CHARACTERIZATION AND VARIABILITY ANALYSIS OF EIGHT F_8 LINES OF BORO RICE

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BY

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CERTIFICATE

*This is to certify that the thesis entitled "**CHARACTERIZATION AND VARIABILITY ANALYSIS OF EIGHT F_8 LINES OF BORO RICE**" submitted to the Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.)** in **SEED TECHNOLOGY**, embodies the results of a piece of bona fide research work carried out by **MD. MASKURUR RAHMAN,** Registration no. **11-04283** 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: June, 2017
Place: Dhaka, Bangladesh

Prof. Dr. Md. Shahidur Rashid Bhuiyan
Supervisor

DEDICATED

TO

MY BELOVED PARENTS,
TEACHERS AND FRIENDS

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June, 2017 ***The Author***

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ABSTRACT

The investigation was carried out under field conditions to characterize eight F_8 boro rice lines and to study the variability among these lines during the period of boro season (2016-2017) at the experimental field of Sher-e-Bangla Agricultural University, Dhaka. The eight lines of boro rice were characterized for 10 quantitative and 31 qualitative traits for following the release procedure. Variability study was carried out on fifteen parameters to select the best lines for further trial. The lines were characterized and categorized as per the descriptors developed by Biodiversity International, IRRI and WARDA-2007 for DUS test of inbred rice. Among the qualitative characteristics variation was observed in- leaf color, penultimate leaf: pubescence of blade, panicle curvature, panicle: exertion, leaf senescence, decorticated grain: shape and decorticated unpolished grain: color. Among the quantitative characteristics-time of heading, stem: culm diameter, days to maturity, grain length, sterile lemma length, decorticated grain length showed difference for all the lines. In case of variability study plant height (cm), spikelets/panicle, filled grains/plant, unfilled grains/plant, yield/plant (g), stem length (cm), days to maturity and yield (t/ha) showed significant result. Minimum days to maturity were observed in L2 (133.66) followed by L8 (134.33), L7 (135.66), L3 (137), L1 (138) and L5 (139) comparing with the checks L9 (141) and L10 (145). Yield/plant (g) was highest for L7 (34.92 g) followed by L2 (33.16g), L3 (32.62g) and L5 (32.4g) comparing with the checks L9 (30.99g) and L10 (31.50g). The highest yield was obtained in L7 (8.79 t/ha), L2 (8.42 t/ha), L3 (8.1 t/ha) and L5 (7.85 t/ha) comparing with the checks L9 (7.69 t/ha) and L10 (7.75 t/ha). So, the most promising lines in respect of yield and time of maturity were L2, L3, L5 and L7 which could be used for further trial in future to follow the release procedure.

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SOME COMMONLY USED ABREVIATIONS

Full Name	Abbreviation
Agricultural	*Agril.*
Agriculture	*Agric*.
Agro-Ecological Zone	AEZ
At the rate	@
And others	*et al.*
Bangladesh	BD
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Bangladesh Rice	BR
Bangladesh Rice Research Institute	BRRI
Biological	*Biol.*
International Rice Research Institute	IRRI
Biodiversity International	WARDA
Seed Certification Agency	SCA
Centimeter	Cm
Days After Transplanting	DAT
Department of Agricultural Extension	DAE
Degree Celsius	ºC
Etcetera	etc.
Food and Agricultural Organization	FAO
Lines	L
Genetics	Genet.
Gram	g
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.*
The eighth generation of a cross between two dissimilar homozygous parents	F_8
Ton	t
Triple Super Phosphate	TSP

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) belongs to family Poaceae of tribe *Oryzeae*. The genus *Oryza* consists of two cultivated species *Oryza sativ*a (Asian species) and *Oryza glabe*rrima (African species) and about 20 wild species (Vaughan *et al*., 2003; Linscombe *et al*., 2006). The cultivated species are *Oryza sativa* and *Oryza glaberrima*. *Oryza sativa* is grown all over the world while *Oryza glaberrima* has been cultivated in West Africa for the last ~3500 years (IRRI, 2001).

Rice (*Oryza sativa* L.) is one of the major staple food crops in the world and is particularly important in Asia where approximately 90 % of world's rice is produced and consumed (Khush, 2004; Zeigler and Barclay, 2008). Rice is the world's most important crop, and the food security in Asia has traditionally been defined as having stable prices for rice in the major urban markets of a country. Rice is the staple 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 percent of the rice is produced and consumed in Asia. World paddy production area was 163.3 million hectares and production was 749.7 million tons (FAO, 2016).

Bangladesh is the fourth largest producer of rice in the world with the annual production of 34.18 million metric (USDA, 2017). In FY2016-17 food grains production stood at 388.14 lakh MT of which Aus accounted for 21.33 lakh MT, Aman 136.56 lakh MT, Boro 180.24 lakh MT. Total area under boro crop has been estimated 1,11,06,337 acres this year as compared to 1,17,99,512 acres of the last year. The harvested area has decreased by 6.217 % this year. Average yield rate of boro in Financial Year 2016-17 has been estimated 4.025 metric tons husked rice per hectare which was 3.968 metric tons per hectare in

2015-16. Total boro production of Financial Year 2016-17 has been estimated at 1,80,13,749 metric tons compared to 1,89,37,581 metric tons of Financial Year 2015-16 which is 4.878% lower (BBS, 2017).

Agro-based developing country like Bangladesh is striving hard for rapid development of its economy. The economic development of the country is mainly based on agriculture and more particularly rice production. Rice (*Oryza sativa* L.) contributes on an average 20% of apparent calorie intake of world population and 30% of population in Asian countries and this calorie contribution varies from 29.5% for China to 72% for Bangladesh (Calpe and Prakash, 2007).

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

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

The information on genetic variation and heritability and genetic advance helps to predict the genetic gain that could be obtained in later generations, if selection is made for improving the particular trait under study and findings

were reported by Iftekharuddaula *et al*. (2001); Gannamani (2001) and Sao (2002).

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

Now, modern high yielding varieties in boro season are essential to increase the total rice production of Bangladesh. The high yielding advanced lines of boro rice were developed through crossing between aus rice and boro rice with the intension to increase the yield of boro rice having genes from aus rice without much affecting the days of maturity. Eight F_8 lines of boro rice were selected in the previous year which would be used in this study. To release a variety it is necessary to characterize the lines as per the descriptors developed by Biodiversity International, IRRI and WARDA-2007 for DUS test of inbred rice. So, the aim of the present study was to characterize the eight F_8 boro rice lines according to the descriptor and to study their variability for providing useful information which was the prerequisite to select the best boro rice lines for further trail to release as a variety.

OBJECTIVES:

1. To characterize the boro rice lines as per descriptors used for rice.
2. To find out the variability among the lines.
3. To select the best F_8 line of boro rice on the basis of their shorter duration and higher yield.

CHAPTER II
REVIEW OF LITERATURE

Rice is the seed of the grass species *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice). As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population, especially in Asia. Yield of rice varieties is determined by various morphological parameters. The identification of suitable combinations of lines in comparison to the best parent varieties for yield and some important yield contributing characters with their variability are essential tool for a successful assessment. The present study aimed to assess the performance of eight F_8 boro rice lines as compared to the check varieties. For this assessment a field experiment was conducted at Sher-e-Bangla Agricultural University farm entitled "Characterization and variability analysis of eight F_8 lines of boro rice." Some related research findings of different researchers from home and abroad have been cited below:

2.1 Characterization

2.1.1 Characterization on rice

Lin *et al.* (1991) stated that agro-morphological characterization of germplasm accessions is fundamental in order to provide information for plant breeding programs.

Li *et al.* (2000) obtained consistent results analyzing the correlation between genetic and morphological differentiation in 111 accessions of rice from the Japonica and Indica groups.

Yibo *et al.* (2010) investigated morphological and genetic diversity in 11 surviving populations of *O. rufipogon* Griff. From Hainan Island, China, and reported a clear morphological differentiation among or within populations. This type of characterization has also been used on wild species in Brazil.

Veasey *et al.* (2008) analyzed the genetic variability among the four wild rice species occurring in South America, reporting agro-morphological variation for *O. glumaepatula*, followed by *O. latifolia* .

Rosa *et al*. (2006) characterized eight populations of *O. glumaepatula* Steud. collected in different hydrographic basins.

Sao (2002); Iftekharudduala *et al.* (2001); Shivani and Reddy (2000) observed similar result and that was, high phenotypic variations were composed of high genotypic variations and less of environmental variations, which indicated the presence of high genetic variability for different traits and less influence of environment. Therefore, selection on the basis of phenotype alone can be effective for the improvement of these traits.

2.1.2 Characterization on leaf

Moulia (2000) stated that in plant, leaf development is a complex process comprising cell division and expansion, axis determination, and tissue differentiation and specification.

