freedom at 5% and 1% level of significance, where, n refers to number of pairs of observation. Thus, the data obtained from various experimental objectives were subjected to pertinent statistical analysis to draw meaningful inference towards the genetic divergence of mustard populations.

SCHAPTER IV

RESULTS AND DISCUSSION

The research work was conducted with a view to characterize and study variability of some advanced lines of fine grain boro rice. Characterization was done based on qualitative and quantitative traits. Variability among the ten advanced lines was studied based on yield contributing characters. Results have been compiled in tabular form according to the descriptors and described by the following ways:

- ❖ Characterization based on qualitative characters
- ❖ Characterization based on quantitative characters
- ❖ Variability study
- ❖ Correlation coefficient

4.1 Characterization based on qualitative characters

4.1.1 Leaf sheath: Anthocyanin color

On the basis of leaf sheath anthocyanin coloration, the observed lines were categorized as absent-1 and present-2 according to guided descriptors as per follows. Anthocyanin coloration was present only in two advanced lines (L1 and L7), no coloration was found in rest eight advanced lines (Table 4).

4.1.2 Leaf color

Based on leaf color the observed lines were categorized in 7 groups like pale green-1, green-2, dark green-3, purple tip-4, purple margins-5, purple blotch-6, and purple-7 as per follows (Table 5). Here two advanced lines (L3 and L5) lines showed pale green

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

Types	Code	Lines
Absent	1	L2, L3 , L4, L5, L6, L8, L9, L10, L11, L12, L13, L14 and L15
Present	2	L1, L7

Table 5. Categorization and grouping based on leaf color

Types	Code	Lines
Pale green	1	L3 and L5
Green	2	L1, L2, L4, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15
Dark green	3	Nil
Purple tip	4	Nil
Purple margins	5	Nil
Purple blotch	6	Nil
Purple	7	Nil

color and 13 lines (L1, L2, L4, L6, L7, L8, L9, L10, L11, L12, L13, L14, L15) showed green color. Dark green, Purple tip, Purple margins, Purple blotch and Purple green type leaf were not found in any lines.

4.1.3 Penultimate leaf: shape of the ligule

On the basis of ligule shape, rice lines were classified as Truncate-1, Acute to acuminate-2 and split or two cleft-3. But our all lines were two cleft type that means there was no significant difference among the lines (Table 6). According to IRRI most of the cultivated rice have two cleft type ligule shape and wild type lines may show other types. From our observation the two cleft type ligule were found (Plate-2).

4.1.4 Flag leaf: Attitude of the blade

Based on leaf blade attitude our observed lines were categorized into 4 groups as Erect-1, Semi erect-3, Horizontal-5 and Reflexed-7. Here two lines showed semi erect type leaf blade and 13 lines (L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L13, L14 and L15) showed erect type leaf blade. Horizontal and reflexed type leaf blade were not found in the observation (Table 7). Plate-3 and Plate-4 showing semi-erect and erect type flag leaf attitude, respectively.

4.1.5 Male sterility

Male sterility was observed at anthesis period of rice and grouped as per descriptors. On the basis of male sterility, rice lines were classified as Absent-1, CMS-3, TLMS-5, PLMS-7 and P(T)LMS. But all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15) had absence of male sterility (Table 8).

Table 6. Categorization and grouping based on ligule shape of penultimate leaf

Types	Code	Lines
Truncate	1	Nil
Acute to acuminate	2	Nil
Two cleft	3	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15

Table 7. Categorization and grouping based on attitude of flag leaf blade

Types	Code	Lines
Erect	1	L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L13, L14 and L15
Semi-erect	3	L1 and L12
Horizontal	5	Nil
Reflexed	7	Nil

Table 8. Categorization and grouping based on male sterility

Types	Code	Lines
Absent	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15
CMS	3	Nil
TGMS	5	Nil
PGMS	7	Nil
P(T)GMS	9	Nil

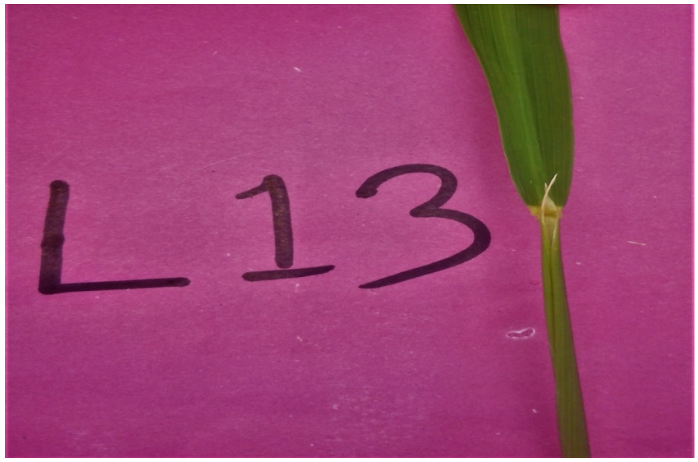

Plate 2. Shape of the ligule (Split or two cleft)

Plate 3. Flag leaf attitude (semi-erect)

Plate 4. Flag leaf attitude (erect)

4.1.6 Lemma and palea : Anthocyanin coloration

On the basis of lemma and palea anthocyanin coloration the observed lines were categorized as absent or very weak-1, weak-3, medium-5, strong-7, and very strong-9 as presented according to descriptors. Here two lines (L1 and L7) showed medium lemma and palea anthocyanin color and other 13 lines (L2, L3, L4, L5, L6, L8, L9, L10, L11, L12, L13, L14, L15) showed no anthocyanin color (Table 9).

4.1.7 Stem: Anthocyanin coloration of nodes

Data was collected after flowering to near maturity stage on stem anthocyanin coloration of nodes and the rice lines were classified into two groups with code according to guided descriptors as Absent -1 and Present-9. In this case all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15) were observed no anthocyanin coloration of nodes (Table 10).

4.1.8 Stem: Anthocyanin coloration of internodes

Data was collected after flowering to near maturity stage on stem anthocyanin coloration of internodes and the rice lines were classified into two groups with Code according to guided descriptors as absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9. In this case L7 showed medium anthocyanin color in internodes and other lines (L1, L2, L3, L4, L5, L6, L8, L9, L10, L11, L12, L13, L14 and L15) were showed no anthocyanin coloration of internodes (Table 11). Plate-5 showing the anthocyanin coloration of internodes.

Table 9. Categorization and grouping based on lemma and palea anthocyanin coloration

Types	Code	Lines
Absent or very weak	1	L2, L3, L4, L5, L6, L8, L9, L10, L11, L12, L13, L14 and L15
Weak	3	Nil
Medium	5	L1 and L7
Strong	7	Nil
Very strong	9	Nil

Table 10. Categorization and grouping based on anthocyanin coloration of nodes

Types	Code	Lines
Absent	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15
Present	9	Nil

Table 11. Categorization and grouping based on anthocyanin coloration of internodes

Types	Code	
Absent	1	L1, L2, L3, L4, L5, L6, L8, L9, L10, L11, L12, L13, L14 and L15
Weak	3	Nil
Medium	5	L7
Strong	7	Nil
Very strong	9	Nil

Plate 5. Anthocyanin coloration of internodes

4.1.9 Stem: Intensity of anthocyanin coloration of nodes

Data was collected after flowering to near maturity stage on stem anthocyanin coloration of nodes and the rice lines were classified into two groups with code according to guided descriptors as weak-3, medium-5, strong-7and very strong-9. No anthocyanin coloration of nodes on the stem were present in all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15) (Table 12).So intensity of anthocyanin coloration of nodes on the stem of all lines was not present.

4.1.10 Spikelet: Color of the tip of lemma

Data were taken after anthesis to hard dough stage or pre-ripening stage on spikelet with color of the lemma and the rice lines were classified into six groups with code according to guided descriptors as white-1, yellowish-2, brownish-3, red-4, purple-5, and black-6.Here, only L10 showed brownish color tip of lemma and other lines showed yellowish color of the tip of lemma (Table 13). Plate-6 showing the color of the tip of lemma.

4.1.11 Panicle: Awns in the spikelet

It was observed at flowering to maturity stage and normally a character of wild species of rice and grouped as absent-1 and present-9. Awns in the spikelet were observed in ten lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) and no awns were found in five lines (L11, L12, L13, L14 and L15) (Table 14). Plate-7 showing awns in the spikelet of the different observed lines.

Table 12. Categorization and grouping based on intensity of anthocyanin coloration of nodes

Types	Code	Lines
Absent	1	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15
Present	9	Nil

Table 13. Categorization and grouping based on color of the tip of lemma of the spikelet

Types	Code	Lines
White	1	Nil
Yellowish	2	L1, L2, L3, L4, L5, L6, L7, L8, L9, L11, L12, L13, L14 and L15
Brownish	3	L10
Red	4	Nil
Purple	5	Nil
Black	6	Nil

Table 14. Categorization and grouping based on awns in the spikelet

Types	Code	Lines
Absent	1	L11, L12, L13, L14 and L15
Present	9	L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10

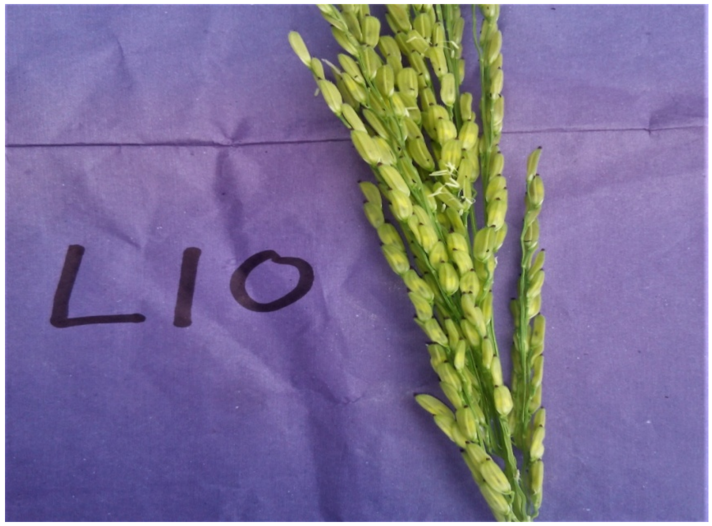

Plate 6. Color of the tip of lemma (Brownish)

Plate 7. Awns in the spikelet of the different observed lines

4.1.12 Panicle: attitude of branches

The compactness of the panicle was classified according to its mode of branching, angle of primary branches, and spikelet density in 5 groups as Erect (compact panicle)-1, Semi-erect (semi-compact panicle)-3, Spreading (open panicle)-5, Horizontal-7 and Drooping- 9. Here one line (L7) was showed spreading type, one line was (L9) showed horizontal type panicle and rest thirteen lines (L1, L2, L3, L4, L5, L6, L8, L10, L11, L12, L13, L14 and L15) were showed drooping type panicle. Erect and semi-erect type panicles were not found among the lines (Table 15). Plate-8 shows drooping type panicle.

4.1.13 Panicle: exertion

Panicle exertion means the panicle comes out from the leaf sheath of flag leaf. On the basis of the degree of exertion it was classified into 5 groups as enclosed-1, partly exerted-3, just exerted-5, moderately exerted-7 and well exerted-9. Here sixlines (L6, L8, L9, L11, L14 and L15) were found just exerted, two lines (L1 and L10) were moderately exerted and seven lines (L2, L3, L4, L5, L7, L12, and L13) were well exerted (Table 16). From Plate-9, Plate-10 and Plate-11 we can see the just exerted, moderately exerted and well exerted panicle, respectively.

4.1.14 Caryopsis scent

Different techniques to detect aroma were developed by several scientists around the world. Based on aroma our tested lines were categorized in 3 groups as Non-scented-0, Lightly scented-1, and Scented-2.Here, nine lines (L1, L2, L3, L4, L5, L6, L7, L9 and L12)were lightly scented and six lines (L8, L10, L11, L13, L14 and L15) were non- scented (Table 17).

Table 15. Categorization and grouping based on panicle attitude of branches

Types	Code	Lines
Erect	1	Nil
Semi-erect	3	Nil
Spreading	5	L7
Horizontal	7	L9
Drooping	9	L1, L2, L3, L4, L5, L6, L8, L10, L11, L12, L13, L14 and L15

Table 16. Categorization and grouping based on panicle exertion

Types	Code	Lines
Enclosed	1	Nil
Partly exerted	3	Nil
Just exerted	5	L6, L8, L9, L11, L14 and L15
Moderately exerted	7	L1 and L10
Well exerted	9	L2, L3, L4, L5, L7, L12, and L13

Table 17. Categorization and grouping based on caryopsis scent

Types	Code	Lines
Non-scented	0	L8, L10, L11, L13, L14 and L15
Lightly scented	1	L1, L2, L3, L4, L5, L6, L7, L9 and L12
Scented	2	Nil

Plate 8. Drooping type panicle

Plate 9. Just exerted panicle

Plate 10. Moderately exerted panicle

Plate 11. Well exerted panicle

4.1.15 Panicle: Length of the longest awn

It was observed at flowering to maturity stage and normally a character of wild species of rice and grouped as very short (<2 mm)-1, short (2-5mm), medium 5-10mm), long(11-20mm), and very long(>20mm). In this case, very short awn was found in L2, L3, L4, L8 and short awn were found in L5 and L9 (Table 18). Plate-12 showing length of the longest awn.

4.1.16 Lemma and palea color (grain color)

On the basis of lemma and palea coloration the observed lines were categorized as straw-1, golden-2, purple-4 and black-5. Lemma and paleacombindly indicates the seed coat color actually. In this case among our observed lines, four lines (G02, G03, G04 and G06) were straw type, and five lines (G01, G05, G07, G08 and G09) were golden type seed coat color (Table 19). Plate-13 showing different grain color of the observed lines.

4.1.17 Culm habit

The estimated average angle of inclination of the base of the main culm from vertical after flowering, rice lines were classified as erect (<15°)-1, semi-erect (intermediate) (~20°)-3, open (~40°)-5, spreading (60-80°)-7 and procumbent -9 type. Here 12 lines (L1, L2, L3, L4, L5, L6, L7, L10, L11, L13, L14 and L15) were showed erect type and 3 lines (L8, L9 and L12) were showed semi-erect type in nature but open, spreading and procumbent type culm were not found in any lines (Table20). From Plate-14 and Plate-15 we can see erect and semi-erect type of culm habit, respectively.

Table 18. Categorization and grouping based on length of the longest awn

Types	Code	Lines
Very short	1	L2, L3, L4 and L8
Short	3	L5 and L9
Medium	5	Nil
Long	7	Nil
Very long	9	Nil

Table 19. Categorization and grouping based on grain color

Types	Code	Lines
Straw	1	L1, L3, L6, L7, L9, L12, L13, L14 and L15
Golden	2	L2, L4, L5, L8, L10 and L11
Purple	4	Nil
Black	5	Nil

Table 20. Categorization and grouping based on culm habit

Types	Code	Lines
Erect	1	L1, L2, L3, L4, L5, L6, L7, L10, L11, L13, L14 and L15
Semi-erect	3	L8, L9 and L12
Open	5	Nil
Spreading	7	Nil
Procumbent	9	Nil

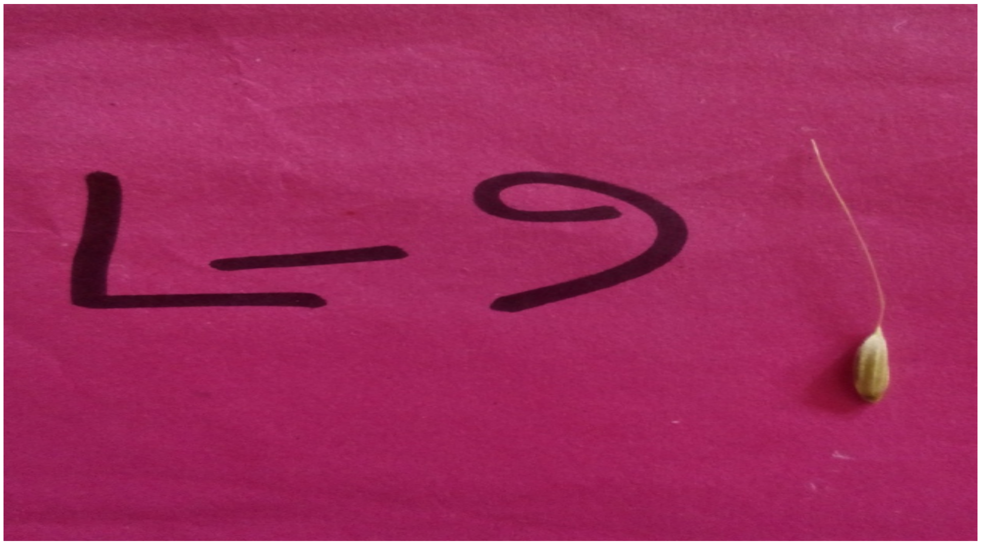

Plate 12. Length of the longest awn in the spikelet

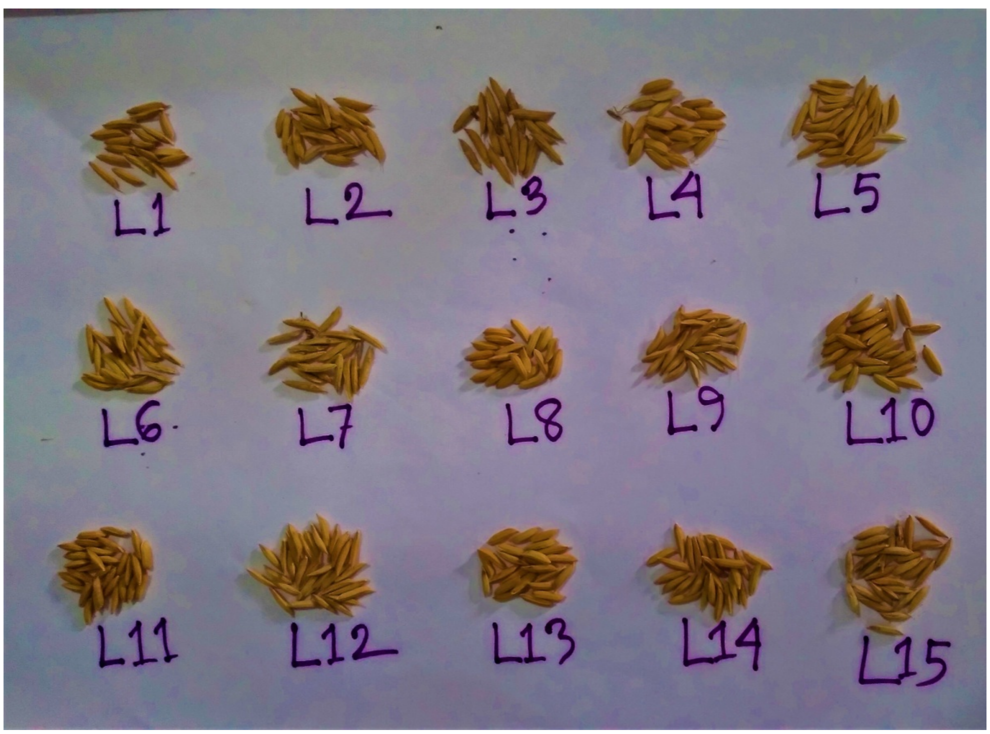

Plate 13. Different grain color of the observed lines

4.2 Quantitative Characteristics Evaluation

4.2.1 Time of heading (50%)

Time of 50% heading of the observed lines ranged from (L11) 115 days to (L1) 135.67 days with a mean value of 123.09 days (Table 21). On the basis of time of 50% heading, rice lines were classified into 5 groups viz. very early (<70 days), early (70-85 days), medium (86-105 days), late (106-120 days) and very late (>120 days). Four lines (L10, L13, L14 and L15) were showed late, eleven lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L11 and L12) were showed very late but no lines were found as very early, early and medium type for 50% heading formation (Table21). Plate-14 showing 50 % of plants with heads. Figure 7 showing the different time of heading of the observed lines of rice.

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 lines ranged from (L12) 24.13 cm- (L7) 30.16 cm with a mean value of 26.74 cm (Table 22). On the basis of this character, the lines 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 all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15) were short type. (Table 22). From the Plate-15 we can see a short type flag leaf. Figure 8 showing the different flag leaf length of the observed lines of rice.

Table 21. Categorization and grouping based on time of heading

Groups	Scale	Code	Lines
Very early	<70 days	1	Nil
Early	70-85 days	3	Nil
Medium	86-105 days	5	Nil
Late	106-120 days	7	L10, L13, L14 and L15
Very late	>120 days	9	L1, L2, L3, L4, L5, L6, L7, L8, L9, L11 and L12
Range	(L11) 115 days – (L1) 135.67 days		
Average	123.09 days		

Table 22. Categorization and grouping based on flag leaf length

Groups	Scale	Code	Lines
Very short	<21 cm	1	Nil
Short	21-30 cm	3	L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15
Intermediate	31-50 cm	5	Nil
Long	51-70 cm	7	Nil
Very long	>70 cm	9	Nil
Range	(L12) 24.13 cm- (L7) 30.16 cm		
Average	26.74 cm		

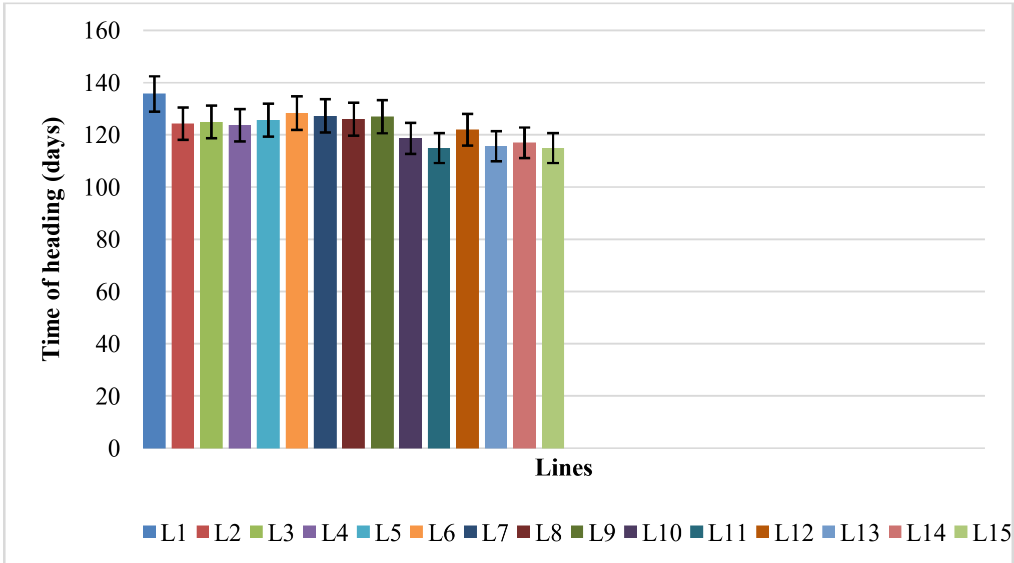

Figure 7. Different time of heading (50%) of the observed lines

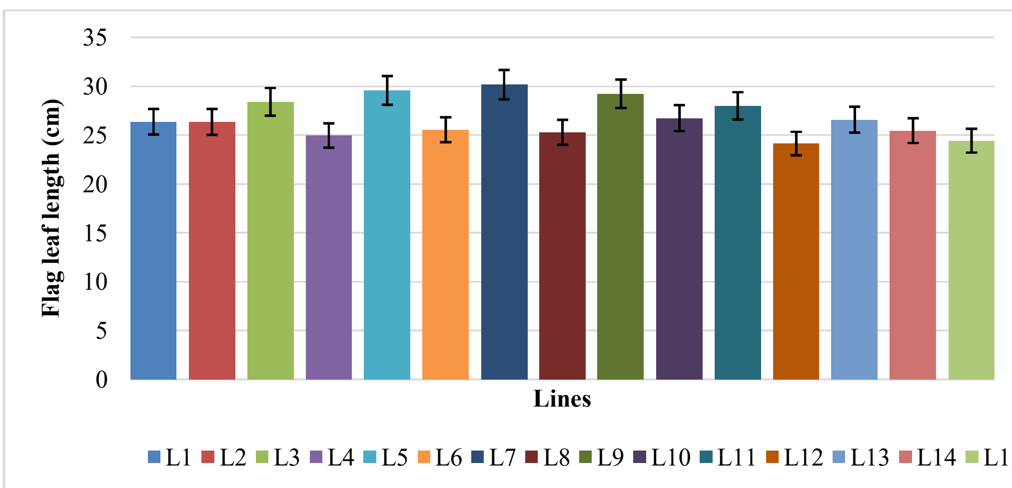

Figure 8. Different flag leaf length (cm) of the observed lines

Plate 14. Time of heading (50 % of plants with heads)

Plate 15. Short type flag leaf

4.2.3 Flag leaf width

Flag leaf width of observed lines ranged from (L13) 1.30 cm to (L1) 2.00 cm with a mean value of 1.20 cm (Table 23). On the basis of this character, the lines were categorized into three groups as narrow (<1 cm), intermediate (1-1.5 cm) and broad (>1.5 cm) as the guided descriptors where six lines (L5, L8, L11, L13, L14 and L15) belongs to intermediate category and nine lines (L1, L2, L3, L4, L6, L7, L9, L10 and L12) belong to broad category (Table 23). Figure 9 showing flag leaf width of the different observed lines of rice.

4.2.4 Culm length

Culm length means the length of a stem from ground level to panicle base. Culm lengths of observed lines ranged from (L14) 61.82 cm to (L1) 82.10 cm with a mean value of 70.64 cm (Table 24). On the basis of this character, the lines were categorized into 9 groups as Very short (<50 cm), Very short to short (51-70 cm), Short (71-90 cm), Short to intermediate (91-105 cm), Intermediate (106-120 cm), Intermediate to long (121-140 cm, Long (141-155 cm), Long to very long (156-180 cm) and Very long (>180 cm) as the guided descriptors where there were nine lines (L3, L4, L7, L8, L10, L12, L13, L14 and L15) belongs to very short to short category, six lines (L1, L2, L5, L6, L9 and L11) belongs to short category (Table 24). Figure 10 showing culm length of the different observed lines of rice.

Table 23. Categorization and grouping based on flag leaf width

Groups	Scale	Code	Lines
Narrow	<1 cm	3	Nil
Intermediate	1-1.5 cm	5	L5, L8, L11, L13, L14 and L15
Broad	>1.5 cm	7	L1, L2, L3, L4, L6, L7, L9, L10 and L12
Range	(L13) 1.30 cm – (L1) 2.00 cm		
Average	1.50 cm		

Table 24. Categorization and grouping based on culm length

Groups	Scale	Code	Lines
Very short	< 50 cm	1	Nil
Very short to short	51-70 cm	2	L3, L4, L7, L8, L10, L12, L13, L14 and L15
Short	71-90 cm	3	L1, L2, L5, L6, L9 and L11
Short to intermediate	91-105 cm	4	Nil
Intermediate	106-120 cm	5	Nil
Intermediate to long	121-140 cm	6	Nil
Long	141-155 cm	7	Nil
Long to very long	156-180	8	Nil
Very long	>180 cm	9	Nil
Range	(L14) 61.82 cm - (L1) 82.10 cm		
Average	70.64 cm		

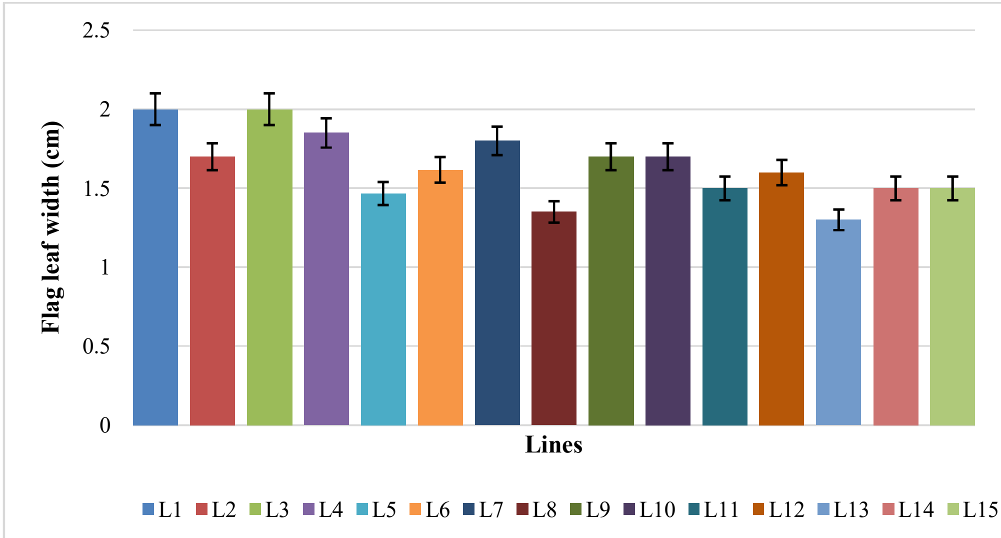

Figure 9. Different flag leaf width (cm) of the observed lines

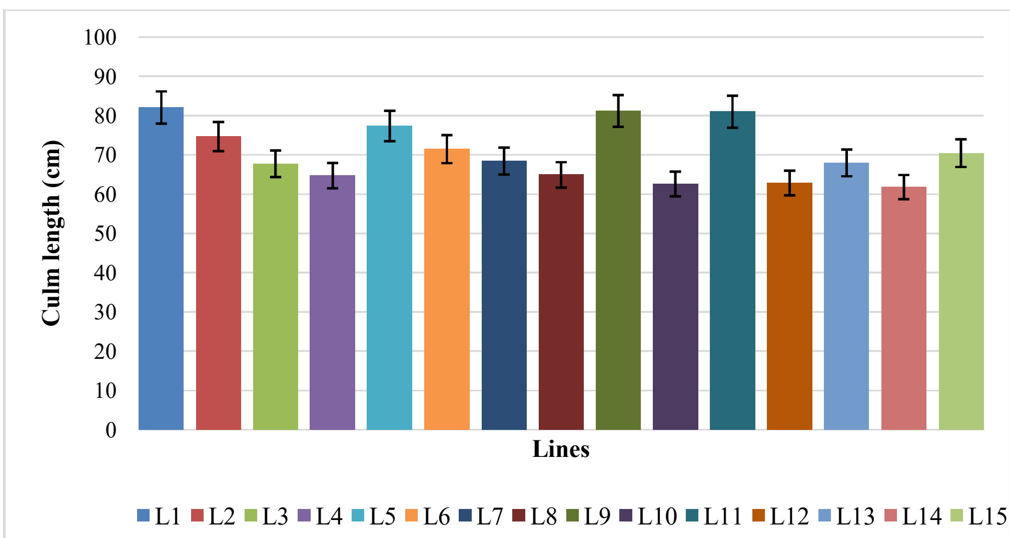

Figure 10. Different culm length (cm) of the observed lines

4.2.5 Culm diameter

Culm diameter was measured from mother tillers in the lowest internode. From our observed lines, it was ranged from (L13) 4.87 mm to (L6) 6.79 mm with a mean value of 5.88 mm (Table 25). Based on this character, the observed lines 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 six lines (L2, L5, L6, L7, L8 and L9) belongs to large category, eight lines (L1, L3, L4, L10, L11, L12, L14 and L15) belongs to medium category and only one line (L13) belongs to small category (Table 25). Figure 11 showing distinguish different groups of observed lines based on culm diameter.

4.2.6 Total number of tillers per hill

The total number of tillers per plant of 9 lines ranged from (L1) 12.40 culms to (L13) 22.33 culms with a mean value of 15.87 culms. Based on this character, the observed lines were identified as few (<10), medium (11-15) and high (>15) number of tillers per plant. From our observed lines we can see that seven lines (L1, L2, L3, L4, L5, L7 and L9) belongs to intermediate category and rest eight lines (L8, L6, L10, L11, L12, L13, L14 and L15) belongs to high category (Table 26).Figure 12 showing distinguish different groups of observed lines based on total no. of tillers per hill.