Itoh *et al.* (2005) worked on rice and he stated that, in terms of *Oryza sativa* (rice), the leaf is polarized along the adaxial–abaxial axis.

Zhou *et al.* (2011) and Zhang *et al.* (2009) found that moderate leaf rolling can maximize the rice yield through more efficient photosynthesis and reduced transpiration, as well as by increasing stomatal resistance, reducing water loss, and the resulting erection of the leaf blade (Sakamoto *et al.*, 2006).

Zou *et al.* (2011) stated that, how to increase crop productivity and yield through manipulating the adaxial and abaxial cells has become an important issue in agriculture. He also stated that more than 10 rice leaf rolling–associated genes have been reported to be involved in abaxial and adaxial polarity establishment.

Fujino *et al.* (2008) suggest that alternation of bulliform cells arranged on the adaxial epidermis of the leaf leads to adaxial or abaxial rolling of mature leaves.

Kadioglu and Terzi (2007) demonstrated that hypodermis cells were involved in leaf rolling in higher plants as well.

Li *et al.* (2010) stated that most of the leaf rolling mutants exhibited an abaxially rolled leaf phenotype, such as abaxially curled leaf 1*(*acl1*) and* acl2.

Zou *et al.* (2011) and Hibara *et al.* (2009) found that there are some regulators involved in regulation of the adaxially rolled leaf, such as adaxialized leaf1 and rice outermost cell-specific gene 5.

Wu *et al.* (2010) stated that other regulators have also been well characterized. For example, narrow and rolled leaves 1 participates in regulating leaf morphology through coordinating the regulation of constitutively wilted1*/* narrow leaf7, rl9, *and* osago7.

Itoh *et al.* (2005) stated on the feature of leaf morphology, the leaf bending at the lamina joint, which results from the unequal elongation that occurs between the adaxial and abaxial cells.

Tong *et al.* (2012); Zhang *et al.* (2012); Tanaka *et al.* (2009) provided the evidence which illustrated that brassinosteroids (BRs) play a pivotal role in leaf bending. For example, depleted rice BR receptor (OsBRI1) mutants exhibit a predominant erect leaf phenotype (Yamamuro *et al.*, 2000).

Bai *et al.* (2007) and Sakamoto *et al.* (2006) stated that suppression of OsBZR1 results in the erect leaf phenotype.

Zhang *et al.* (2012) stated that leaf and tiller angle increased controller *(*LIC*)* regulate leaf bending through inhibition of the transcription of OsBZR1, by binding to its promoter. Dwarf and Low-Tillering (DLT) is another newly identified gene participating in leaf morphology.

Tong *et al.* (2012) further indicated that OsBIN2 also participated in establishment of leaf morphology through the interaction with DLT.

2.1.3 Characterization on leaf senescence

Buchanan-Wollaston *et al*. (2003) stated that leaf senescence is a key developmental step in the life of annual plants. During growth, green leaves accumulate nutrients. The main purpose of senescence is the mobilization and recycling of these nutrients to the developing seeds to prepare the next generation. Developmental signals, aging, or stress can induce leaf senescence. The final stage of this process is death, but cell death is actively delayed until nutrients have been removed.

Hortensteiner and Feller (2002) stated that during senescence, cell constituents are dismantled in an ordered progression. Chlorophyll degradation is the first visible symptom of senescence, but by the time yellowing can be seen, some senescence has already occurred. Chlorophyll, protein, and lipid degradation processes have been largely investigated.

Mae (2004) found that accelerated metabolism of membrane lipids results in a decline in the structural and functional integrity of cellular membranes. Thylakoid membranes provide an abundant source of carbon that can be mobilized for use as an energy source during senescence. Rubisco is one of the major sources of nitrogen for mobilization. A major question in leaf senescence is how leaf proteins, up to 75% of which are located within the chloroplast, are degraded and mobilized.

2.1.4 Characterization on lemma, palea and spikelet

Zanis (2007) and Rudall *et al*. (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. Recent phylogenetic, genetic, and bioinformatics investigations have shed light on the molecular basis regulating the development of the inflorescence and spikelet in grasses

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 typically 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 or prophyll, called the palea, and the outer bract, called the lemma.

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

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

Sarawgi (2008) characterized thirty two aromatic rice accessions of Badshahbhog group from IGKV. Raipur, Chhattisgar germplasm. These germplasm accessions were evaluated for twenty-two morphological, six agronomical and eight quality characters viz. leaf blade pubescence, leaf blade colorstigma color, lemma and palea color, lemma and palea pubescence etc. The specific genotypes B: 1340, B: 2039, B: 2495, B: 2816, B: 16930, B: Z354, B: 1163, B: 2094 were identified for quality and agronomical characteristics. It was concluded that these accessions may be used in hybridization program to achieve desired segregant for good grain quality with higher yield.

2.1.5 Characterization on male sterility

Virmani (1994) stated that being a self-pollinated crop, commercial production of hybrid seed plays a key role in successful implementation of hybrid rice.

Anther dehiscence or pollination and spikelet-flowering in rice occur more or less simultaneously so male sterility has to be adapted to the female parents to prevent self-pollination and secure cross-pollination.

Tian (1991) found that side effects of the male sterility usually create barriers for cross-pollination of the female parent including incomplete exertion of panicle which prevents access to about 20% of the spikelets and the failure of about 20% of spikelets to open at all.

Ali *et al*. (1995) stated that the use of male sterility is a prerequisite for commercial exploitation of heterosis, as rice is a self-pollinating crop. One of the possible alternatives is the two-line breeding system, which is achieved using environmental sensitive genic male sterility (EGMS) and chemical induction of male sterility.

Viraktamath and Virmani (2001) found that the EGMS is composed of two types: photo-sensitive genic male sterility (PGMS), which is responsive to variations in day length, and thermo-sensitive genic male sterility (TGMS), which is caused by high temperature. India is tropical country with significant temperature variation at different altitudes and in different seasons, making sterility difficult to control. Successful exploitation of this novel male sterility system relies on the knowledge of fertility behavior of TGMS, since the nuclear sterile gene reacts differently to temperature based on genetic factors.

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

2.1.6 Characterization on stem

Marschner (1995) found that minerals taken up by the plant roots are transported to the shoot and distributed to each leaf and the meristem to maintain proper growth. Primary long-distance transport from the roots to the

shoot is assumed to be driven by transpiration flow and root pressure within xylem vessels. After translocation to the leaf, minerals are loaded into the phloem and exported from the old tissue to the developing young tissue at a low transpiration rate. This step known as remobilization occurs depending on the kind of solute. In addition to these transport steps, intervascular transport systems in the stem tissue, such as xylem-to-phloem transfer, have been suggested to be of particular importance for elemental partitioning among shoot tissues.

Jeschke and Hartung (2000) studied 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 exudate.

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

Ookawa *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.

Ma *et al*. (2004) and Khush (2000) stated that cultivars with large culms, therefore, may be ideotypes for super rice breeding because the characteristics of semi-dwarfism, lodging resistance, and heavy panicles have been considered to be important traits for super rice breeding.

Cholewa and Griffith (2004) stated that the vascular system (including xylem, phloem, and the bundle sheath) is the most important architectural component in plant tissues, is responsible for the transport of water and assimilates.

He and Zhang (2003) found that the vascular bundle size and the density of bundle sheath cells (Ogle, 2003) are strongly correlated with photosynthesis and transpiration.

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

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

2.1.7 Characterization on panicle

Duan *et al*. (2004); Ma *et al*. (2004) and Khush (2000) found that characteristics such as semi-dwarfism, strong lodging resistance, and large panicles are considered the most important traits in super rice breeding.

Xu *et a*l. (2005) stated that panicle length is strongly negatively correlated with the grain insertion density, grain quality, and seed-setting ability because excessive panicle length is not favorable for erect positioning and thus disadvantageous for photosynthesis.

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

2.1.8 Characterization on awn

Gross and Zhao (2014); Zong *et al.* (2007) stated that the domestication of Asian cultivated rice (*Oryza sativa* L.) is a research focus of genetics and archaeology. Common wild rice (*Oryza rufipogon* Griff.) is considered to be the progenitor of cultivated rice.

Doebley *et al.* (2006) found that series of morphological and physiological characteristics distinguish the wild and cultivated species, such as seed shattering, stem growth habit, awn length, and hull or seed color.

Hirano and Toriba (2014) found that the awn that usually has a spinose surface is a spicule-like structure extending from the primordial tip of the lemma long and burry awns of wild rice are pivotal for propagation since they protect grains against animal predation and facilitate seed dispersal.

Hu *et al*. (2011) stated that awns in cultivated rice were partially or completely eliminated by artificial selection for the convenience of agricultural practices. Long awns in closed panicles significantly decrease the outcrossing rate. The genetics of awn length and distribution in rice has been studied in intricate detail.