Table 25. Categorization and grouping based on culm diameter

Groups	Scale	Code	Lines
Small	<5.0 mm	1	L13
Medium	5.1-6.0 mm	3	L1, L3, L4, L10, L11, L12, L14 and L15
Large	6.1-7.0 mm	5	L2, L5, L6, L7, L8 and L9
Very large	>7.0 mm	7	Nil
Range	(L13) 4.87 mm – (L6) 6.79 mm		
Average	5.83 mm		

Table 26. Categorization and grouping based on total number of tillers per hill

Groups	Scale	Code	Lines
Low	<10 culms	3	Nil
Intermediate	11-15 culms	5	L1, L2, L3, L4, L5, L7 and L9
High	>15 culms	7	L8, L6, L10, L11, L12, L13, L14 and L15
Range	(L1) 12.40 culms- (L13) 22.33 culms		
Average	15.87 culms		

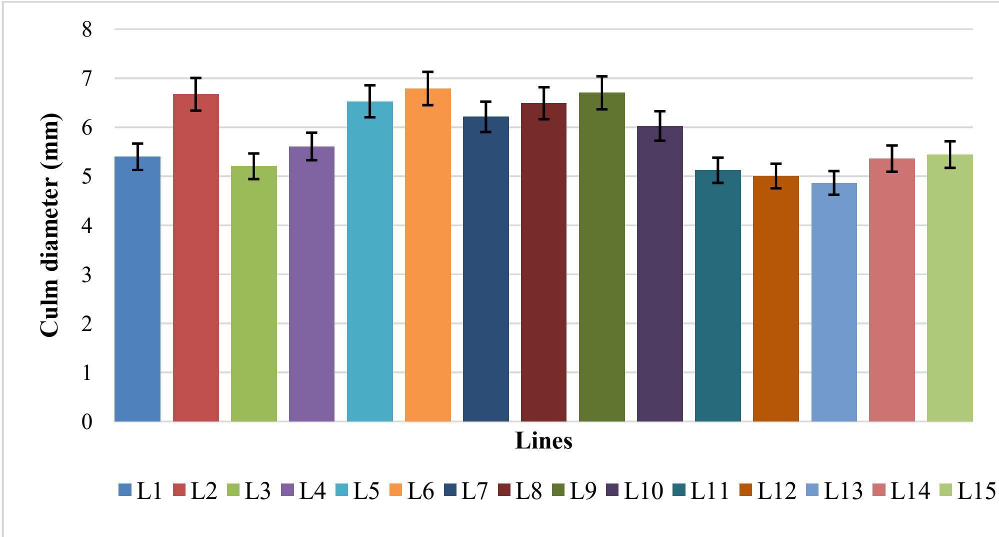

Figure 11. Different culm diameter (mm) of the observed lines

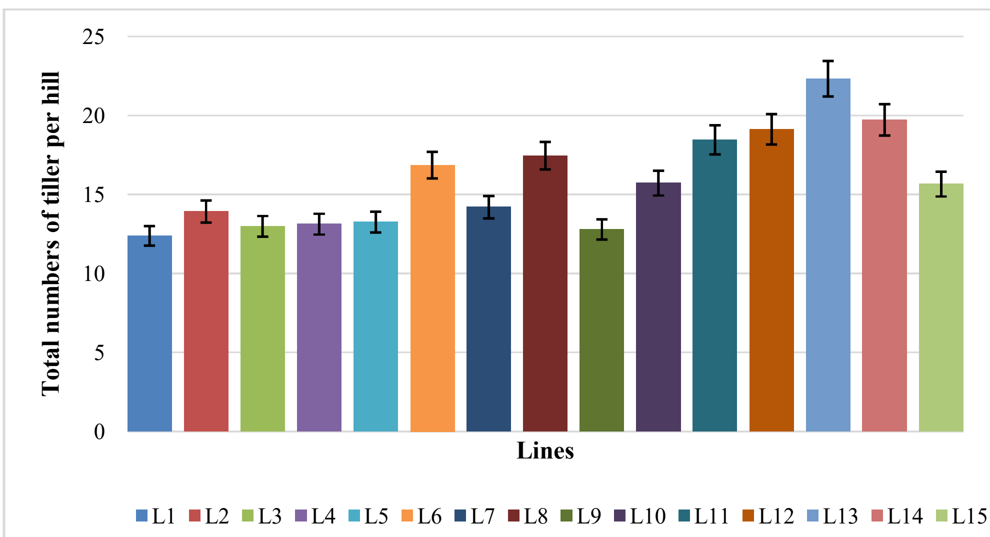

Figure 12. Total numbers of tiller per hill of the different observed lines

4.2.7 Effective tillers per hill

The number of effective tillers per plant of the observed lines ranged from (L1) 12.13 culms to (L13) 21.93 culms with a mean value of 15.49 culms (Table 27) considering this character, the observed lines were categorized as low (<7), intermediate (8- 12) and high (>12) effective tillers per plant. From the observed lines we can see that one line (L1) belongs to intermediate category and rest fourteen lines (L1, L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15) belongs to high category (Table 27).Figure 13 showing distinguish different groups of observed lines based on effective tiller per hill.

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 lines ranged from (L1) 27.60 cm to (L12) 21.74 cm with a mean value of 24.83 cm (Table 28) and based on this character, the lines 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 lines we can see that nine lines (L2, L4, L8, L9, L11, L12, L13, L14 and L15) were under Medium group and rest six lines (L1, L3, L5, L6, L7 and L10) were under Long group and other types of panicle were not found (Table 28). Figure 14 showing distinguish different groups of observed lines based on panicle length.

Table 27. Categorization and grouping based on effective tillers per hill

Groups	Scale	Code	Lines
Low	<7 culms	3	Nil
Intermediate	8-12 culms	5	L1
High	>12 culms	7	L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15
Range	(L1) 12.13 culms - (L13) 21.93 culms		
Average	15.49 culms		

Table 28. Categorization and grouping based on panicle length

Groups	Scale	Code	Lines
Very short	< 11 cm	1	Nil
Short	12-15 cm	3	Nil
Medium	16-25 cm	5	L2, L4, L8, L9, L11, L12, L13, L14 and L15
Long	26-35 cm	7	L1, L3, L5, L6, L7 and L10
Very long	>35 cm	9	Nil
Range	(L1) 27.60 cm – (L12) 21.74 cm		
Average	24.83 cm		

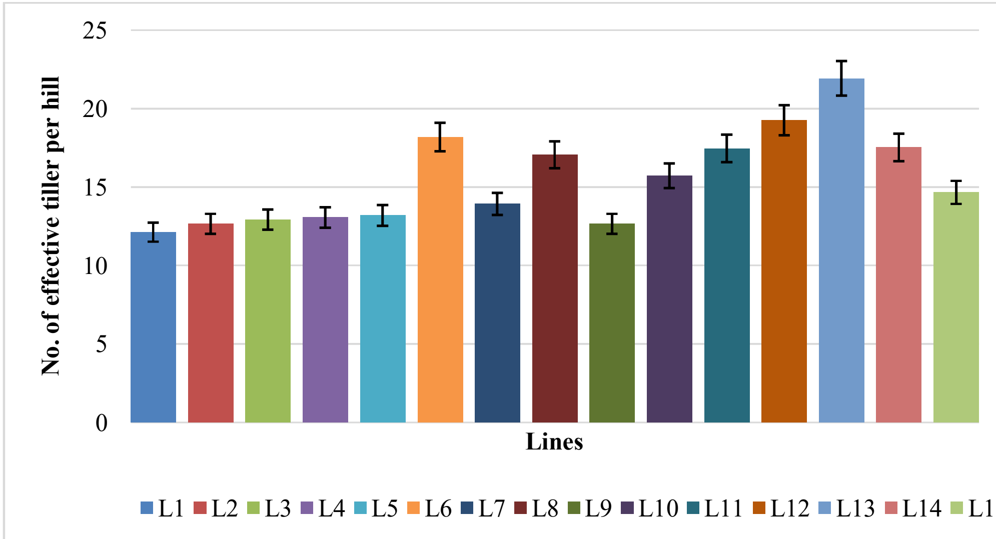

Figure 13. No. of effective tiller per hill of the observed lines

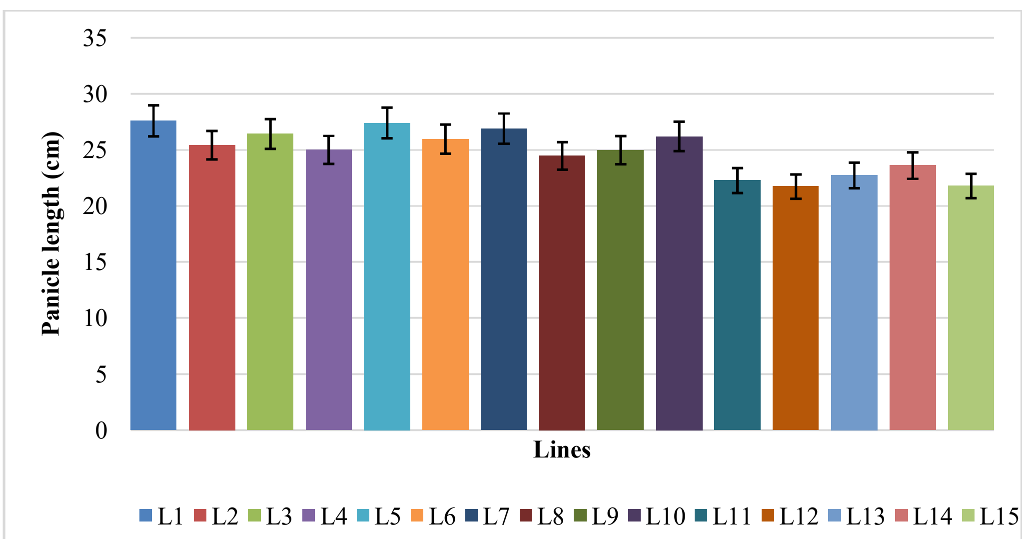

Figure 14. Different panicle length (cm) of the observed lines

4.2.9 Number of filled grains per panicle

The number of filled grains per panicle ranged from 111.33 (L13) to 207.07 (L9) with a mean value 150.66 (Table 29). On the basis of this character, the lines were grouped as few (<150), medium (150-200), many (201-300) and so many (>301) where eight lines (L3, L6, L8, L10, L11, L12, L13 and L14) were recorded as Few, six lines (L1, L2, L4, L5, L7 and L15) as Medium and one line (L9) as Many category (Table 29).From the Figure 15showing distinguish different groups of observed lines based on filled grain per panicle.

4.2.10 Number of unfilled grains per panicle

The number of unfilled grains per panicle ranged from (L2) 9.80 to (L6) 68.40 with a mean value of 28.64 (Table 30). On the basis of this character, the lines were grouped as few (<30), medium (31-50) and many (>51) number of unfilled grain per panicle. Here nine lines (L2, L3, L4, L5, L8, L11, L12, L13 and L15) belong to Few, four lines (L1, L7, L9, L10 and 14) belongs to Medium and one line (L6) belongs to Many category (Table 30).

4.2.11 Thousand seed weight (dry)

Thousand grain weight of the observed lines ranged from (L3) 26.16 gm to (L12) 18.16 gm with a mean value of 22.37 gm (Table 31) and considering this character, the lines were grouped as very low (<l5 g), low (l6-19 g), medium (20-23 g) and high (24-27 g). Here only one line (L12) was recorded as low, ten lines (L5, L6, L7, L8, L9, L10, L11, L13, L14 and L15) was recorded as medium, four lines (L1, L2, L3 and L4) recorded as high category (Table 31). Figure 16showing distinguish different groups of observed lines based on thousand grain weight.

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

Groups	Scale	Code	Lines
Few	<150	1	L3, L6, L8, L10, L11, L12, L13 and L14
Medium	151-200	3	L1, L2, L4, L5, L7 and L15
Many	201-300	5	L9
So many	>300	7	Nil
Range	(L9) 207.07 – (L13) 111.33		
Average	150.66		

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

Groups	Scale	Code	Lines
Few	<30	1	L2, L3, L4, L5, L8, L11, L12, L13 and L15
Medium	31-50	3	L1, L7, L9, L10 and 14
Many	>51	5	L6
Range	(L2) 9.80 – (L6) 68.40		
Average	28.64		

Table 31. Categorization and grouping based on thousand seed weight (dry)

Groups	Scale	Code	Lines
Very low	<15 gm	1	Nil
Low	16-19 gm	3	L12
Medium	20-23 gm	5	L5, L6, L7, L8, L9, L10, L11, L13, L14 and L15
High	24-27 gm	7	L1, L2, L3 and L4
Very high	>27 gm	9	Nil
Range	(L3) 26.16 gm-(L12) 18.16 gm		
Average	22.37 gm		

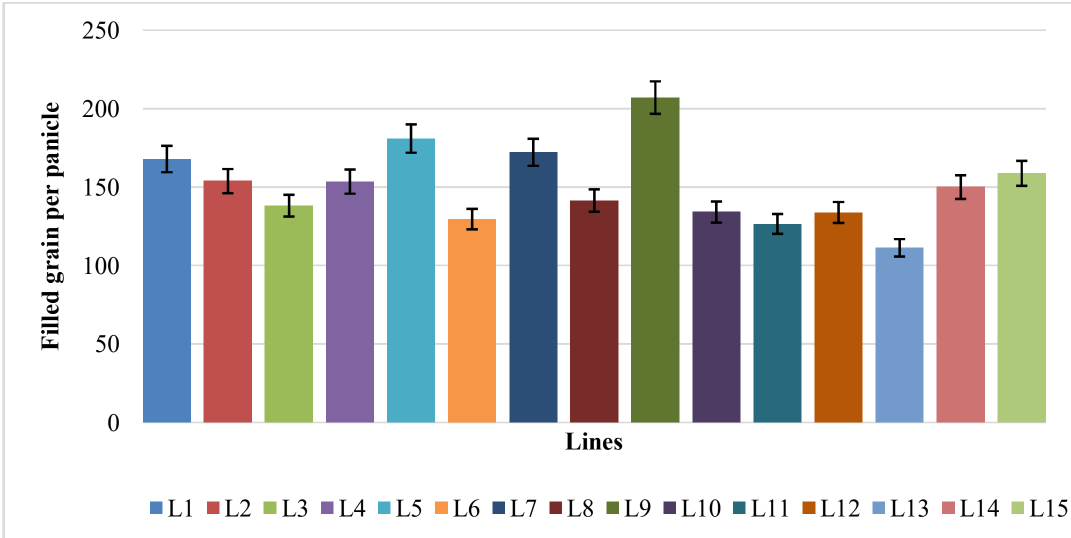

Figure 15. No. of filled grain per panicle of the observed lines

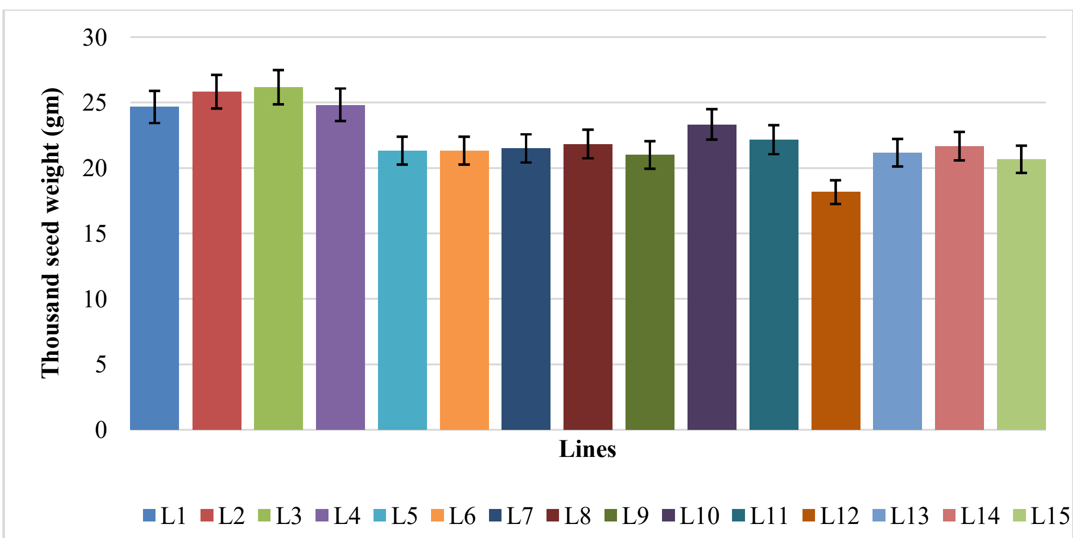

Figure 16. Different thousand seed weight (gm) of the observed lines

4.2.12 Days to maturity

Time of maturity was calculated as days required from sowing to maturity. Time of maturity of the observed lines ranged from 136.67 days (L11) to 153.67 days (L1) with a mean value of 143.15 days (Table 32) 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 fourteen lines (L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15) as late and only one line (L1) 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 17. Plate 16 showing days of maturity of different observed lines.