2.1.9 Characterization on grain

Yoshida (1981) found that improvement of rice grain yield is the main target of breeding program to develop rice varieties. Grain yield is a complex trait, controlled by many genes and highly affected by environment. In addition, grain yield is also related to other characters such as plant type, growth duration, and yield components.

Murthy *et al*. (2014) revealed that a significant and positive co relation of grain yield per plant with days of flowering, days of maturity and leaf length. There were strong positive correlations of panicle length with number of spikelets per panicle, 100 seeds weight and yield per plant.

Ghosh *et al*. (2004) and Surek (2002) reported that the tiller number and grain number per panicle were affected by the environmental and cultivation factors as well.

Manzoor *et al*. (2006) stated that 1000 g weight was affected by cultivation methods. However, Aidei and Beighly (2006) reported that cultivation methods didn't have such effect on 1000-grain weight.

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

Pandey and Anurag (2010) studied the genetic variability among forty rice genotypes for yield and yield contributing components. High significant difference was found for all the characters for the presence of substantial genetic variability. The maximum genotypic and phenotypic coefficient of variability was found for harvest index, grain yield per hill, plant height and biological yield per hill. High heritability coupled with high genetic advance was found for plant height and number of spikelet per panicle.

2.1.10 Characterization on endosperm

Hehenberger *et al*. (2012) reported that for most of the higher plants, endosperm, cellularization is the key event during early seed development.
Olsen (2004) stated that after fertilization, the primary endosperm nucleus undergoes several rounds of mitotic divisions that are uncoupled from cell wall synthesis and cytokinesis to form the syncytium, a cell containing multiple free nuclei. The syncytium stage is conserved in both monocots and dicots.

Olsen (2001) found that in plants, the syncytium transitions from the free nuclear stage by initiating cellularization of the peripheral nuclei, which is followed by simultaneous cytokinesis and cell wall formation. After that, cell division continues to proceed in a centripetal direction until the endosperm cells occupy most of the central vacuole.

2.2 Variability

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

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

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

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

Ashrafuzzaman *et al*. (2009) found that the larger the leaf area, the more the solar interception and photosynthate production provided that all other factors of production are not limiting. Therefore, flag leaf area was found to be directly related to the yield components: number of panicles, panicle length, number of grains per panicle, 100 grain weight, total grain weight per hill, and yield per hectare. Furthermore, the flag leaf has been found to be metabolically active to support higher grain yield. Corroborating our finding in this work, it have made clear that yield components positively correlate with flag leaf area. Ashrafuzzaman *et al*. (2009) are reported that the weight of 100 or 1000 grain weight contributes significantly to the final yield per unit area. It represents the weight of individual seeds which could not be directly measured because of the size of individual seeds. The result of the present study showed that 100 grain weight varied significantly among the tested varieties. This could also be due to their differences in origin and genetic makeup.

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

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

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

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

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

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

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

Chakraborty *et al.* (2010) found that Panicle length determines how many spikelets will be found in a panicle and therefore filled spikelets and

consequently final grain yield. The longer the panicle, the more the spikelets and the filled grains, if other environmental conditions are not limiting. As found here, panicle length correlated positively with the final yield. Who also found a significant positive association between panicle length and grain yield per hill.

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

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

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted at the experimental farm, Sher-e-Bangla Agricultural University, Dhaka during the period from November to April, 2016-2017. Detailed of the experimental materials and methods followed in the study are presented in this chapter. The experiment was conducted to characterize and to study variability of eight F_8 lines of boro rice.

3.1 Experimental Site

The experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka, during November 2016 to April 2017. The experimental area was situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above the sea level. Geographically the experimental field is located at 8.4 metre above the mean sea level. The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.2 Climate and Soil

The experimental site was medium high land belonging to old Madhupur tract (AEZ-28) and the soil series was Tejgaon. The soil of the experimental plot was clay loam in texture having pH around 6.5 and organic carbon content is 0.84%. The experiment area was above flood level and having available irrigation and drainage system and has been presented in Appendix V.

The experimental site was under the subtropical climate. It is characterized by three distinct seasons, winter season from November to February and the pre-monsoon or hot season from March to April and the monsoon period from May to October. Details of the metrological data on air temperature, relative humidity, rainfall and sunshine hour at the time of experiment was collected from the weather station of Bangladesh, Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix VI.

3.3 Planting Materials

Eight boro lines of F_8 generation obtained from crossing between aus and boro with two check varieties (BRRI dhan 28 and BRRI dhan 29) were used as experimental materials. Descriptions of the lines are given in Table l.

Table 1. List of materials used for the experiment

Lines	Pedigree	Source
L1	BR 21× BRRI dhan 29 $S_6P_1P_1S_1$	GEPB, SAU
L2	BR 21× BRRI dhan 29 $S_6P_1P_1S_2$	GEPB, SAU
L3	BR 21× BRRI dhan 29 $S_2P_1S_1$	GEPB, SAU
L4	BR 21× BRRI dhan 28 $S_5P_1P_2S_1$	GEPB, SAU
L5	BR 21× BRRI dhan 28 $S_5P_4P_1S_1$	GEPB, SAU
L6	BR 21× BRRI dhan 28 $S_5P_1P_2S_4$	GEPB, SAU
L7	BR 26× BRRI dhan 28 $S_1P_9P_4S_1$	GEPB, SAU
L8	BR 24× BRRI dhan 36 $S_8P_1P_1S_1$	GEPB, SAU
L9	BRRI dhan 28	BRRI
L10	BRRI dhan 29	BRRI

L=lines

3.4 Design and Layout

The experiment was laid out in randomized complete block design (RCBD). The field was divided into three blocks which indicated three replications; each block was sub-divided into 10 plots where boro lines were randomly assigned. The experimental field size was 29 m x 14 m where 50cm boarder was maintained surrounding the field and every block. The experimental field was designed such a way where row to row distance was 20 cm and plant to plant distance was 20 cm. The eight lines with two check varieties were distributed to each plot within each block randomly.

3.5 Collection of Seed

The seeds of eight F_8 boro lines were collected from germplasm center of Sher-e-Bangla Agricultural University (SAU). Seeds of two check varieties (BRRI dhan 28 and BRRI dhan 29) were collected from Bangladesh Rice Research Institute (BRRI).

3.6 Germination of Seed

Seeds of all collected rice lines were soaked separately for 24 hours in cloth bags. Soaked seeds were picked out from water and wrapped with straw and gunny bag to increase the temperature for facilitating germination. Seeds were sprouted properly after 72 hours.

3.7 Seedbed Preparation and Seedling Raising

The seed bed was prepared by puddling the wetland with repeated ploughing following by laddering. Sprouted seeds were sown separately in the previously wet seedbed on 20 November, 2016. The beds were surround by nets and proper care was taken so that there was no infestation of pest, diseases and no damage took place by birds.

3.8 Preparation of Main Field

The land was prepared by 3-4 ploughing followed by laddering to attain a good puddle. Weeds and stubbles were removed and the land was finally prepared by the addition of basal dose of fertilizers recommended by BRRI. Plate 1 showing experimental works from seed soaking to transplanting.

Plate 1. Experimental work from seed soaking to transplanting

3.9 Application of Fertilizers

The fertilizers N, P, K, S and B were applied in the form of urea, TSP, MP, Gypsum and Borax, respectively. The entire amount of TSP, MP, Gypsum, Zinc Sulphate and Borax were applied during final preparation of field. Urea was applied in three equal installments *viz.* during ploughing, vegetative stage and before flowering. According to BRRI (2014) the dose and method of application of fertilizer are sown in Table 2.

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

Fertilizers	**Dose(kg/ha)**	**Application (%)**		
		Basal	**1st installment**	**2nd installment**
Urea	127	33.33	33.33	33.33
TSP	52	100	--	--
MP	60	100	--	--
Gypsum	0	100	--	--
Borax	0	100	--	--

3.10 Transplanting of Seedling

Healthy seedlings of 30 days old were transplanted on 20 December 2016 in three separate blocks of the experimental field. Water level was maintained properly after transplanting.

3.11 Intercultural Operation and After Care

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

3.11.1. Irrigation and Drainage

Flood irrigation was given to maintain a constant level of standing water up to 6 cm in the early stages to enhance tillering, proper growth and development of

the seedlings and 10-12 cm in the later stage to discourge late tillering. The field was finally dried out 15 days before harvesting.

3.11.2. Gap Filling

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

3.11.3. Weeding

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

3.11.4. Top Dressing

After basal dose, the remaining doses of urea were top dressed in two equal installments. The fertilizers were applied on both sides of each plots so that proper distribution of fertilizer was maintained in the field.

3.11.5. Plant Protection Measure

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

3.11.6. Harvesting, Threshing and Cleaning

The rice was harvested depending upon the maturity of plant and harvesting was done manually from each plot. The harvested crop of each plot was bundled separately. Properly tagged and brought to threshing floor. Enough care was taken for threshing and also cleaning of rice seed. Fresh weight of grain was recorded. The grains were cleaned and finally the weight was adjusted to moisture content 12%.

3.12 Methods of Recording of Observations

To study the stable diagnostic characteristics data and morphological characters were collected from ten randomly selected hills from each replicated plots. The plants were selected from middle of each plot to avoid border effect and portion of the plot. The mean was estimated. Thirty one qualitative and ten quantitative traits were recorded using the descriptors developed by Biodiversity International, IRRI and WARDA-2007. The descriptors are shown in the Appendix II. Then the variability study was done on fifteen parameters to select the best lines. The observations for characterization were recorded under field condition as follows.

3.12.1 Qualitative Traits Evaluation Methods

The experimental plots were visited every day and required data were collected as per schedule. An appropriate data record book was used for keeping records of data related to identification of the lines. Rice descriptors developed by The Biodiversity International, IRRI and WARDA-2007 (Appendix II) were used for data collection and recording. The photographs of specific trait considered to be helpful for identification of the lines were taken from the experimental field at appropriate times for different traits to compare the distinctness among the rice lines.

3.12.1.1 Leaf Sheath: Anthocyanin color

Data was collected at early vegetative stage on leaf sheath anthocyanin color and the rice lines were classified into two groups with codes according to guided descriptors as per follows (Table 3).

Absent-1 and Present-9.

3.12.1.2 Leaf Color

Observations with respect to green coloration of leaf at late vegetative stage the rice lines were classified into seven groups with codes according to guided descriptors as per follows (Table 3). The leaf color chart in Figure 1 showing different colors (green, dark green and pale green).

Pale green-1, Green-2,

Dark green-3, Purple tip-4,

Purple margins-5 and

Purple blotch-6 and Purple-7.

Figure 1. Leaf color chart (Green, dark green, pale green)

3.12.1.3 Penultimate Leaf Pubescence

It was assessed both visually and by touch, rubbing fingers over the leaf surface from the tip to downwards at late vegetative stage. The observed lines were categorized in five groups as per descriptors by following way (Table 3).

Absent or very weak-1,

Weak or only on the margins-3,

Medium hairs on the medium portion of the leaf-5,

Strong hairs on the leaf blade-7 and

Very strong-9.

3.12.1.4 Penultimate Leaf: Anthocyanin coloration of auricles and collar

Data was collected at late vegetative stage on penultimate leaf anthocyanin coloration of auricles and collar and the rice lines were classified into two groups with codes according to guided descriptors as per follows (Table 3).

Absent-1 and Present-9.

Table 3. Descriptors with codes for qualitative characteristics

SL. No.	Characteristics	Descriptors with Codes
1	Leaf sheath: anthocyanin color	Absent-1, Present-9.
2	Leaf color	Pale green-1, Green-2, Dark green-3, Purple tip-4, Purple margins-5, Purple blotch-6, Purple-7.
3	Penultimate leaf pubescence	Absent or very weak-1, Weak or only on the margins-3, Medium hairs on the medium portion of the leaf-5, Strong hairs on the leaf blade-7, Very strong-9.
4	Penultimate leaf: anthocyanin coloration of auricles and collar	Absent-1, Present-9.
5	Penultimate leaf: ligule	Absent-1, Present-9.
6	Penultimate leaf: shape of the ligule	Truncate-1, Acute-2, Split or two-cleft-3.
7	Flag leaf: attitude of the blade	Erect ($<30^0$)-1, Intermediate or Semi-erect (30^0-45^0)-3, Horizontal (46^0-90^0)-5, Reflexed or descending ($>90^0$)-7.
8	Male sterility	Absent-1, CMS-3, TGMS-5, PGMS-7, P(T)GMS-9.
9	Microscopic observation of pollen with I_2-KI solution	Completely sterile with TA pollen-1, Completely sterile with 80% TA pollen-2, Completely sterile with 50% TA pollen-3, Sterile (91-99%)-4, Partial sterile(31-70%)-5, Partial fertile (31-70%)-6, Fertile (21-30%)-7 and Fully fertile (0-20%)-8.
10	Lemma and Palea: anthocyanin coloration	Absent or very weak-1, Weak-3, Medium-5, Strong-7, Very strong-9.
11	Lemma: anthocyanin coloration of area below apex	Absent or very weak -1, Weak-3, Medium-5, Strong- 7, Very strong-9.
12	Lemma: anthocyanin coloration of apex	Absent or very weak -1, Weak-3, Medium-5, Strong- 7, Very strong-9.
13	Color of stigma	White-1, Light green-2, Yellow-3, Light purple-4 and Purple-5.
14	Stigma exertion	No or a few (>5%)-1, Low (5-20%)-3, Medium (21-40%), High (41-60%)-7, Very high (>61%)-9.
15	Stem: anthocyanin coloration of nodes	Absent-1, Present-9.
16	Stem: intensity of anthocyanin coloration of nodes	Weak-3, Medium-5, Strong-7 and Very strong-9.

Table 3. Descriptors with codes for qualitative characteristics (cont'd)

SL. No.	Characteristics	Descriptors with Codes
17	Stem: anthocyanin coloration of internodes	Absent or very weak -1, Weak-3, Medium-5, Strong-7, Very strong-9.
18	Panicle: curvature of main axis (i.e. recurved main axis)	Absent or very weak -1, Weak-3, Medium-5, Strong-7.
19	Spikelet: pubescence of lemma and palea	Absent or very weak -1, Weak-3, Medium-5, Strong-7, Very strong-9.
20	Spikelet: color of the tip of lemma	White-1, Yellowish-2, Brownish-3, Red-4, Purple-5, Black-6.
21	Panicle: awns in the spikelet	Absent-1, Present-9.
22	Panicle: Length of the longest awn	Very short (<2 mm)-1, Short (2-5 mm)-3, Medium (5-10 mm)-5, Long (11-20 mm)-7 and Very long (>20 mm)-9.
23	Panicle: Distribution of awns	Tip only-1, Upper half only-3 and Whole length-5.
24	Panicle: Color of awns	Yellow white-1, Brown-3, Reddish-5, Purple-7 and Black-9.
25	Panicle: attitude of branches	Erect-1, Semi-erect-3, Spreading-5.
26	Panicle: exertion	Enclosed-1, Partly exerted-3, Just exerted-5, Moderately exerted-7, Well exerted-9.
27	Leaf senescence: Penultimate leaves are observed at the time of harvest.	Late and slow (2 or more leaves retain green color at maturity)-1, Intermediate-5 and Early and fast (leaves are dead at maturity)-9.
28	Decorticated grain: shape (length-width ratio of de-hulled grain)	Round (L:W<1.5)-1, Bold (L:W=1.5-2.0)-3, Medium (L:W=2.1-2.5)-5, Medium slender (L:W=2.6-3.0)-7 and Slender (L:W>3.0)-9.
29	Decorticated grain (bran): color	White-1, Light brown-2, Variegated brown-3, Dark brown-4, Red-5, Variegated purple-6 and Purple-7.
30	Polished grain: size of white core or chalkiness (% of kernel area)	Absent or very small-1, Small (<10%)-3, Medium (11-20%)-5 and Large (11-20%)-7.
31	Decorticated grain: aroma	Absent-1, Lightly present-5 and Strongly present-9.
32	Endosperm: content of amylose (nonwaxy type varieties)	Low (>20%), Intermediate (21-25%), High (>25%)
33	Other distinct special character (if any)	

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

3.12.1.5 Penultimate Leaf: Ligule

Data was collected at late vegetative stage on penultimate leaf ligule and the rice lines were classified into two groups with codes according to guided descriptors as per follows (Table 3).

Absent-1 and Present-9.

3.12.1.6 Penultimate Leaf: Shape of the ligule

Shape of the penultimate leaf ligule was observed and the lines were categorized according to guided descriptors as per follows (Table 3). Which are also shown hypothetically in Figure 2.

Absent-0, Truncate-1,

Acute to acuminate-2 and

Split or two-cleft-3.