4.2.13 Grain length (Without dehulling)

Grain length of rice lines ranged from (L6) 11.68 mm-(L8) 8.45 mm with a mean value of 9.22 mm (Table 33). On the basis of grain length, the observed lines were grouped as very short (<6.0 mm), short (6.1-7.0 mm), medium (7.1-8.0 mm), long (8.1 – 9.0 mm) and very long (>9.00 mm) where two lines (L8 and L11) were recorded as long and thirteen lines (L1, L2, L3, L4, L5, L6, L7, L9, L10, L12, L13, L14 and L15) as very long group (Table 33). Pictorial view of grain length is presented in Plate 17. Figure 18 showing distinguish different groups of observed lines based on grain length.

Table 32. Categorization and grouping based on time of maturity

Groups	Scale (days)	Code	Lines
Very early	>100	1	Nil
Early	101-115	3	Nil
Medium	116-135	5	Nil
Late	136-150	7	L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15
Very late	>150	9	L1
Range	(L11) 136.67 days – (L1) 153.67 days		
Average	145.13 days		

Table 33. Categorization and grouping based on grain length (Without Dehulling)

Groups	Scale	Code	Lines
Very short	<6.0 mm	1	Nil
Short	6.1-7.0 mm	3	Nil
Medium	7.1-8.0 mm	5	Nil
Long	8.1 – 9.0 mm	7	L8 and L11
Very long	>9.00 mm	9	L1, L2, L3, L4, L5, L6, L7, L9, L10, L12, L13, L14 and L15
Range	(L6) 11.68 mm-(L8) 8.45 mm		
Average	10.09 mm		

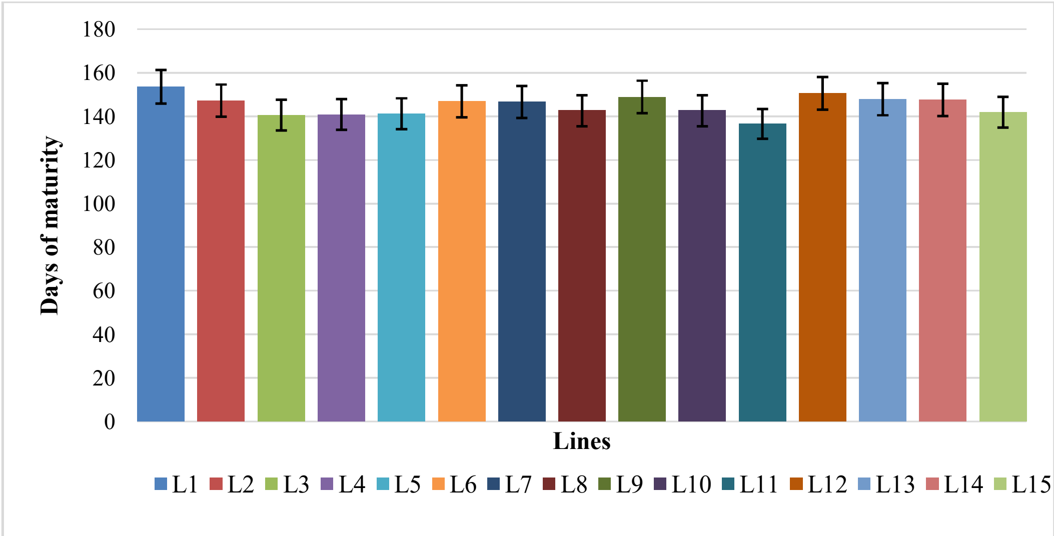

Figure 17. Different days of maturity (80%) of the observed lines

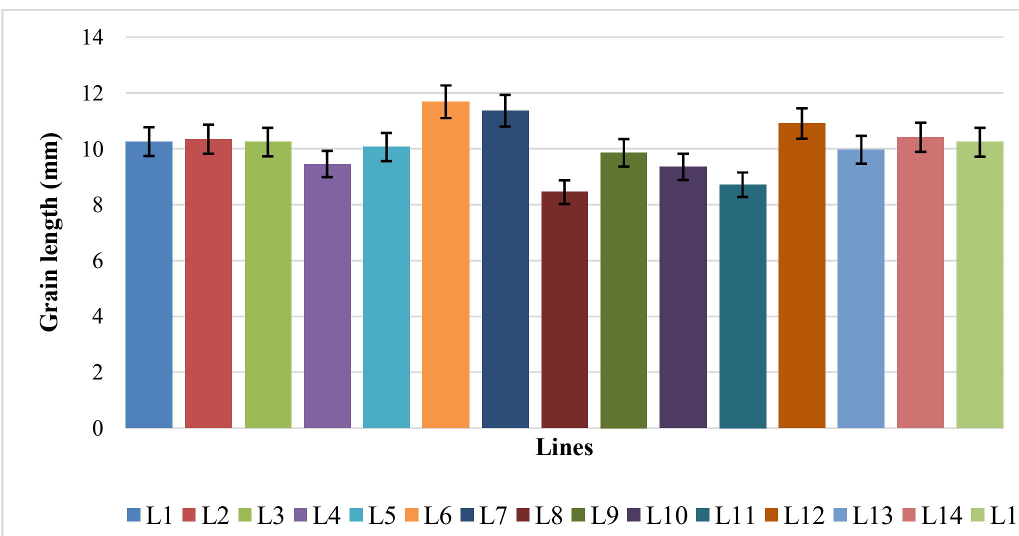

Figure 18. Different grain length (without dehulling) of the observed lines

Plate 16. Days of maturity (80%) of the observed lines

Plate 17. Different types of grain length (Without dehulling)

4.2.14 Decorticated grain : Length (After dehulling)

Decorticated grain length was measured in mm and a digital caliper was used for clear visualization. Ten grains from every lines were measured and the mean value was recorded. On the basis of decorticated grain length, the observed lines were grouped as short (<5.5 mm), medium (5.6-6.5mm), long (6.6-7.5 mm) and very long (>7.5 mm). Four lines were recorded as medium, six lines were recorded as long and five lines were recorded as very long(Table 34). No lines were found as short. From the Figure 19showing distinguish different groups of observed lines based on decorticated grain length. Plate 18 showing the different decorticated grain length (after dehulling) of the observed lines.

4.2.15 Yield per Plant

Yield per plant ranged from (L6) 22.24 gm to (L3) 45.60 gm with a mean value of 40.00 gm (Table 34). On the basis of seed yield per plant, the observed lines were grouped as low (<20gm), medium (20-27gm) and high (>27gm) seed yielder where only one line (L6) was recorded as medium category and rest eight lines (L1, L2, L3, L4, L5, L7, L8, L9, L10, L11, L12, L13, L14 and L15) were as high category (Table 35).From the Figure 20showing distinguish different groups of observed lines based on yield per plant.

Table 34. Categorization and grouping based on decorticated grain length (After dehulling)

Groups	Scale	Code	Lines
Short	<5.5 mm	1	Nil
Medium	5.51-6.5 mm	3	L4, L8, L11 and L15
Long	6.51-7.5 mm	5	L5, L9, L10, L12, L13 and L14
Very long	>7.51 mm	7	L1, L2, L3, L6 and L7
Range	(L3) 9.02 mm – (L4) 6.09 mm		
Average	7.15 mm		

Table 35. Categorization and grouping based on yield per plant

Groups	Scale	Code	Lines
Low	<20 gm	1	Nil
Medium	20-27 gm	3	L6
High	>27 gm	5	L1, L2, L3, L4, L5, L7, L8, L9, L10, L11, L12, L13, L14 and L15
Range	(L3) 45.60 gm - (L6) 22.24 gm		
Average	40.00 gm		

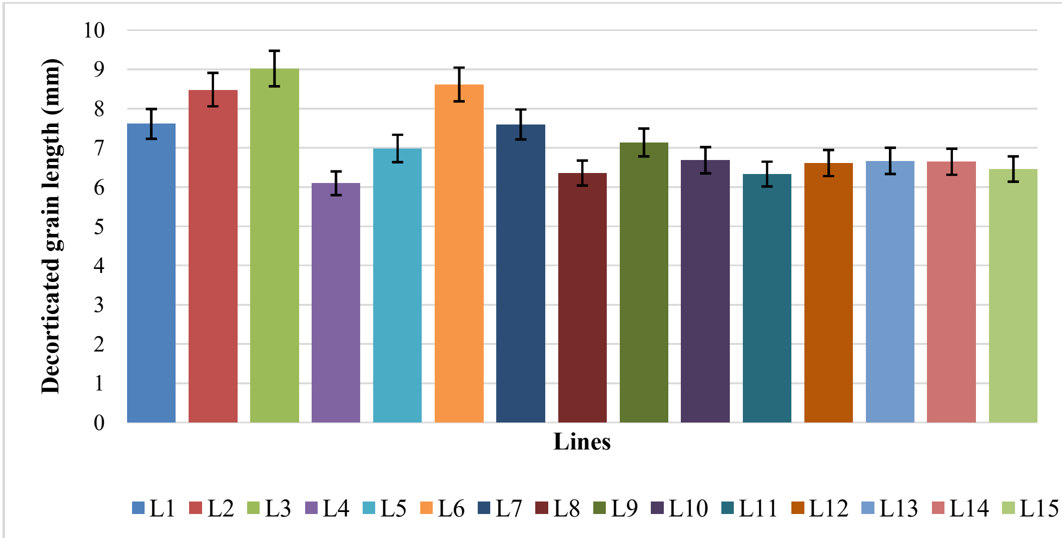

Figure 19. Decorticated grain length (mm) of the observed lines

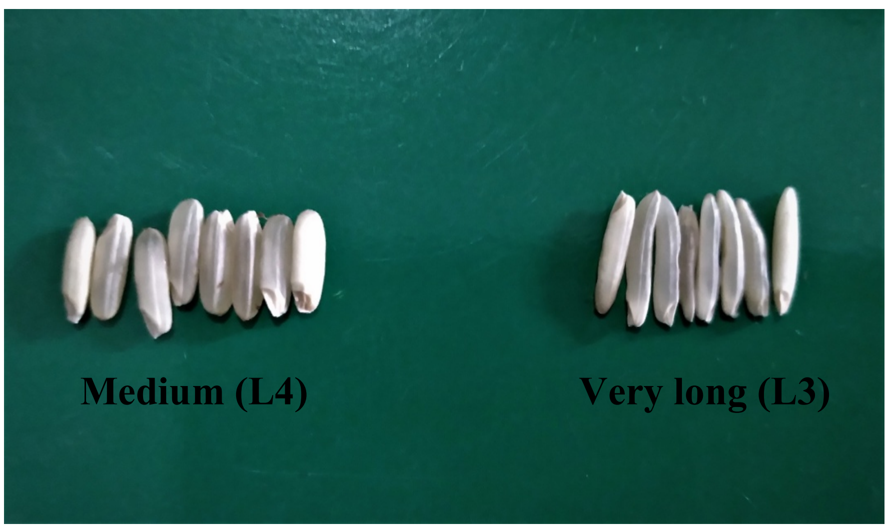

Plate 18. Different decorticated grain length (after hulling)

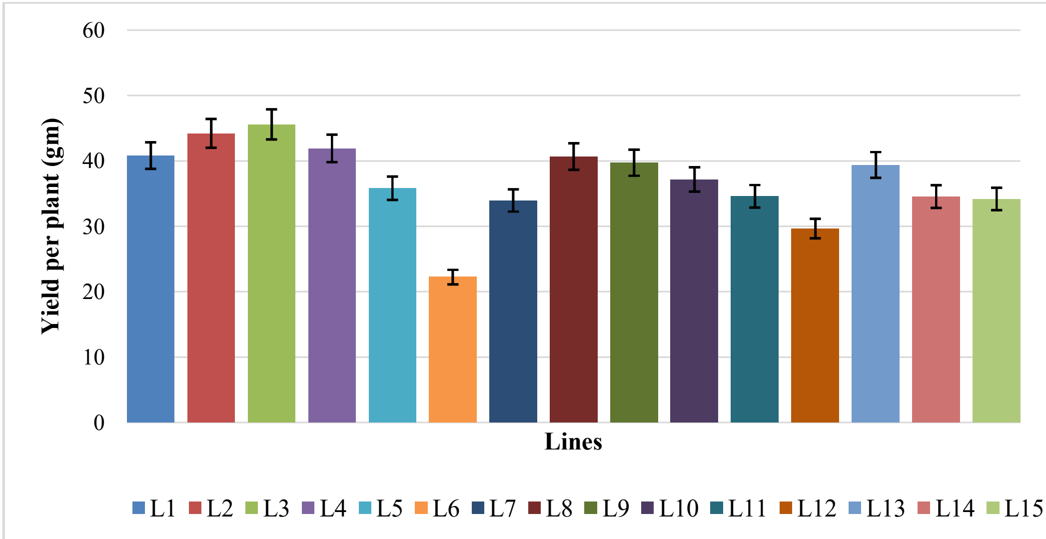

Figure 20. Yield per plant (gm) of the observed lines

4.3 Variability Study

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

4.3.1 Plant height (cm)

The analysis of variance indicated significant difference among rice lines (183.63*), studied for plant height at 5% level of probability (Table 36). The highest plant height was observed in L1 (109.70 cm) followed by L9 (106.22 cm).The lowest plant height was observed in L12 (84.64 cm). The mean value of plant height was 95.48 cm (Table 37). Plant height showed phenotypic variance (63.8) and genotypic variance (59.91) with relatively medium differences between them which indicating considerable environmental influences on this trait (Table 38). The low difference between PCV (8.36) and GCV (8.10) indicated that the genetic variation was very low among the genotypic variation and environment had medium influence on this character expression. Figure 28 showing genotypic, phenotypic and environmental variability of the fine grain boro rice lines with their check varieties for plant height. Figure 21 showing variation in plant height of different observed lines. Ookawa*et al.* (2010) and Chen *et al.* (2005) observed plant height at the heading stage have been considered important traits in breeding both super rice and bioenergy crops.

High heritability (93.91%) in association with moderate genetic advance (19.80) and highgenetic advance in percentage of mean (20.73)were noted for this character was controlled by additive and non-additive gene rendering them inappropriate for advancement through direct selection (Table 38).