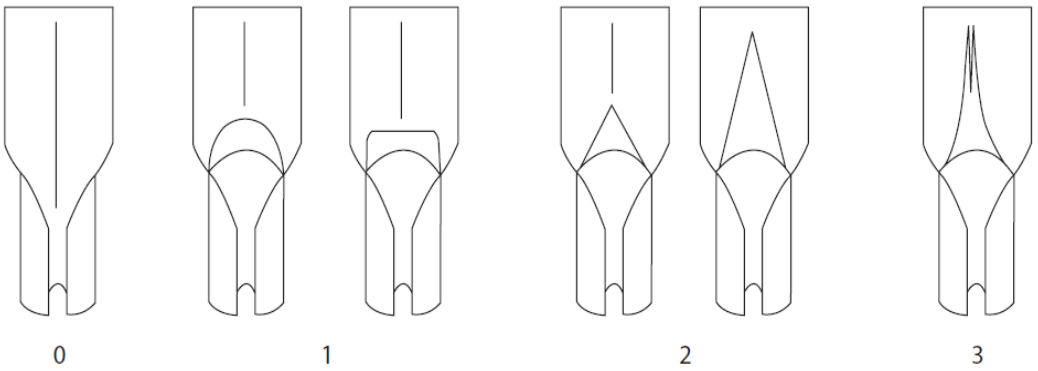


Figure 2. Ligule shape

3.12.1.7 Flag Leaf: Attitude of the blade

Attitude of the blade of flag leaf is angle of attachment between the flag leaf blade and the main panicle axis. It was just visually observed at anthesis period and classified into following four groups according to guided descriptors as per follows (Table 3).

Erect ($<30^0$)-1,

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

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

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

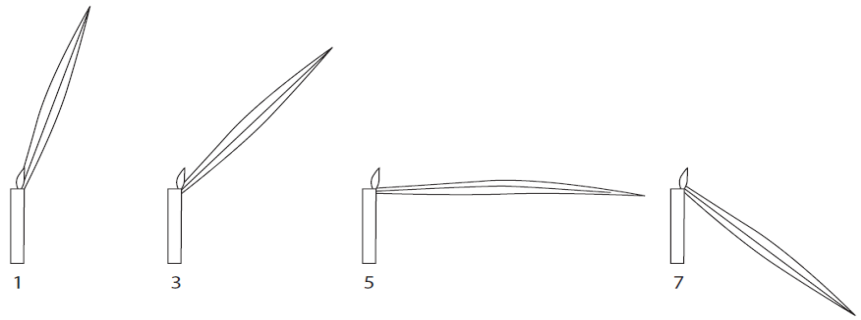


Figure 3. Flag leaf attitude

3.12.1.8 Male Sterility

It was observed at anthesis period and grouped as per descriptors (Table 3).

Absent-1,

CMS-3, TGMS-5,

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

3.12.1.9 Microscopic Observation of Pollen with I_2-KI solution

It was observed at anthesis period of rice using microscope and the rice lines were classified into eight groups with codes according to guided descriptors as per follows (Table 3).

Completely sterile with TA pollen-1,

Completely sterile with 80% TA pollen-2,

Completely sterile with 50% TA pollen-3,

Sterile (91-99%)-4,

Partial sterile (31-70%)-5,

Partial fertile (31-70%)-6,

Fertile (21-30%)-7 and

Fully fertile (0-20%)-8.

3.12.1.10 Lemma and Palea: Anthocyanin coloration

Data was collected at pre-ripening stage on grain anthocyanin coloration of lemma and palea and the rice lines were classified into five groups with codes according to guided descriptors as per follows (Table 3).

Absent or very weak-1,

Weak-3, Medium-5,

Strong-7 and Very strong-9.

3.12.1.11 Lemma: Anthocyanin coloration of area below apex

Data was collected at pre-ripening stage on grain anthocyanin coloration of lemma and the rice lines were classified into five groups with codes according to guided descriptors as per follows (Table 3).

Absent or very weak-1,

Weak-3, Medium-5,

Strong-7 and Very strong-9.

3.12.1.12 Lemma: Anthocyanin coloration of apex

Data was collected at pre-ripening stage on grain anthocyanin coloration of lemma and the rice lines were classified into five groups with codes according to guided descriptors as per follows (Table 3).

Absent or very weak-1,

Weak-3, Medium-5,

Strong-7 and Very strong-9.

3.12.1.13 Color of Stigma

Data was observed at anthesis period using a hand lens or magnifying glass and the rice lines were classified into five groups with codes according to guided descriptors as per follows (Table 3).

White -1, Light green-2,

Yellow-3, Light purple-4 and

Purple-5.

3.12.1.14 Stigma Exertion

Data was observed at anthesis period using a hand lens or magnifying glass and the rice lines were classified into five groups with codes according to guided descriptors as per follows (Table 3).

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

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

Very high (>61%)-9.

3.12.1.15 Stem: Anthocyanin coloration of nodes

Data was collected after flowering to near maturity stage on stem anthocyanin coloration of nodes and the rice lines were classified into two groups with codes according to guided descriptors as per follows (Table 3).

Absent-1 and

Present-9.

3.12.1.16 Stem: Intensity of anthocyanin coloration of nodes

Data was collected after flowering to near maturity stage on stem anthocyanin coloration of nodes and the rice lines were classified into four groups with codes according to guided descriptors as per follows (Table 3).

Weak-3, Medium-5,

Strong-7 and Very strong-9.

3.12.1.17 Stem: Anthocyanin coloration of internodes

Data was collected at near coloration maturity stage on stem anthocyanin coloration of internodes and the rice lines were classified into five groups with codes according to guided descriptors as per follows (Table 3).

Absent or very weak-1,

Weak-3, Medium-5,

Strong-7 and Very strong-9.

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

Data was collected at near maturity stage and the rice lines were classified into four groups with codes as per descriptors as follows (Table 3).

Absent or very weak (upright)-1, Weak (semi-upright)-3,

Medium (slightly drooping)-5 and

Strong (strongly dropping)-7.

3.12.1.19 Spikelet: Pubescence of lemma and palea

Data was collected after anthesis to hard dough stage or pre-ripening stage on spikelet with pubescence of lemma and palea and the rice lines were classified into five groups with codes according to guided descriptors as per follows (Table 3).

Absent or very weak-1,

Weak-3, Medium-5,

Strong-7 and Very strong-9.

3.12.1.20 Spikelet: Color of the tip of lemma

Data was collected after anthesis to hard dough stage or pre-ripening stage on spikelet with color of the tip of lemma and the rice lines were classified into six groups with codes according to guided descriptors as per follows (Table 3).

White-1, Yellowish-2,

Brownish-3, Red-4,

Purple-5 and Black-6.

3.12.1.21 Spikelet: Awns in the spikelet

It was observed at flowering to maturity stage and it is normally a character of wild species of rice. Based on this character the rice lines were grouped as per descriptors as follows (Table 3).

Absent-1 and

Present-9.

3.12.1.22 Spikelet: Length of the longest awn

It was observed at maturity stage and normally a character of wild species of rice and grouped as per descriptors as follows (Table 3).

Very short (<2 mm)-1,

Short (2-5 mm)-3,

Medium (5-10 mm)-5,

Long (11-20 mm)-7 and

Very long (>20 mm)-9.

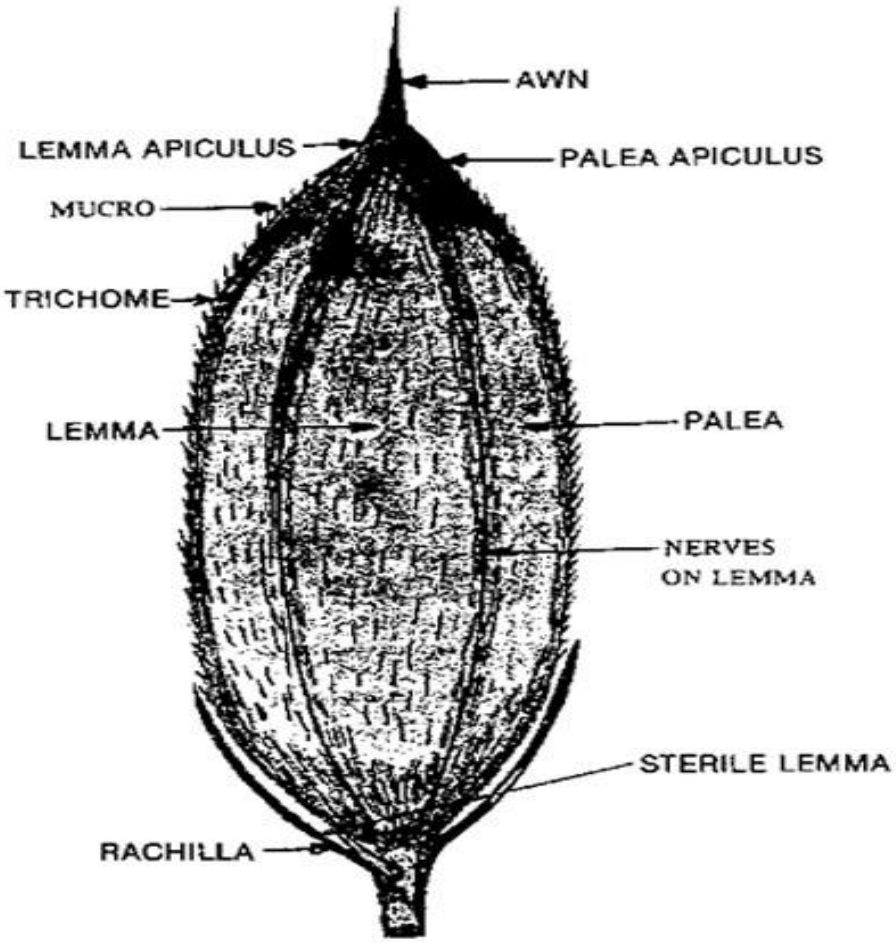


Figure 4. Rice grain showing different parts

3.12.1.23 Panicle: Distribution of awns

It was observed at flowering to maturity stage and normally a character of wild species of rice and grouped as per descriptors as follows (Table 3).

Tip only-1, Upper half only-3 and

Whole length-5.

3.12.1.24 Panicle: Color of awns

It was observed at flowering to maturity stage and normally a character of wild species of rice and grouped as per descriptors as follows (Table 3).

Yellow white-1, Brown-3,

Reddish-5, Purple-7 and

Black-9.

3.12.1.25 Panicle: Attitude of branches

The compactness of the panicle was classified according to its mode of branching, angle of primary branches, and spikelet density by the following groups (Table 3).

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

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

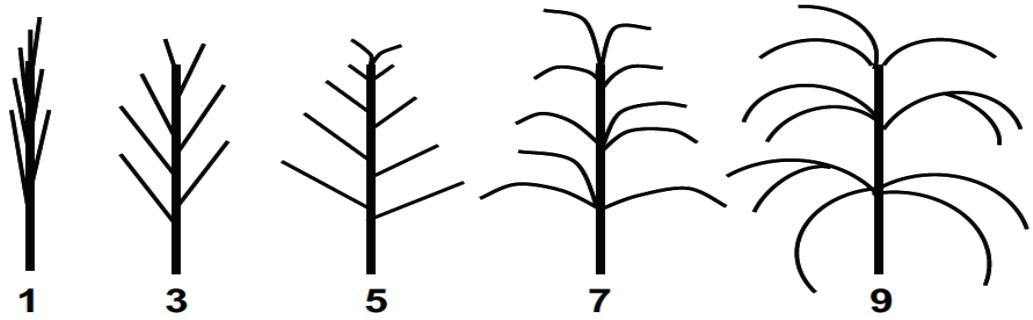


Figure 5. Attitude of panicle branches

3.12.1.26 Panicle: Exertion

Extent to which the panicle is exerted above the flag leaf sheath is known as panicle exertion. Data was collected at near maturity stage and the rice lines were classified into five groups with codes according to guided descriptors as per follows (Table 3).

Enclosed-1, Partly exerted-3

Just exerted-5, Moderately exerted-7 and

Well exerted-9.

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

Data was collected at the time of harvest and the rice lines were classified into three groups with codes according as per descriptors as follows (Table 3).

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

Intermediate-5 and

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

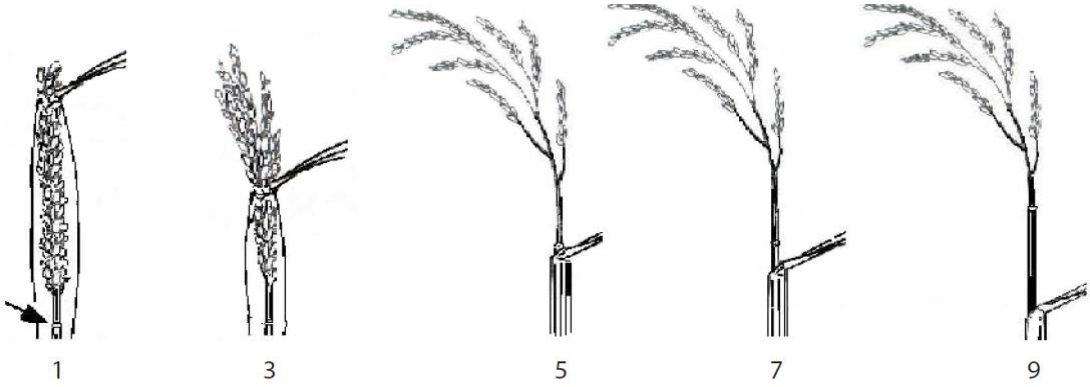


Figure 6. Panicle exertion

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

Data was collected at the time of harvest and the rice lines were classified into five groups with codes as per guided descriptors as follows (Table 3).

Round (L: W<1.5)-1

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

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

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

Slender (L: W>3.0)-9.

Figure 7 showing the procedure measuring grain shape.

3.12.1.29 Decorticated Grain (bran): Color

Data was collected at the time of harvest and the rice lines were classified into seven groups with codes according to the guided descriptors as per follows (Table 3).

White-1, Light brown-2,

Variegated brown-3,

Dark brown-4, Red-5

Variegated purple-6 and

Purple-7.

Figure 7 showing different bran colors.

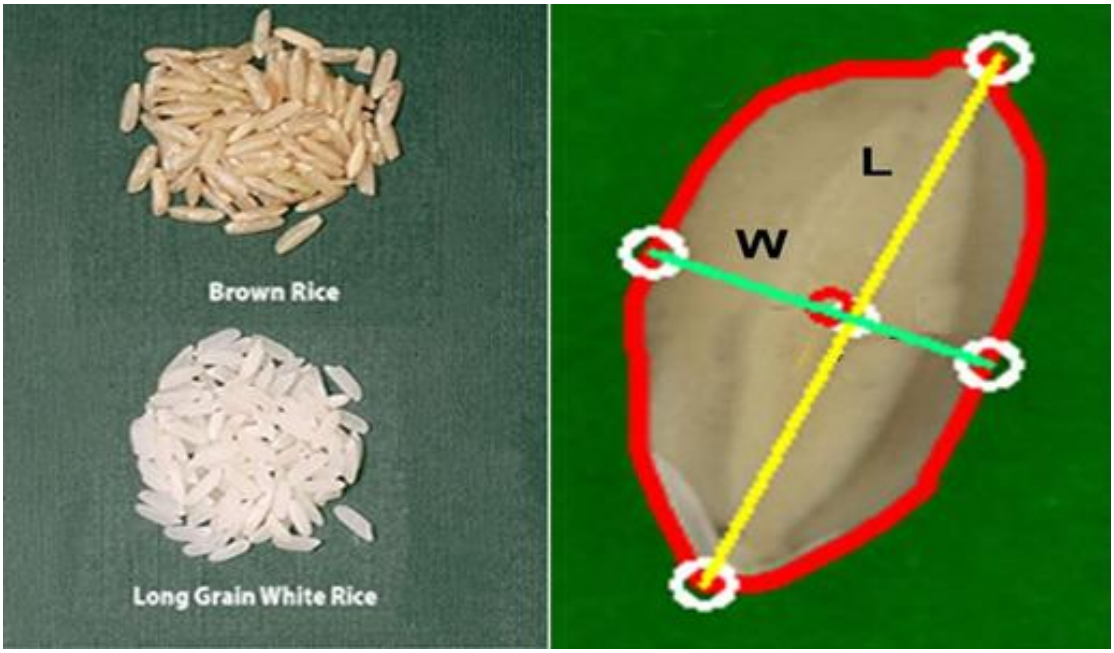


Figure 7. Grain shape measuring procedure and bran color of rice

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

Data was collected at the time of harvest and the rice lines were classified into four groups with codes as per guided descriptors as follows (Table 3).

Absent or very small-1,

Small (<10%)-3,

Medium (11-20%)-5 and

Large (11-20%)-7.

3.12.1.31 Decorticated Grain: Aroma

Data was collected at the time of harvest and the rice lines were classified into three groups with codes as per guided descriptors as follows (Table 3).

Absent-1,

Lightly present-5 and

Strongly present-9.

3.12.1.32 Endosperm content: Content of amylose (Nonwaxy type varieties)

Data was collected at the time of harvest and the rice lines were classified into three groups with codes as per guided descriptors as follows (Table 3).

Low (>20%),

Intermediate (21-25%),

High (>25%)

3.12.1.33 Other Distinct Special Character (if any)

No other Distinct Special Character was recorded.

3.12.2 Quantitative Traits Evaluation Methods

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

Culm diameter of the stem was measured in millimeter scale at the lowest internode of the stem during flowering or late reproductive stage by using digital caliper and categorized as per descriptors as follows (Table 4).

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

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

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

Stem length (culm length) was measured in centimeter from the base of the plants to the neck of the panicles after flowering to maturity stage and categorized as per descriptors as follows (Table 4).

Very short (<40 cm)-1,

Short (41–60 cm)-3,

Medium (61–80 cm)-5,

Long (81-110 cm)-7 and

Very long (>110 cm)-9.

Figure 8 showing culm length of rice plant.