4.3.2 Total no. of tillers per hill

Analysis of variance for total no. of tillers per hill exhibited significant mean sum of square (27.472*) (Table 36). The highest number of total tillers per hill was observed in L13 (22.33) followed by L14 (19.73). The lowest number of total tillers per hill was observed in L1 (12.40) and the mean value was total no. of tillers per hill was

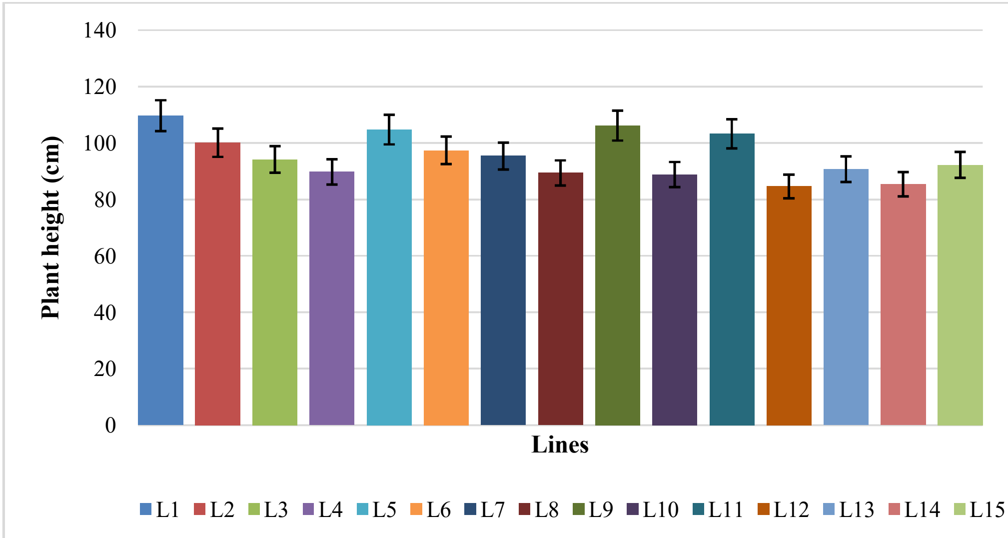

Figure 21. Significant variation in plant height (cm) of the observed lines

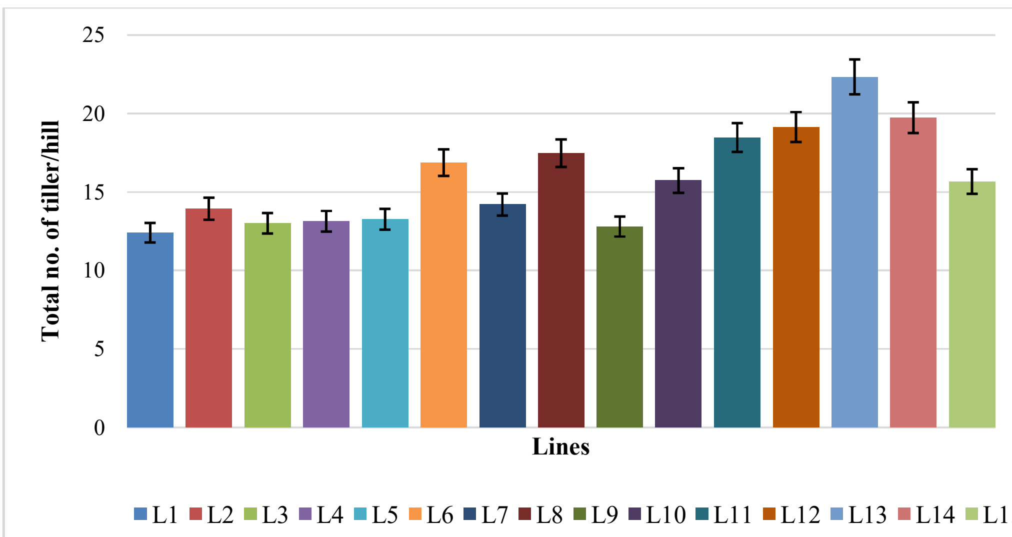

Figure 22. Significant variation in total no. of tiller per hill of the observed lines

Table 36. Analysis of variance of fourteen important characters of rice lines with their check varieties

Source of variation	D.F.	PH	NTH	ETH	PL	PBP	SBP	SP	FLP	UFLP	TSW	YP	SL	TH	DM
Replication	2	6.45	10.58	6.147	0.613	0.526	1.184	124.29	518.84	221.65	7.622	30.995	9.665	13.489	11.466
Lines	14	183.63**	27.472**	26.08**	12.04**	77.29**	51.23**	2750.56**	1780.30**	704.35**	14.207*	105.748**	150.55**	103.594**	61.89**
Error	28	3.89	2.84	2.72	1.96	3.81	7.80	339.10	278.55	81.17	5.854	34.959	5.327	1.370	3.276

**, Significant at 1 % level of significance *, Significant at 5 % level of significance

PH = Plant height (cm), NTH = No. of tiller/hill, ETP = Effective tiller/hill, PL = Panicle length (cm), PBP = Primary branch/panicle, SBP = Secondary branch/panicle, SP = Spikelet/panicle, FLP = Filled grain/plant, UFLP = Unfilled grain/plant, TSW = Thousand seed weight (g), YP = Yield/plant (g), SL = Stem length (cm), TH = Time of heading, DM = Days to maturity, YH = Yield (t/ha)

Table 37: Maximum, minimum, mean and CV of parameters of boro rice lines

Parameters	Minimum	Maximum	Mean	CV (%)
PH	84.64	109.70	95.48	2.07
NTH	12.40	22.33	15.87	10.62
ETH	12.13	21.93	15.49	10.66
PL	21.74	27.60	24.83	5.64
PBP	6.86	28.40	11.20	6.95
SBP	22.20	34.40	29.97	9.32
SP	124.60	238.60	179.31	10.27
FLP	111.33	207.07	150.66	11.08
UFLP	9.80	68.40	28.64	31.45
TSW	18.16	26.16	22.37	10.81
YP	22.24	45.60	36.97	15.99
SL	61.82	82.10	70.64	3.27
TH	115.00	135.67	123.09	0.95
DM	153.67	136.67	145.13	1.25
YH	5.28	7.70	5.89	12.19

PH = Plant height (cm), NTH = No. of tiller/hill, ETH = Effective tiller/hill, PL = Panicle length, PBP = Primary branch/panicle, SBP = Secondary branch/panicle, SP = Spikelet/panicle, FLP = Filled grain/plant, UFLP = Unfilled grain/plant, TSW = Thousand Seed Weight, YP = Yield per plant (g), SL = Stem length (cm), TH = Time of heading, DM = Days to maturity, YH = Yield/ha

Table 38. Estimation of genetic parameters of different characters of the rice lines

Parameters	σ^2p	σ^2g	σ^2e	PCV	GCV	ECV	h_b^2	GA	GA (%mean)
PH	63.8	59.91	3.89	8.36	8.10	0.26	93.90	19.80	20.73
NTH	11.05	8.21	2.84	20.94	18.05	2.89	74.29	6.51	41.08
ETH	10.5	7.78	2.72	20.91	18.00	2.91	74.09	6.34	40.91
PL	5.32	3.36	1.96	9.28	7.38	1.90	63.15	3.84	15.48
PBP	80.5	76.69	3.81	78.19	74.49	3.70	95.26	22.56	201.46
SBP	22.27	14.47	7.80	15.74	12.69	3.05	64.97	8.09	27.00
SP	1142.42	803.32	339.10	18.84	15.79	3.05	70.31	62.73	34.98
FLP	779.13	500.58	278.55	18.52	14.85	3.67	64.24	47.34	31.42
UFLP	288.89	207.72	81.17	59.34	50.32	9.02	71.90	32.26	112.64
TSW	8.63	2.78	5.85	13.13	7.45	5.68	32.21	2.49	11.16
YP	58.54	23.59	34.95	20.69	13.13	7.56	40.29	8.13	22.01
SL	53.72	48.40	5.32	10.37	9.84	0.53	90.09	17.43	24.67
TH	35.44	34.07	1.37	4.83	4.74	0.09	96.13	15.10	12.27
DM	22.81	19.54	3.27	39.64	36.69	2.95	85.65	10.80	7.44
YH	0.72	0.21	0.51	14.40	8.28	6.12	29.17	0.65	11.09

σ^2_P = Phenotypic variance, σ^2g = Genotypic variance, and σ^2e = environmental variance, PCV = Phenotypic coefficient of variation, GCV = Genotypic coefficient of variation, ECV = Environmental coefficient of variation, $\mathbf{h_b}^2$=heritability, GA= genetic advance and GA(% mean) = Genetic advance in percentage of mean

PH = Plant height (cm), NTH = No. of tiller/hill, ETH = Effective tiller/hill, PL = Panicle length, PBP = Primary branch/panicle, SBP = Secondary branch/panicle, SP = Spikelet/panicle, FLP = Filled grain/plant, UFLP = Unfilled grain/plant, TSW = Thousand Seed Weight, YP = Yield per plant (g), SL = Stem length (cm), TH = Time of heading, DM = Days to maturity, YH = Yield/ha

15.87 (Table 36). Number of total tillers per hill showed phenotypic variance (11.05) and genotypic variance (8.21) with relatively medium differences between them which indicating minimum environmental influences on this trait (Table 38). Values of PCV and GCV were 20.94 and 18.05, respectively (Table 37). The lower difference between PCV and GCV indicated that the genetic variation was lower among the genotypic variation and environment had much influence on his character expression. Figure 27 showing genotypic, phenotypic, and environmental variability of ten lines of fine grain boro rice with their check varieties for total number of tillers per hill. Figure 22 showing variation in tiller per hill of different lines. Pandey and Anurag (2010) observed that number of tillers per hill plays a significant role in determining yield of the rice grain since it is directly related to panicle number.

High heritability (74.29 %) with low genetic advance of (6.51) (Table 38) and high genetic advance in percentage of mean (41.08 %) were recorded (Table38). High heritability with low genetic advance stated that the character was controlled by additive and non-additive gene action and selection for such trait maynot be operative during crop improvement.

4.3.3 No. of effective tillers per hill

Analysis of variance for total no. of tillers per hill exhibited significant (26.08*) mean sum of square due to lines difference (Table 36). The highest number of total effective tillers per hill was observed in L13 (21.93) followed by L12 (19.26). The lowest number of total effective tillers per hill was observed in L1 (12.13) and mean value was 15.49 (Table 37). Number of total effective tillers per hill showed phenotypic variance (10.5) and genotypic variance (7.78) with relatively low differences between them which indicating lower environmental influences on this trait (Table 38). Values of PCV and GCV were 20.91 and 18.00, respectively (Table 38). The low difference between PCV and GCV indicated that the genetic variation was low among the genotypic variation and environment had low influence on this character expression. Figure 28 showing genotypic, phenotypic and environmental variability of ten lines of fine grain boro rice with their check varieties for no. of effective tillers per hill. Hasanuzzaman*et al.* (2008) found that the number of effective tillers per hill rests on the number of tillers produced and this was directly proportional to the panicles produced per unit area and finally depends on variety.

High heritability (74.09 %) with low genetic advance of (6.34) (Table 38) and high genetic advance in percentage of mean (40.91%) were recorded (Table 38). High heritability with low genetic advance stated that the character was controlled by additive and non-additive gene action and selection for such trait may not be operative during crop improvement.

4.3.4 Panicle length (cm)

Analysis of variance for panicle length (cm) exhibited significant mean sum of square (12.04*) (Table 36). The panicle length (cm) was observed highest in L1 (27.60 cm) followed by L5 (27.40 cm). The lowest panicle length was observed in L12 (21.74 cm) and the mean value for the trait was 24.83 cm (Table 37). The panicle length (cm) showed phenotypic variance (5.32) and genotypic variance (3.36) with relatively minimal differences between them which indicating much lower genetic influences on this trait (Table 38). Values of PCV and GCV were 9.28 and 7.38, respectively (Table 38). The lower difference between PCV and GCV indicated that the genetic variation was low among the genotypic variation and environment had low influence on his character expression. Figure 28 showing genotypic, phenotypic and environmental variability in ten lines of fine grain boro rice with their check varieties for panicle length (cm). Murthy *et al.* (2014) found that there were strong positive correlations of panicle length with number of spikelets per panicle, thousand seeds weight and yield per plant.

High heritability (63.15 %) with low genetic advance of (3.84) (Table 38) and moderate genetic advance in percentage of mean (15.48%) were recorded (Table 38). High heritability with low genetic advance stated that the character was controlled by non-additive gene action and selection for such trait may not be operative during crop improvement.

4.3.5 Number of primary branches per panicle

Analysis of variance for primary branch per panicle exhibited significant mean sum of square (77.29*) (Table 36). Among these observed lines the highest number of primary branches per panicle was taken in case of L1 (28.40) followed by L7 (12.93). The lowest number of primary branches per panicle was taken in L13 (8.93) which was close to L11 (7.20). The mean value for this trait was 11.20 (Table 37).

Phenotypic variance and genotypic variance were calculated as (77.29) and (76.69), respectively (Table 38). The phenotypic variance appeared to be slightly higher than the genotypic variance indicating a little influence of environment on the expression of the genes controlling this trait and relatively low difference between PCV (74.49) and GCV (78.19) value suggested that the apparent variation not only due to lines but also due to the influence of environment (Table 38). Figure 30 showing genotypic, phenotypic and environmental variability of ten lines of fine grain boro rice with their check varieties for number of primary branches per panicle. Figure 23 showing variation in primary branches per panicle of different lines. Karim et al. (2007) observed higher differences between GCV and PCV for this character. Figure 20 showing variation in primary branch per panicle of different lines.

High heritability of 95.26% with high genetic advance of 22.56 and very high genetic advance in percentage of mean (201.46) (Table 38) indicating the presence of additive gene effectwhich gives the opportunity of improvement through selection for this trait.

4.3.6 Number of secondary branches per panicle

Number of secondary branches per panicle exhibited significant mean sum of square (51.23*) (Table 36). The highest number of secondary branches per panicle was observed in L9 (34.40) followed by L5 (34.00). The lowest number of secondarypanicle was observed in L13 (22.20) and the mean value for this trait was 29.97 (Table 37). The phenotypic and genotypic variances for this number of secondary branches per panicle were (22.27) and (14.47), respectively (Table 38) The phenotypic variance appeared to be higher than the genotypic variance suggested that considerable influence of environment on the expression of the genes controlling this trait. The value of PCV and GCV were (15.74) and (12.69), respectively for number of secondary branches per panicle which denoted that medium variation existed among these lines (Table 38). Figure 24 showing variation in secondary branch per panicle of different rice lines. Figure 30 showing genotypic, phenotypic and environmental variability of ten lines of fine grain boro rice with their check varieties for number of secondary branches per panicle. High heritability of 64.97% with low genetic advance of 8.09 and very high genetic advance in percentage of mean (27.00%) (Table 38)indicating the presence of non-additive gene effectwhich limits the opportunity of improvement through selection for this trait.

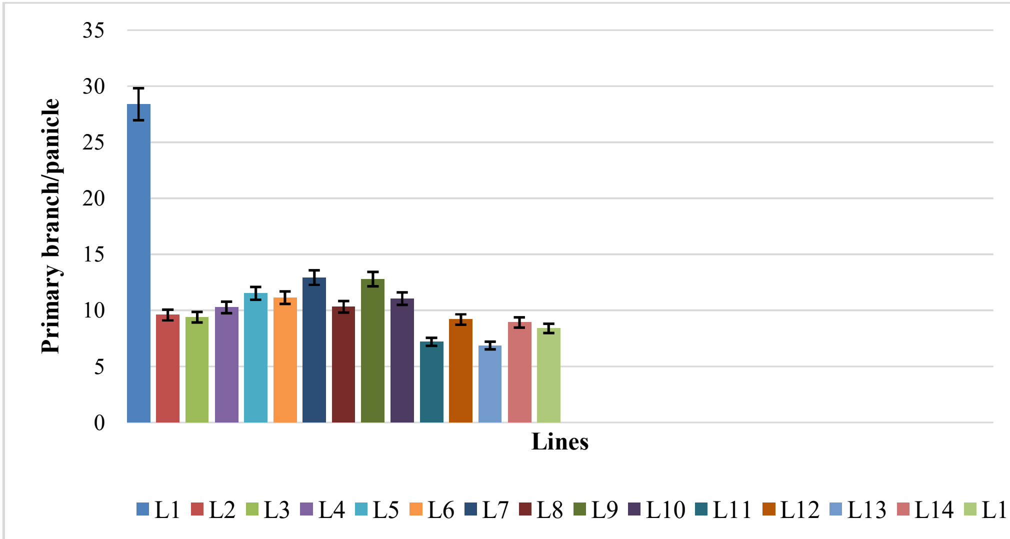

Figure 23. Significant variation in primary branch per panicle of the observed lines

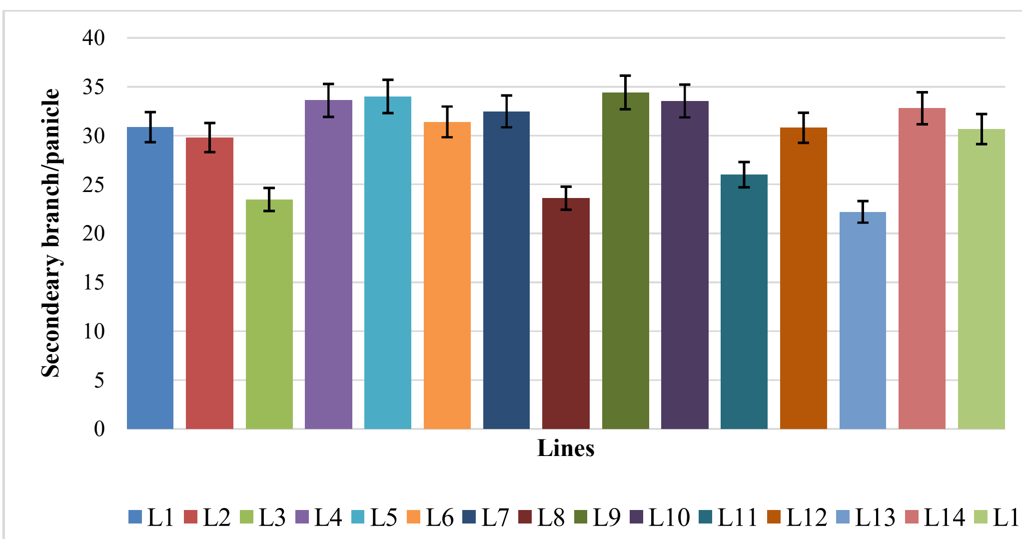

Figure 24. Significant variation in secondary branch per panicle of the observed lines

4.3.7 Total number of spikelets per panicle

Total number of spikelet per panicle exhibited significant mean sum of square (2750.56*) due to lines difference (Table 36). Like other traits, total number of spikelet per panicle also differed significantly in different rice lines which ranged from 124.60 to 238.60. Maximum total number of spikelets per panicle was recorded in L9 (238.60) followed by L1 (212.80), L5 (211.00) and L7 (209.07) those were significantly better than rest of the ten rice lines. The minimum number of spikelets per panicle was recorded in L13 and it was124.60 and the mean value for this trait was 179.31 (Table 38). The phenotypic and genotypic variance for the total number of spikelet per panicle were (1142.42) and (802.32), respectively (Table 38). The phenotypic variance was higher than the genotypic variance suggested that large influence of environment on the expression of the genes controlling this trait. The value of PCV and GCV were (18.84) and (15.79), respectively for number of spikelets per panicle which denoted that medium variation existed among different those lines (Table 38). Figure 29 showing genotypic, phenotypic and environmental variability in ten advanced lines of fine grain boro rice. Figure 25 showing variation in spikelets per panicle of different lines. Singh *et al* (2013) recorded the similar findings.

High heritability of 70.31% with high genetic advance of 60.73 and very high genetic advance in percentage of mean (34.98%) (Table 38) indicating the presence of additive gene effect and selection for such trait may be operative during crop improvement.

4.3.8 Number of filled grains per panicle

Number of filled grains per panicle exhibited highly significant mean sum of square (1780.30*) due to lines difference (Table 36). The maximum number of filled grains per panicle was found in L9 and it was 207.07 followed by L5 (181.00) and the minimum number of filled grains per panicle was recorded in L13 and that was (111.33). The mean value for this trait was 150.66 (Table 37). The phenotypic and genotypic variances for the number of filled grains per panicle were (779.13) and (500.58), respectively (Table 38). The phenotypic variance was higher than the genotypic variance suggested that moderate influence of environment on the expression of the genes controlling this character. The value of PCV and GCV were

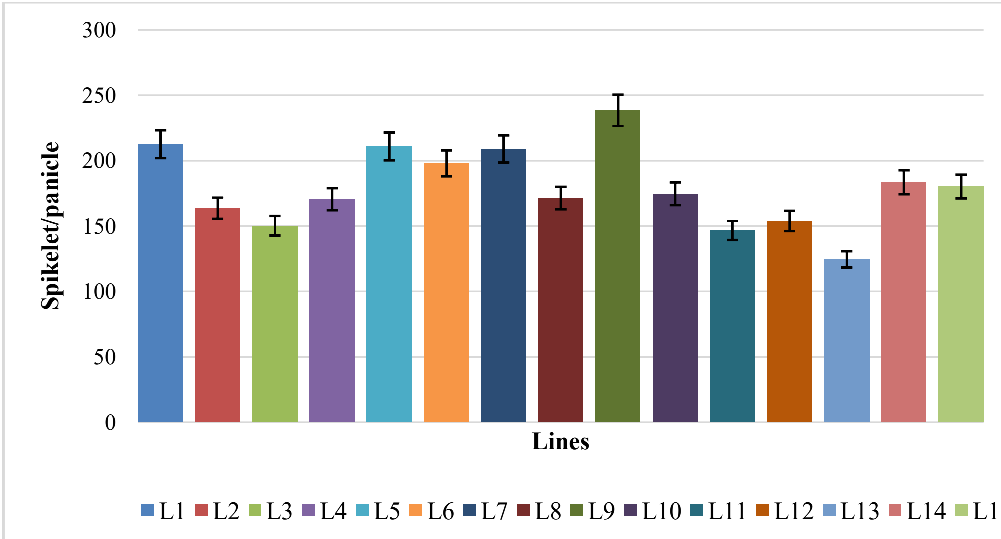

Figure 25. Significant variation in total number of spikelets per panicle of the observed lines

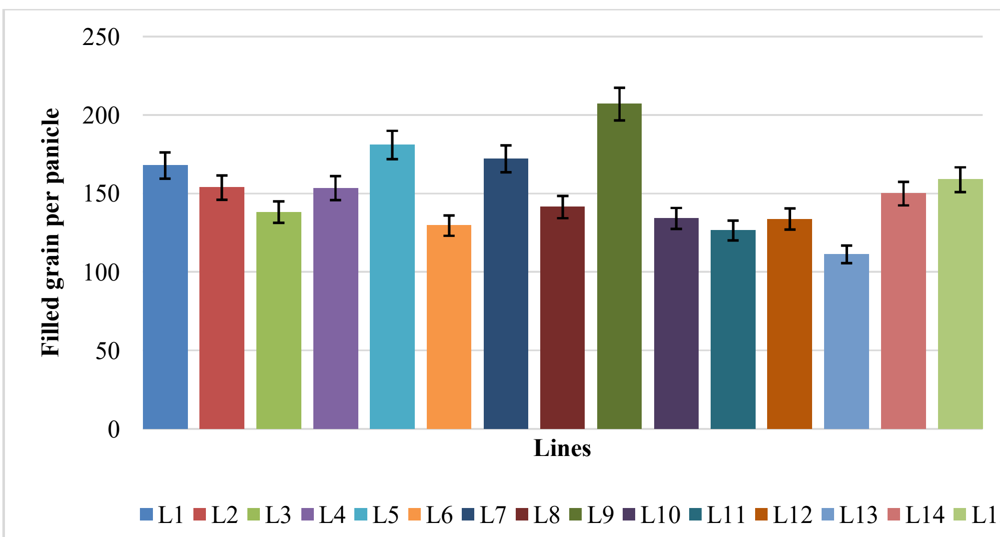

Figure 26. Significant variation in filled grain per panicle of the observed lines

(18.52) and (14.85), respectively for number of filled grains per panicle which denoted that moderate variation existed among the difference rice lines (Table 38). Figure 26 showing variation in filled grain per panicle of different lines. Figure 29 showing genotypic, phenotypic and environmental variability in ten advanced lines of fine grain boro rice with their check varieties for number of filled grains per panicle. Akhter et al. (2001) reported that Paddy yield had significant positive correlation with number of grains per panicle and 1000 grain weight.

High heritability of 64.24% with high genetic advance of 47.34 and very high genetic advance in percentage of mean (31.42) (Table 5)indicating the presence of additive gene effect and selection for such trait may be operative during crop improvement. (Table 38).

4.3.9 Number of unfilled grains per panicle

Number of unfilled grains per panicle exhibited highly significant mean sum of square (704.35*) due to lines difference (Table 36). The maximum number of unfilled grains per panicle was found in L6 and it was 68.40 followed by L1 (44.86) and the minimum number of unfilled grains per panicle was recorded in L2 and that was (9.80). The mean value for this trait was 28.64 (Table 37). The phenotypic and genotypic variances for the number of unfilled grains per panicle were (288.89) and (207.72), respectively (Table 38). The phenotypic variance was higher than the genotypic variance suggested that moderate influence of environment on the expression of the genes controlling this character. The value of PCV and GCV were (59.34) and (50.32), respectively for number of unfilled grains per panicle which denoted that moderate variation existed among the difference rice lines (Table 38). Figure 23 showing variation in filled grain per panicle of different lines. Figure 29 showing genotypic, phenotypic and environmental variability in ten advanced lines of fine grain boro rice with their check varieties for number of unfilled grains per panicle. Figure 32 showing variation in unfilled grain per panicle of different lines.

High heritability of 71.90% with high genetic advance of 32.20 and very high genetic advance in percentage of mean (112.64) (Table 38) indicating the presence of additive gene effect and selection for such trait may be operative during crop improvement.

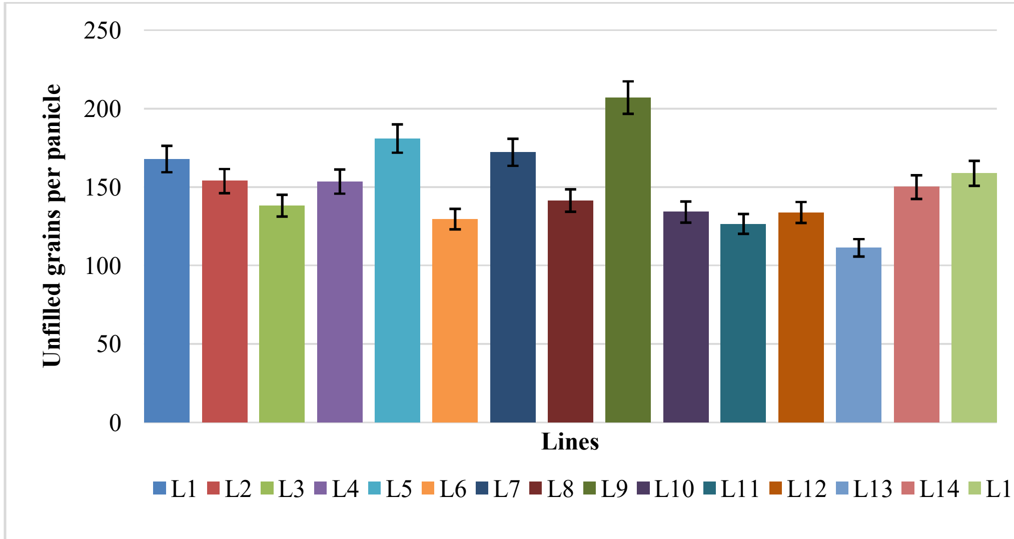

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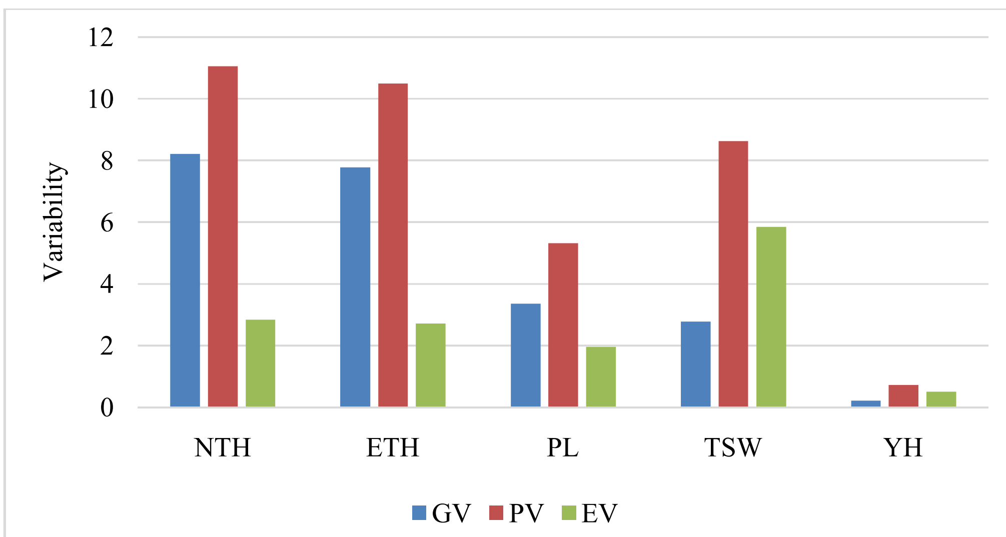
Figure 27. Significant variation in unfilled grains per panicle of the observed lines



NTH = No. of tiller/hill, ETH = Effective tiller/hill, PL = Panicle length, TSW = Thousand seed weight, YH = Yield/ha, GV = Genotypic variability, PV = Phenotypic variability, EV = Environmental variability

Figure 28. Genotypic, phenotypic and environmental variability in ten advanced lines of fine grain boro rice with their check varieties

4.3.10 Thousand seed weight (g)

Thousand seed weight exhibited non- significant mean sum of square (14.20) due to lines difference (Table 36). The maximum 1000 seed weight was found in L3 and it was 26.16 g followed by L2 (25.83 g) and the minimum number of 1000 seed weight was recorded in L12 and that was (18.16 g). The mean value for this trait was 22.37 g (Table 37). The phenotypic and genotypic variances for the 1000 seed weight were (8.63) and (2.78), respectively (Table 38). The phenotypic variance was higher than the genotypic variance suggested that moderate influence of environment on the expression of the genes controlling this character. The value of PCV and GCV were (13.13) and (7.45), respectively for 1000 seed weight which denoted that maximum variation existed among the difference rice lines (Table 38). Figure 28 showing genotypic, phenotypic and environmental variability in ten advanced lines of fine grain boro rice with their check varieties for 1000 seed weight (g). Aidei and Beighly (2006) reported that cultivation methods didn't have much effect on thousand seed weight.

High heritability of 32.21% with low genetic advance of 2.49 and very moderate genetic advance in percentage of mean (11.16%) (Table 38)indicating the presence of additive and non-additive gene effectwhich may or may not be given the opportunity of improvement through selection for this trait.

4.3.11 Stem length (cm)

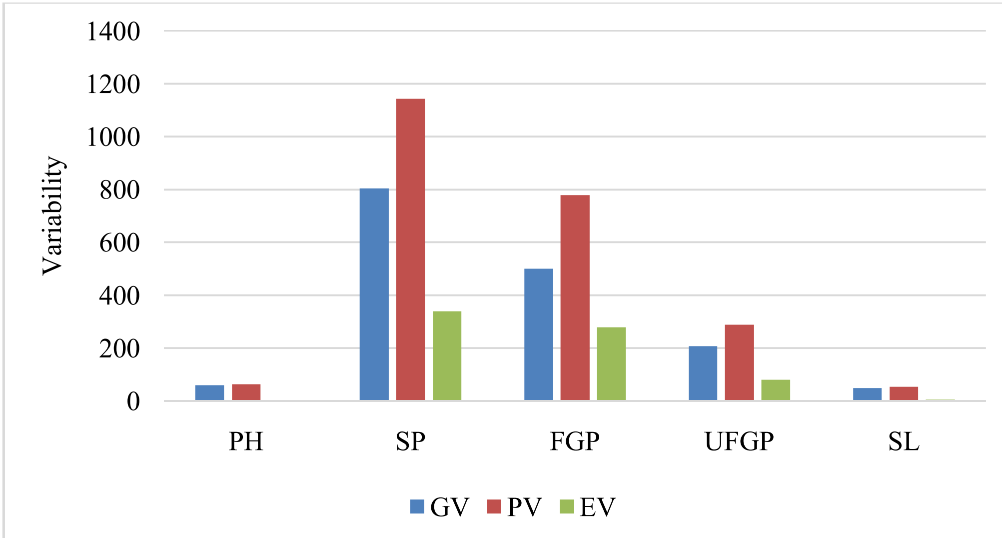
Stem length exhibited significant mean sum of square (150.55*) due to lines difference (Table 36). The highest stem length (cm) was found in L1 and it was 82.10 cm followed by L9 (81.23 cm). The lowest stem length (cm) was recorded in L14 and that was 61.82 (Table 37). Phenotypic variance and genotypic variance were measured as (53.72) and (48.40), respectively (Table 38). The phenotypic variance observed to be higher than the genotypic variance indicating influence of environment on the expression of the genes controlling this trait and relatively little difference between PCV (4.83) and GCV (4.74) value indicated that the apparent variation not only due to lines but also due to the influence of environment (Table 38). So there was a possibility for selection. Figure 29 showing genotypic, phenotypic and environmental variability of ten advanced lines of fine grain boro rice with their check varieties for stem length (cm).