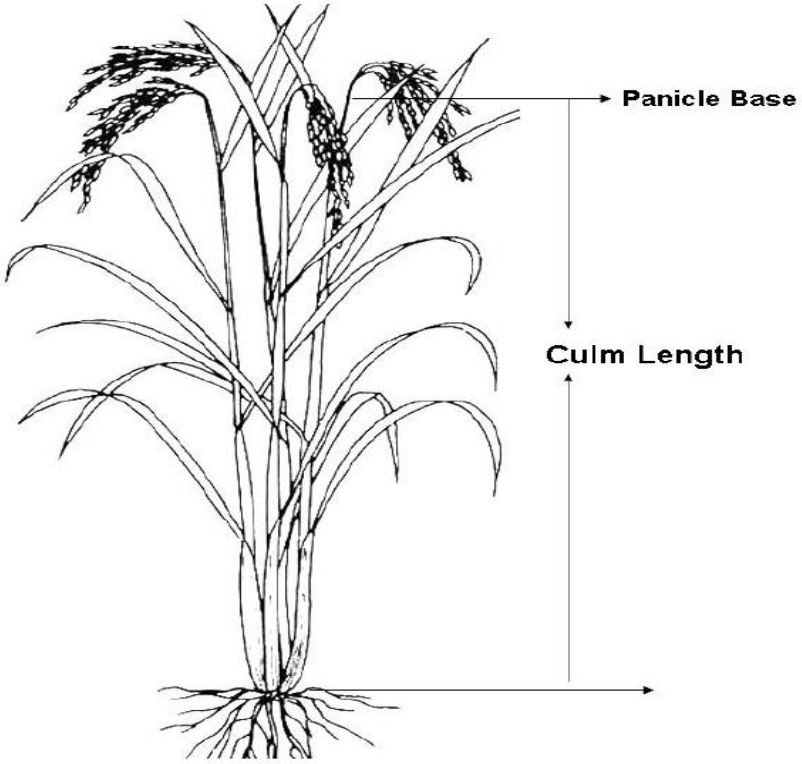


Figure 8. Culm length

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

The mean length often randomly selected panicles of main tillers from ten hills was measured from neck to the tip of the panicle of main tiller without awn in centimeters. Data was collected at 7 days after anthesis or full panicle exertion stage According to their length, the observed rice lines were classified into four groups with codes as per descriptors as follows (Table 4).

Short (<20 cm)-3,

Medium (21-25 cm)-5,

Long (26-30 cm)-7 and

Very long (>30 cm)-9.

3.12.2.4 Panicle: Number of the effective tillers per plant

Effective tillers are the tillers which bears panicle and the total number of tillers were counted from each of the sample plants and the average was taken. Based on this character, all the lines were grouped into following groups as per the guided descriptors as follows (Table 4).

Few (>6)-3,

Medium (6-10)-5 and

Many (>10)-7.

Figure 9 showing tiller of rice plant.

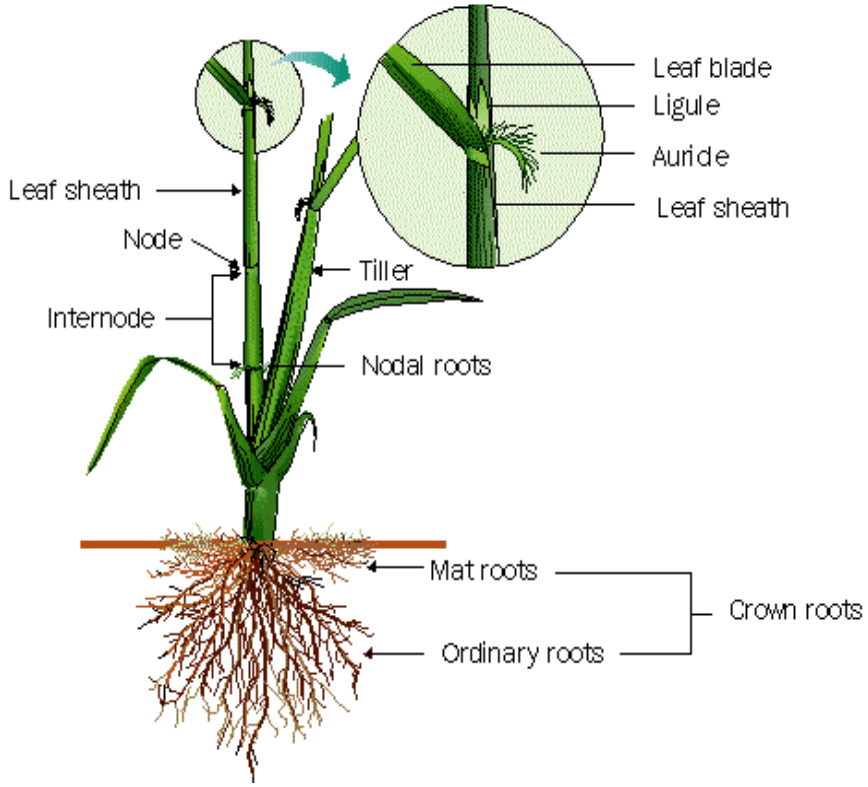


Figure 9. Morphology of a rice plant (vegetative stage)

3.12.2.5 Time of heading (50% of plants with heads)

The number of days from date of sowing until 50% seeds become matured considering each replication was recorded on each individual plot and the lines were classified as per the guided descriptors as follows (Table 4).

Very early (< 70 days)-1,

Early (70-85 days)-3,

Medium (86-105 days)-5,

Late (106-120 days)-7 and

Very late (>120 days)-9.

3.12.2.6 Time of Maturity

The number of days from date of sowing until 80% seeds become matured considering each replication was recorded on each individual plot and the lines were classified as per the guided descriptors as follows (Table 4).

Very early (>100 days)-1,

Early (101-115 days)-3,

Medium (116-135 days)-5,

Late (136-150 days)-7 and

Very late (>150 days)-9.

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

After threshing and recording the net yield, a random sample of fully grown 1000 seeds were counted and weighed at 12% moisture content to record the test weight. According to test weight, the lines were categorized into five different groups as per the guided descriptors as follows (Table 4).

Very low (<15 g)-1,

Low (16-19 g)-3,

Medium (20-23 g)-5,

High (24-27 g)-7 and

Very high (>27 g) – 9.

Table 4. Descriptors with codes for quantitative characteristics

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

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

3.12.2.8 Grain: Length (without dehulling)

Grain length was measured in mm and a digital caliper was used for clear visualization. Ten grains from every lines were measured and the mean value was recorded. The lines were classified as per the guided descriptors as follows (Table 4).

Very short (<6.0 mm)-1,

Short (6.1-7.0 mm)-3,

Medium (7.1-8.0 mm)-5,

Long (8.1-9.0 mm)-7 and

Very Long (>9.0 mm)-9.

3.12.2.9 Sterile Lemma Length: Measure at post-harvest stage

Sterile lemma length was measured in mm and a digital caliper was used for clear visualization. Ten grains from every lines were measured and the mean value was recorded. The lines were classified as per the guided descriptors as follows (Table 4).

Short (<1.5 mm)-1,

Medium (1.5-2.5 mm)-3,

Long (2.6-3.0 mm)-5 and

Very Long (>3.0 mm)-7.

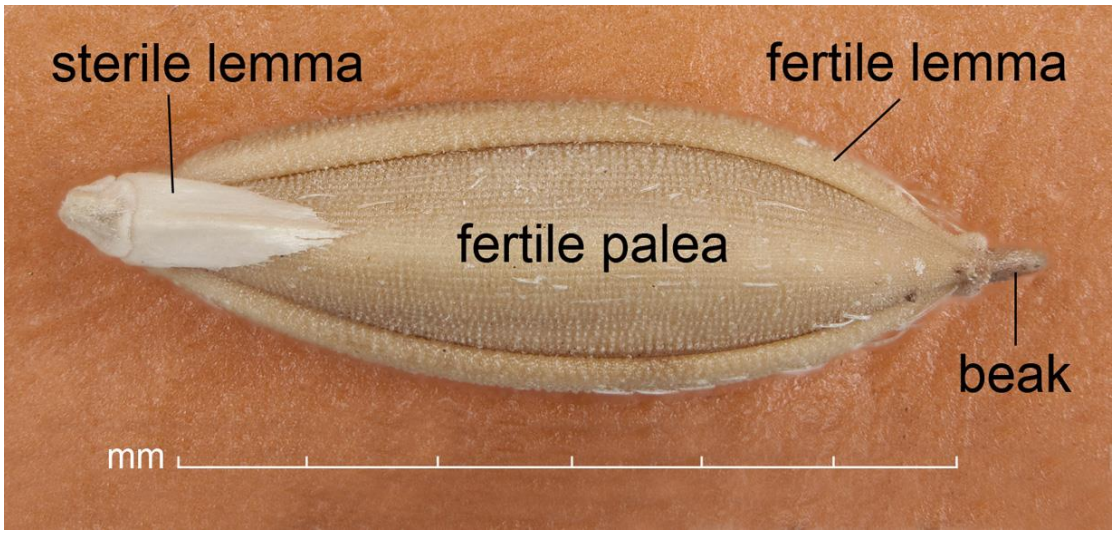


Figure 10. Lemma and palea of rice grain

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

Decorticated grain length was measured in mm and a digital caliper was used for clear visualization. Ten grains from every lines were measured and the mean value was recorded. The lines were classified as per the guided descriptors as follows (Table 4).