High heritability of 90.09% with moderate genetic advance of 17.43 and very high genetic advance in percentage of mean (24.67%) (Table 38)indicating the presence of additive and non-additive gene effectwhich may or may not be given the opportunity of improvement through selection for this trait.

4.3.12 Days of 80% maturity

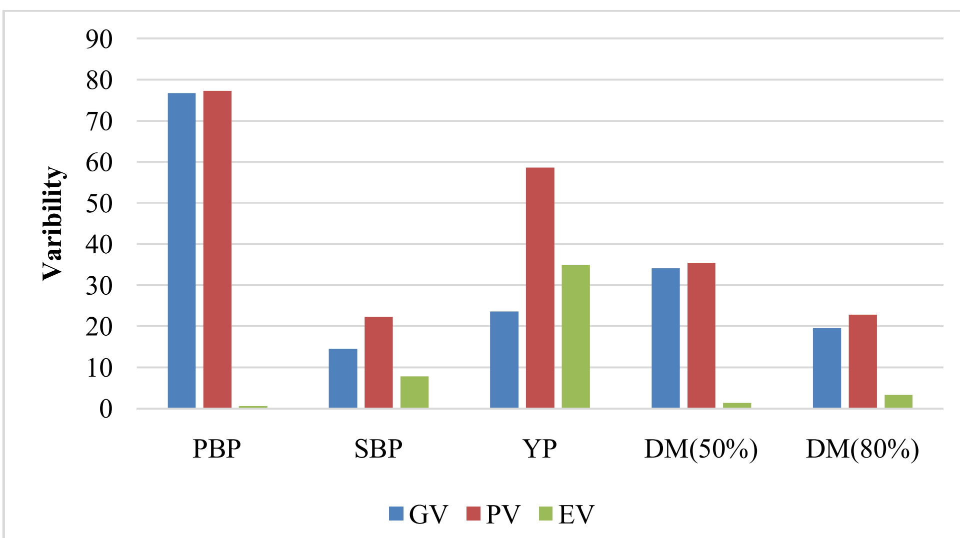
Days of 80% maturity exhibited significant mean sum of square (61.89*) due to lines difference (Table 36). The highest days of maturity was found in L1 and it was 153.67 days followed by L12 (150.67 days) (Table 37). The lowest days of maturity was recorded in L11 and that was (136.67 days) followed by L3 (140.67 days). The mean value of this trait was 145.13 days (Table 37). Phenotypic variance and genotypic variance were measured as (22.81) and (19.54), respectively (Table 38). The phenotypic variance observed to be higher than the genotypic variance indicating influence of environment on the expression of the genes controlling this trait and relatively little difference between PCV (39.64) and GCV (36.69) value indicated that the apparent variation not only due to lines but also due to the influence of environment (Table 38). So there was a possibility for selection. Figure 30 showing genotypic, phenotypic and environmental variability of ten lines of fine grain bororice with their check varieties for days of 80% maturity. Murthy *et al*. (2014) revealed that there was a significant and positive co-relation of grain yield per plant with days of flowering, days of maturity and leaf length.

High heritability of 85.65% with moderate genetic advance of 10.80 and very low genetic advance in percentage of mean (7.44) (Table 38)indicating the presence of non-additive gene effectwhich limits the opportunity of improvement throughdirect selection for this trait.



PH = Plant height (cm), SP = Spikelets/panicle, FGP = Filled grain/panicle, UFGP = Unfilled grain/panicle, SL = Stem length (cm), GV = Genotypic variability, PV = Phenotypic variability, EV = Environmental variability

Figure 29. Genotypic, phenotypic and environmental variability in ten advanced lines of fine grain boro rice with their check varieties



PBP = Primary branch/panicle, SBP = Secondary branch/panicle, YP = Yield/plant (g), DM = Days of maturity, GV = Genotypic variability, PV = Phenotypic variability, EV = Environmental variability

Figure 30. Genotypic, phenotypic and environmental variability in ten advanced lines of fine grain boro rice with their check varieties

4.3.13 Yield per plant (g)

Yield per plant exhibited significant mean sum of square (105.748*) due to lines difference ((Table 36)). The highest yield per plant (g) was found in L3 and it was 45.60 g followed by L2 (44.23 g), L4 (41.93 g) and L1 (40.83 g). The lowest yield per plant (g) was recorded in L6 and that was (22.24 g) followed by L12 (29.67 g) (Table 37). Phenotypic variance and genotypic variance were measured as (58.54) and (23.59), respectively (Table 38). The phenotypic variance observed to be higher than the genotypic variance indicating influence of environment on the expression of the genes controlling this trait. Relatively higher difference between PCV (20.69) and GCV (13.13) value indicated that the apparent variation not only due to the influence of environment (Table 38). So there was a possibility for selection.Figure 29 showing genotypic, phenotypic and environmental variability of ten lines of fine grain boro rice with their check varieties for yield per plant (g). Figure 30 showing variation in yield per plant of different lines with their check varieties. Yoshida (1981) found that improvement of rice grain yield was the main target of breeding program to develop rice varieties.

High heritability of 40.29% with low genetic advance of 8.13 and very high genetic advance in percentage of mean (22.01%) (Table 38)indicating the presence of non-non-additive gene effectwhich limits the opportunity of improvement throughdirect selection for this trait.

4.3.14 Yield (t/ha)

Yield exhibited non-significant mean sum of square (1.154) due to lines difference ((Table 36)). The highest yield was found in L10 and it was 7.70 t/ha followed by L8 (7.50 t/ha), L5 (7.40 t/ha) comparing with the checks L11 (6.03), L12 (5.28 t/ha), L13 (6.26 t/ha), L14 (7.06 t/ha) and L15 (6.21 t/ha). The lowest yield was recorded in L9 and that was (5.19 t/ha) followed by L12 (5.28 t/ha) (Table 37). Phenotypic variance and genotypic variance were measured as (0.72) and (0.21), respectively (Table 38). The phenotypic variance observed to be higher than the genotypic variance indicating influence of environment on the expression of the genes controlling this trait. Relatively medium difference between PCV (14.40) and GCV (8.28) value indicated that the apparent variation not only due to the influence of environment (Table 38). So

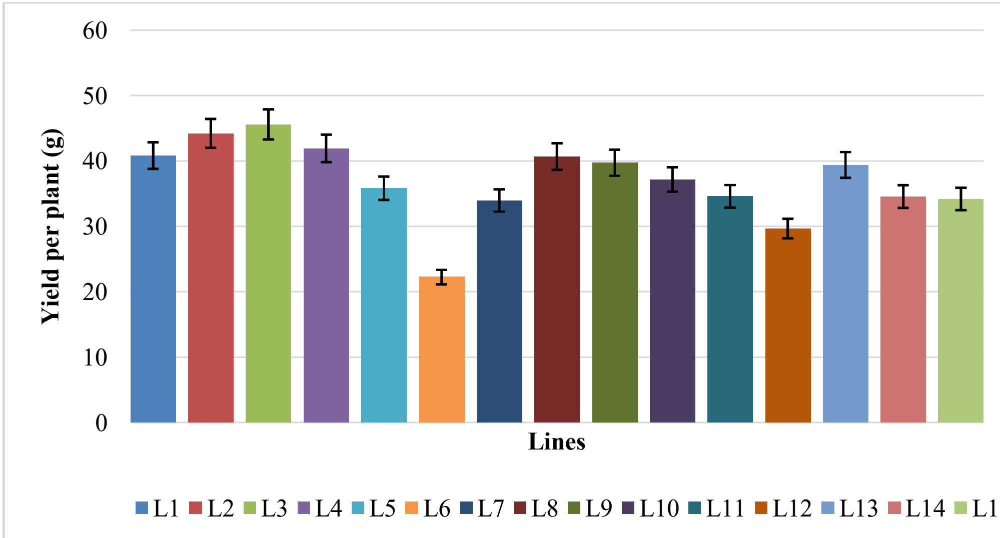


Figure 31. Significant variation in yield per plant (g) of the observed lines

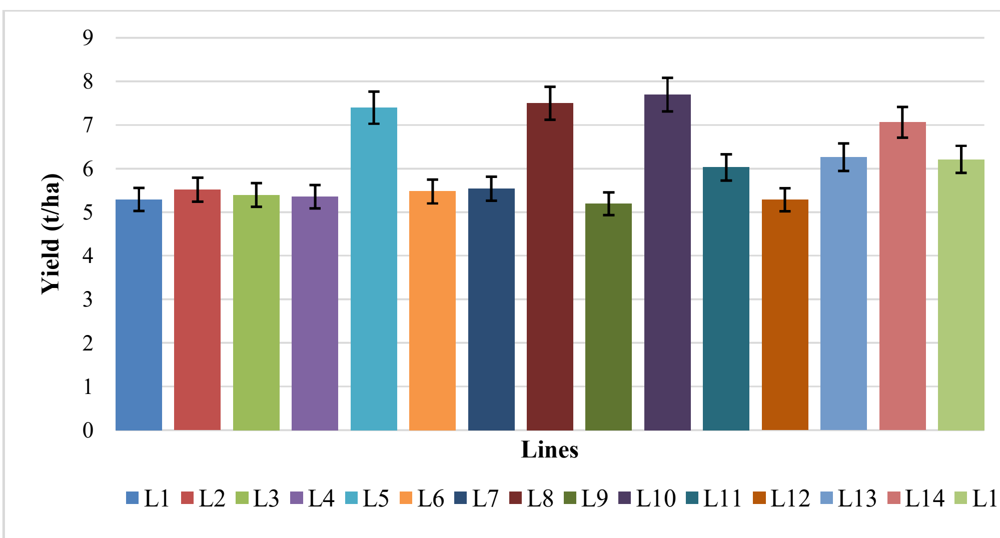


Figure 32. Significant variation in yield (t/ha) of the observed lines

there was a possibility for selection. Figure 32 showing variation in yield/ha of different lines. Figure 28 showing genotypic, phenotypic and environmental variability of ten lines of fine grain boro rice with their check varieties for yield (t/ha). Sadeghi (2011) observed positive significant association of grain yield with grains per panicle, days to maturity, number of productive tillers and days to flowering.

Low heritability of 29.17% with low genetic advance of 0.65 and very moderate genetic advance in percentage of mean (11.09%) (Table 38)indicating the presence of non-additive gene effectwhich limits the opportunity of improvement through selection for this trait.

4.4 CORRELATION COEFFICIENT

Identification of simple genotypic and phenotypic correlation co-efficient was made among yield and yield contributing characters of the 15boro rice genotypes in all possible one way paired combinations. Genotypic correlation co-efficient were higher than phenotypic correlation coefficient in all most of cases were suggested that character association had not been largely influenced by environment in this cases.

4.4.1 Plant height (cm)

Plant height (cm)exhibited significant and positive correlation with panicle length (cm) (r_g=0.524, r_p=0.417), primary branch/panicle (r_g=0.567, r_p=0.553), filled grain/plant (r_g=0.562, r_p=0.498) and thousand seed weight (g) (r_g=0.357)at both genotypic and phenotypic level. It showed significant and negative correlation with no. of tiller/hill (r_g=-0.622, r_p=-0.516) and effective tiller/hill (r_g=-0.581, r_p=-0.480) indicating very little contribution of this trait toward the increase in no. of tiller/hill and effective tiller/hill.Correlation of secondary branch/panicle (r_g=0.167, r_p=0.148),unfilled grain/plant (r_g=0.210, r_p=0.177), thousand seed weight (g) (r_p=0.177) and yield/plant (g) (r_g=0.180, r_p=0.121) was non-significant and positive.(Table 39)

4.4.2 No. of tiller/hill

Correlation of no. of tiller/hillwas significant and positive with effective tiller/hill (r_g=0.998, r_p=0.916) pointing out a possible increase in effective tiller/hill by increasing no. of tiller/hill. It exhibited significant and negative correlation with panicle length (cm) (r_g=-0.866, r_p=-0.501), primary branch/panicle (r_g=-0.571, r_p=-0.471), secondary branch/panicle (r_g=-0.517, r_p=-0.393),filled grain/plant (r_g=-0.801, r_p=-0.641), thousand seed weight (g) (r_g=-0.809) and yield/plant (g) (r_g=-0.601). Non-significant and positive correlation was observed with unfilled grain/plant (r_p=0.001). Association of unfilled grain/plant (r_g=-0.156), thousand seed weight (g) (r_p=-0.268) and yield/plant (g) (r_p=-0.159)wasnon-significant and negative. (Table 39)

4.4.3 Effective tiller/hill

Significant and positive correlation of effective tiller/hill was observed with panicle length (cm) (r_g=-0.773, r_p=-0.448), primary branch/panicle (r_g=-0.511, r_p=-0.443), secondary branch/panicle (r_g=-0.467, r_p=-0.406),filled grain/plant (r_g=-0.807, r_p=-0.667), thousand seed weight (g) (r_g=-0.866, r_p=-0.346) and yield/plant (g) (r_g=-0.790) at both genotypic and phenotypic level.Non-significant and positive correlation was observed with unfilled grain/plant (r_g=0.041, r_p=0.041). Association of yield/plant (g) (r_p=-0.185)wasnon-significant and negative. (Table 39)

4.4.4 Panicle length (cm)

Panicle length (cm)exhibited significant and positive correlation with primary branch/panicle (r_g=0.662, r_p=0.507), secondary branch/panicle (r_g=0.342),filled grain/plant (r_g=0.504, r_p=0.332), unfilled grain/plant (r_g=0.456, r_p=0.387), thousand seed weight (g) (r_g=0.672, r_p=0.427) and yield/plant (g) (r_g=0.325)at both genotypic and phenotypic level pointing out a possible increase in primary branch/panicle,secondary branch/panicle,filled grain/plant,unfilled grain/plant,thousand seed weight (g)and yield/plant (g) by increasing panicle length (cm). It showed significant and positive correlation with secondary branch/panicle (r_p=0.272) and yield/plant (g) (r_p=0.136)(Table 39)

4.4.5 Primary branch/panicle

Correlation of primary branch/paniclewith filled grain/plant (r_g=0.456, r_p=0.392), unfilled grain/plant (r_g=0.471, r_p=0.420) and thousand seed weight (g) (r_g=0.351*) was significant and positive pointing out a possible increase in filled grain/plant,unfilled grain/plant and thousand seed weightby increasing primary branch/panicle. It also showed non-significant and positive correlation withsecondary branch/panicle (r_g=0.289, r_p=0.261),thousand seed weight (g) (r_p=0.205) and yield/plant (g) (r_g=0.177, r_p=0.095)indicating that it had a very little contribution toward the increase in primary branch/panicle (Table 39).

4.4.6 Secondary branch/panicle

Significant and positive correlation of secondary branch/panicle was observed with filled grain/plant (r_g=0.642, r_p=0.624) and unfilled grain/plant (r_g=0.448, r_p=0.371) enunciating that the traits are less influenced by environment.It also exhibited non-significant and negative correlation with yield/plant (g) (r_g=-0.350) indicating a possible increase in yield/plant (g) by decreasing number secondary branch/panicle (Table 39).

4.4.7 Filled grain/plant

Correlation of filled grain/plant with yield/plant (g) (r_g=0.327) was significant and positive pointing out a possible increase in yield/plant (g)by increasing filled grain/plant. It also showed non-significant and positive correlation with unfilled grain/plant (r_g=0.151, r_p=0.081), thousand seed weight (g) (r_p=0.011) and yield/plant (g) (r_p=0.055)indicating that it had a very little contribution toward the increase in filled grain/plant. It exhibited non-significant and negative correlation with thousand seed weight (g) (r_g=-0.004) indicating a possible increase in yield/plant (g) by decreasing filled grain/plant. (Table 39).

4.4.8 Unfilled grain/plant

Unfilled grain/plant exhibited significant and negative correlation with thousand seed weight (g) (r_g=-0.323) and yield/plant (g) (r_g=-0.872, r_p=-0.409) enunciating that a decrease in unfilled grain/plant results in an increase in thousand seed weight and yield/plant. It also showed non-significant and negative correlation with thousand seed weight (g) (r_p=-0.108) stated that a possible increase in thousand seed weight (g) by decreasing unfilled grain/plant (Table 39).

4.4.9 Thousand seed weight (g)

Thousand seed weight exhibited highly significant and positive correlation with yield/plant (g) (r_g=0.629, r_p=0.398) at both genotypic and phenotypic level indicating that an increase in thousand seed weight tends to increase yield/plant (g) (Table 39).

Table 39. Coefficients of genotypic and phenotypic correlation among different yield components

Traits		PH	NTH	ETH	PL	PBP	SBP	FLP	UFLP	TSW
NTH	r_g	-0.622**								
	r_p	-0.516**								
ETH	r_g	-0.581**	0.998**							
	r_p	-0.480**	0.916**							
PL	r_g	0.524**	-0.866**	-0.773**						
	r_p	0.417**	-0.501**	-0.448**						
PBP	r_g	0.567**	-0.571**	-0.511**	0.662**					
	r_p	0.553**	-0.471**	-0.443**	0.507**					
SBP	r_g	0.167	-0.517**	-0.467**	0.342*	0.289				
	r_p	0.148	-0.393**	-0.406**	0.272	0.261				
FLP	r_g	0.562**	-0.801**	-0.807**	0.504**	0.456**	0.642**			
	r_p	0.498**	-0.641**	-0.667**	0.332*	0.392**	0.624**			
UFLP	r_g	0.210	-0.156	0.041	0.456**	0.471**	0.448**	0.151		
	r_p	0.177	0.001	0.041	0.387**	0.420**	0.371*	0.081		
TSW	r_g	0.357*	-0.809**	-0.866**	0.672**	0.351*	-0.230	-0.004	-0.323*	
	r_p	0.177	-0.268	-0.346*	0.427**	0.205	-0.065	0.011	-0.108	
YPP	r_g	0.180	-0.601**	-0.790**	0.325*	0.177	-0.350*	0.327*	-0.872**	0.629**
	r_p	0.121	-0.159	-0.185	0.136	0.095	-0.258	0.055	-0.409**	0.398**

**, Significant at 1 % level of significance *, Significant at 5 % level of significance

PH = Plant height (cm), NTH = No. of tiller/hill, ETP = Effective tiller/hill, PL = Panicle length (cm), PBP = Primary branch/panicle, SBP = Secondary branch/panicle, FLP = Filled grain/plant, UFLP = Unfilled grain/plant, TSW = Thousand seed weight (g), YP = Yield/plant (g)

CHAPTER V

SUMMARY AND CONCLUSION

A research work was carried out at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh for characterization and variability study among fifteen advanced lines of fine grain boro rice during the period of boro seasons in 2018-19. The experiment was designed to characterize and to determine variability among these lines on the basis of morphological and quality traits. Ten lines were evaluated for seventeen qualitative and fifteen quantitative traits of morphological and fifteen parameters were used for variability study.

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

All the lines showed variation for thirteen qualitative characters viz. leaf sheath: anthocyanin color, leaf color, flag leaf: attitude of the blade, lemma and palea: anthocyanin coloration, stem: anthocyanin coloration of internodes, spikelet: color of the tip of lemma, panicle exertion, panicle: awns in the spikelet, panicle: length of the longest awn, grain color and culm habit. No variation was observed in these lines for four qualitative characters viz. penultimate leaf: shape of the ligule, male sterility, stem: intensity of anthocyanin coloration of nodes and stem: intensity of anthocyanin coloration of internodes.

Fifteen quantitative characters viz. time of heading (50 % of the plants with head), flag leaf width, culm length, culm diameter, total no. of tillers per hill, effective tillers per hill, panicle length, number of filled grains per panicle, number of unfilled grains per panicle, thousand seed weight, days to maturity, grain length, decorticated grain length and yield per plant showed variation among the rice lines. Only one quantitative character flag leaf length showed no variation for these rice lines.

In case of variability analysis all the parameters showed significant result viz. plant height (cm), total no. of tillers per hill, no. of effective tillers per hill, panicle length (cm), number of primary branches per panicle, number of secondary branches per panicle, number of filled grains per panicle, number of unfilled grains per panicle, thousand seed weight (g), days of 80 % maturity, yield per plant (g) and yield (t/ha).

The following characters such as leaf color, panicle: attitude of the leaf blade, panicle: curvature of main axis, panicle: exertion, plant height (cm), filled grains/plant, unfilled grains/plant, yield/plant (g), stem length (cm), days to maturity (80%), grain color, grain length and yield (t/ha) were the important characters for selection of better rice lines. In case of panicle: attitude of leaf blade thirteen lines (L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L13, L14 and L15) showed erect type leaf blade and two lines (L1 and L12) showed semi-erect type leaf blade. Panicle length is one of the most important yield contributing character of rice. Panicle length of observed lines ranged from (L12) 21.74 to (L1) 27.60 cm with a mean value of 24.83 cm where nine lines showed medium panicle length (L2, L4, L8, L9, L11, L12, L13, L14 and L15) and six lines (L1, L3, L5, L6, L7 and L10)showed long panicle length. Culm length of observed lines ranged from (L1) 82.10 cm to (L14) 61.82 cm with a mean value of 70.64 cm. In case of days of maturity L2, L3, L4, L5, L6, L7, L8, L9, L10, L11, L12, L13, L14 and L15 lines showed late in maturity (136-150 days) and L1 showed very late (>150 days) in maturity with an average of 145.35 days.

In case of variability study total no. of spikelets/panicle showed significant variation. The maximum spikelets/panicle was 238.60 recorded in L9 followed by L1 (212.80). The phenotypic and genotypic variance were 1142.92 and 803.82, respectively which showed that large influence of environment on the expression of the genes controlling this trait. The filled grains/panicle were highly significant where L9 showed highest filled grains/panicle and it was 207.07. The phenotypic and genotypic variance were 779.13 and 500.58 respectively which showed that the influence of environment on the expression of the genes controlling this trait. Phenotypic coefficient of variation was always higher than the genotypic coefficient of variation for all the characters. High phenotypic and genotypic coefficient of variation was found in Unfilled grain/plant and days to 80% maturity. High heritability coupled with high genetic advance and genetic advance in percentage of mean was found in primary branch/panicle, spikelet/panicle, filled grain/plant and unfilled grain/plantwhich indicated that additive gene expression on this character.Plant height (cm) and stem length (cm) showed high heritability with moderate genetic advance and high genetic advance in percentage of mean that might be presence of additive and non-additive gene expression. Investigation on character association indicating that yield/plant had highest significant positive correlation with thousand seed weight (g) in both genotypic and phenotypic level indicating the importance of these trait in selection for increasing yield and were identified as yield attributing characters. Thus selection can be relied upon these characters for the genetic improvement of yield of rice genotypes.Significant result was obtained in yield/plant (g) in case of variability where highest yield/plant was observed in L3 (45.60g) followed by L2 (44.23g), L4 (41.93g) and L1 (40.83g), here the difference between phenotypic and genotypic variance was 34.95 which indicated the influence of environment on this parameter. Yield/plant (g) for the checks were L11 (34.60g), L12 (29.67g), L13 (39.40g), L14 (34.56g) and L15 (34.20g) which was lower than the above lines. The most important parameter was yield (t/ha) to select the best line, where the lines showed significant result indicating the variation of yield (t/ha). Here L10 showed maximum result and it was 7.70 t/ha followed by L8 (7.50 t/ha) and L5 (7.40 t/ha). On the other hand, yield (t/ha) for the check varieties were L11 (6.03), L12 (5.28 t/ha), L13 (6.26 t/ha), L14 (7.06 t/ha) and L15 (6.21 t/ha). So among the ten lines L10, L8 and L5 were selected as the best lines in respect of yield (t/ha) and time of maturity which could be used for further trail in future to follow the release procedure.

Based on the research findings, two recommendations could be made as- firstly, the lines viz. L5, L8 and L10 could be selected as new variety for considering their higher yield performance and days of maturity. Secondly, five lines viz. L1, L2, L3, L6 and L7 could be selected in respect of extra-long fine rice grain character.

CHAPTER VI

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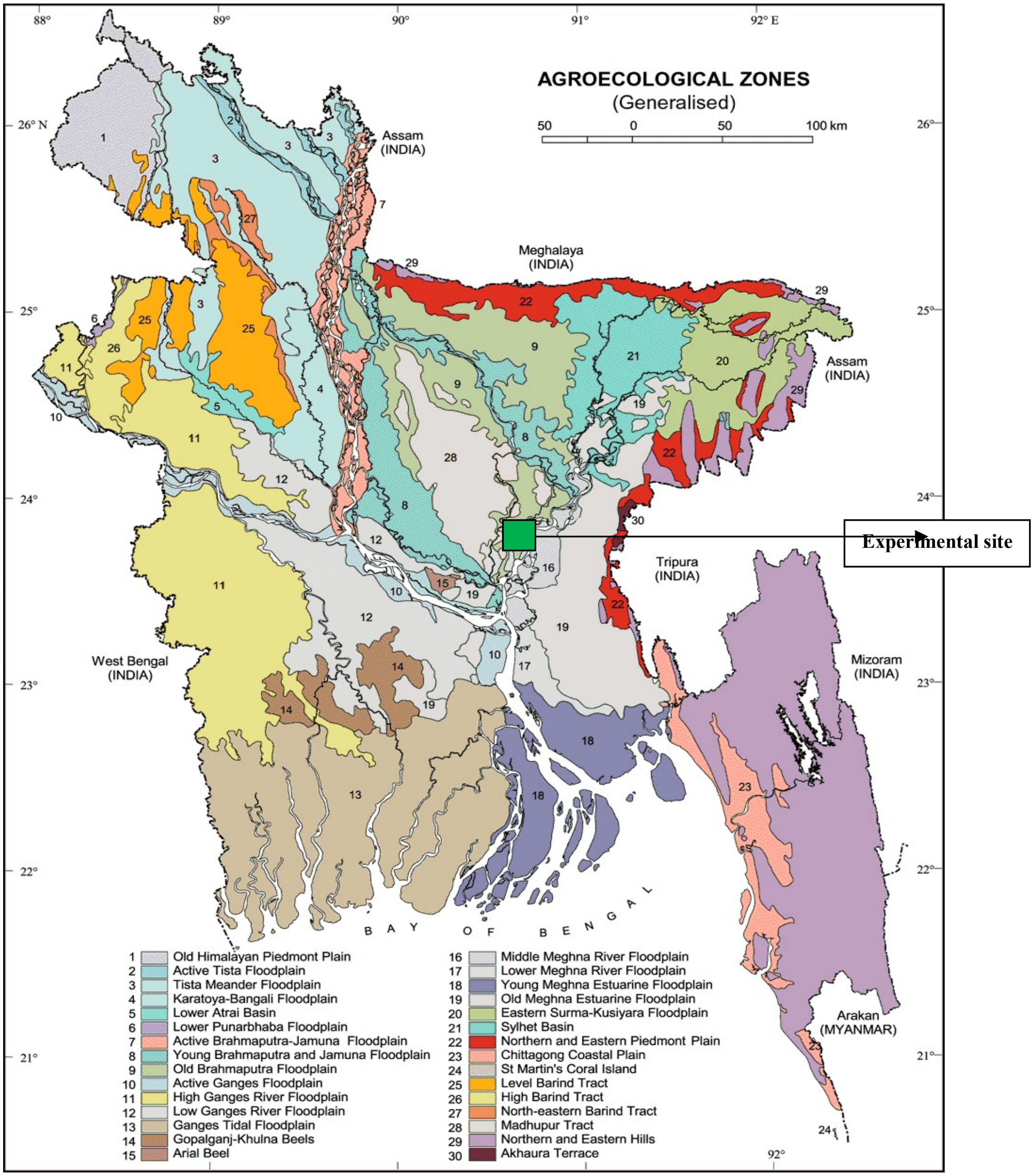
CHAPTER VII

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Mean performance of various growth parameter and yield components (quantitative character) of ten advanced lines of fine grain boro rice with their check varieties

Lines	PH	NTH	ETH	PL	PBP	SBP	FLP	UFLP	TSW	YP	TH	DM	YH
L1	109.70	12.40	12.13	27.60	28.40	30.86	167.93	44.86	24.66	40.83	135.67	153.67	5.29
L2	100.13	13.93	12.66	25.43	9.60	29.80	153.87	9.80	25.83	44.23	124.33	147.33	5.51
L3	94.18	13.00	12.93	26.43	9.40	23.46	138.27	12.06	26.16	45.60	125.00	140.67	5.39
L4	89.76	13.13	13.06	25.00	10.26	33.60	153.53	17.06	24.83	41.93	123.67	141.00	5.35
L5	104.78	13.26	13.20	27.40	11.53	34.00	181.00	30.00	21.33	35.83	125.67	141.33	7.40
L6	97.48	16.86	18.20	25.96	11.13	31.40	129.67	68.40	21.33	22.24	128.33	147.00	5.47
L7	95.38	14.20	13.93	26.90	12.93	32.46	172.20	36.86	21.50	33.96	127.33	146.67	5.54
L8	89.41	17.46	17.06	24.47	10.33	23.60	141.47	30.00	21.83	40.66	126.00	142.67	7.50
L9	106.22	12.80	12.66	24.98	12.80	34.40	207.07	31.53	21.00	39.73	127.00	149.00	5.19
L10	88.86	15.73	15.73	26.20	11.06	33.53	134.20	40.60	23.33	37.16	118.67	142.67	7.70
L11	103.29	18.46	17.46	22.26	7.20	26.00	126.60	20.06	22.16	34.60	115.00	136.67	6.03
L12	84.64	19.13	19.26	21.74	9.20	30.80	133.87	20.20	18.16	29.66	122.00	150.67	5.28
L13	90.73	22.33	21.93	22.72	6.86	22.20	111.33	13.26	21.16	39.40	115.67	148.00	6.26
L14	85.44	19.73	17.53	23.61	8.93	32.80	150.07	33.53	21.66	34.56	117.00	147.67	7.06
L15	92.27	15.66	14.66	21.78	8.40	30.66	158.87	21.46	20.66	34.20	115.00	142.00	6.21

PH = Plant height (cm), NTH = No. of tiller/hill, ETP = Effective tiller/hill, PL = Panicle length (cm), PBP = Primary branch/panicle, SBP = Secondary branch/panicle, SP = Spikelet/panicle, FLP = Filled grain/plant, UFLP = Unfilled grain/plant, TSW = Thousand seed weight (g), YP = Yield/plant (g), SL = Stem length (cm), TH = Time of heading, DM = Days to maturity, YH = Yield (t/ha)

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

A. Morphological characteristics of the experiment field

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

B. Physical composition of the soil

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

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

C. Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.82	Walkley and Black, 1947
2	Total N (kg/ha)	1790.00	Bremner and Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lanester, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner, 1965
6	Available P (kg/ha)	69.00	Olsen and Dean, 1965
7	Exchangeable K (kg/ha)	89.50	Pratt, 1965
8	Available S (ppm)	816.00	Hunter, 1984
9	Ph (1 : 2.5 soil to water)	95.55	Jackson, 1958
10	CEC	11.23	Chapman, 1965

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

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

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

Source: Sher-e-Bangla Agricultural University Weather Station