Short (<5.5 mm)-1,

Medium (5.6-6.5 mm)-3,

Long (6.6-7.5 mm)-5 and

Very Long (>7.5 mm)-7.

3.13 Statistical Application

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

3.14 Data collection for estimation of variability

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

3.14.1 Days to 50% maturity

Days to 50% Maturities of the crops of different combination were recorded considering the symptom such as color changing of the plant from greenish to straw colored appearance, color and hardness of the grain.

3.14.2 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.

3.14.3. 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.

3.14.4 Number of total tillers per plant

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

3.14.5 Number of effective tillers per plant

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

3.14.6 Panicle length (cm)

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

3.14.7 Number of primary branches per panicle

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

3.14.8 Number of secondary branches per panicle

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

3.14.9 Total number of spikelets per panicle

The total number of spikelet per panicle were counted from the 10 randomly selected plants of each plot and then averaged.

3.14.10 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.

3.14.11 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.

3.14.12 1000-seed weight (g)

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

3.14.13 Yield per plant (g)

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

3.14.14 Yield per hectare (t)

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

3.14.15 Stem length up to neck (cm)

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

3.15 Estimation of variability

Collected 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 Statistix10 software and then phenotypic, genotypic variance, environmental variance, PCV, GCV and ECV were estimated.

3.15.1 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/M3
Lines (l)	l- 1	M2	$\delta_e^2 + \delta_g^2$	M2/M3
Error	(r-1)(l-1)	M3	δ_e^2	

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.

3.15.2 Estimation of genetic parameters

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

3.15.2.1 Estimation of variance components

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

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

Where,

MSL = Mean sum of square for lines

MSE = Mean sum of square for error and

r = Number of replication

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

Where,

δ_g^2 = Genotypic variance,

δ_e^2 = Environmental variance = Mean square of error

3.15.2.2 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 coefficient of variance (GCV) (%) $= \frac{\sqrt{\delta_g^2}}{\bar{x}}$ x 100

Where,

δ_g^2 = genotypic varirnce

$\bar{x}$ = population mean

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

Where,

δ_p^2 = phenotypic variance

$\bar{x}$ = population mean

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

CHAPTER IV
RESULTS AND DISCUSSION

The research work was conducted with a view to characterize and study variability of eight F_8 lines of boro rice with two check varieties (BRRI dhan 28 and BRRI dhan 29) as per the guided descriptors developed by Biodiversity International, IRRI and WARDA-2007. Characterization was done based on thirty one qualitative and ten quantitative traits. Variability among the eight F_8 lines was studied based on fifteen 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

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. But no coloration was found in this investigation (Table 5). A pictorial view of leaf sheath anthocyanin color is presented in Plate 2.

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 according to guided descriptors as per follows. Here 3 lines (L2, L4 and L7) showed pale green color, 7 lines (L1, L3, L5, L6, L8, L9 and L10) showed green color. Dark green, purple tip, purple margins, purple blotch and purple green type leaf were not found in any lines (Table 6). Pictorial view of leaf color is presented in Plate 3.

Table 5. Categorization and grouping based on leaf sheath anthocyanin Color

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

Table 6. Categorization and grouping based on leaf color

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

Plate 2. Leaf sheath anthocyanin color

Plate 3. Green and pale green color leaf

4.1.3 Penultimate Leaf: Pubescence of blade

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

4.1.4 Penultimate Leaf: Anthocyanin coloration of auricles and collar

On the basis of penultimate leaf anthocyanin coloration of auricles and collar, rice lines were classified as absent-1 and present-2. No anthocyanin coloration of auricles and collar were present in any of these lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) (Table 8). A pictorial view of anthocyanin coloration of auricles and color of penultimate leaf is presented in Plate 4.

4.1.5 Penultimate Leaf: Ligule

On the basis of penultimate leaf ligule shape, rice lines were classified as absent-1 and present-9. All lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) had ligule on the penultimate leaf (Table 9). A pictorial view of ligule is presented in Plate 5.

4.1.6 Penultimate Leaf: Shape of the ligule

On the basis of ligule shape of penultimate leaf, rice lines were classified as truncate-1, acute to acuminate-2 and split or two-cleft-3 type. But all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were two-cleft type that means there was no significant difference among the lines (Table 10). According to IRRI (2001) most of the cultivated rice have two-cleft type ligule shape and wild type genotypes may show others type. From our observation the two-cleft type ligule was found. A pictorial view of shape of the ligule of penultimate leaf is presented in Plate 5.

Table 7. Categorization and grouping based on penultimate leaf pubescence

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

Table 8. Categorization and grouping based on penultimate leaf anthocyanin coloration of auricles and collar

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

Table 9. Categorization and grouping based on penultimate leaf ligule

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

Table 10. Categorization and grouping based on ligule shape of penultimate leaf

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

Plate 4. Anthocyanin coloration of auricle and collar

Plate 5. Split or two-cleft type of ligule

4.1.7 Flag Leaf: Attitude of the blade

Based on angle of attachment between the flag leaf blade and the main panicle axis the observed lines were categorized in 4 groups like erect ($<30^0$)-1, intermediate or semi-erect (30^0-45^0)-3, horizontal (46^0-90^0)-5, reflexed or descending ($>90^0$)-7 type. Here all ten lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) showed erect type flag leaf (Table 11). Pictorial view of attitude of the blade of flag leaf is presented in Plate 6 and 7. According to Tripathi and Raj (2000) flag leaf plays a significant role in enhancing rice yield because it remains the only source of assimilate production for the filling spikelets during grain-filling stage.

4.1.8 Male Sterility

Male sterility was observed at anthesis period of rice and grouped as per descriptors. On the basis of male sterility, rice lines were classified as absent-1, CMS-3, TLMS-5, PLMS-7 and P (T) LMS-9. But all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) had absence of male sterility (Table 12). Ali *et al*. (1995) stated that the use of male sterility was a prerequisite for commercial exploitation of heterosis, as rice is a self-pollinating crop.

4.1.9 Microscopic Observation of Pollen with I_2-KI solution

It was observed at anthesis period of rice using microscope and the rice lines were classified into eight groups with codes according to guided descriptors as per follows. Completely sterile with TA pollen-1, completely sterile with 80% TA pollen-2, completely sterile with 50% TA pollen-3, sterile (91-99%)-4, partial sterile (31-70%)-5, partial fertile (31-70%)-6, fertile (21-30%)-7 and fully fertile (0-20%)-8. In this situation all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were fertile (Table 13).

Table 11. Categorization and grouping based on attitude of the blade of flag leaf

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

Table 12. Categorization and grouping based on male sterility

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

Table 13. Categorization and grouping based on microscopic observation of pollen with I_2-KI solution

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

Plate 6. Attitude of flag leaf of L1

Plate 7. Attitude of flag leaf of L4

4.1.10 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. Lemma and palea combinedly indicated the seed coat color actually. But all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were observed no anthocyanin coloration of lemma and palea or very weak anthocyanin coloration of lemma and palea for seed coat color (Table 14). According to Abebe *et al*. (2004) palea and lemma were unique structures found only in the Poaceae, where they were responsible for protecting the florets and kernels.

4.1.11 Lemma: Anthocyanin coloration of area below apex

On the basis of lemma anthocyanin coloration of area below apex the observed lines were categorized as absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9 as presented according to descriptors. Lemma indicated the seed coat color actually. But all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were observed no anthocyanin coloration of area below apex of lemma or very weak anthocyanin coloration of area below apex of lemma for seed coat color (Table 15).

4.1.12 Lemma: Anthocyanin coloration of apex

On the basis of lemma anthocyanin coloration of apex the observed lines were categorized as absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9 as presented according to descriptors. Lemma indicated the seed coat color actually. But all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were observed no anthocyanin coloration of apex of lemma or very weak anthocyanin coloration of apex of lemma for seed coat color (Table 16).

Table 14. Categorization and grouping based on lemma and palea anthocyanin color

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

Table 15. Categorization and grouping based on anthocyanin coloration of area below lemma apex

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

Table 16. Categorization and grouping based on anthocyanin coloration of lemma apex

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

4.1.13 Color of Stigma

Data was observed at anthesis period using a hand lens or magnifying glass and the rice lines were classified into five groups with codes according to guided descriptors as white -1, light Lreen-2, yellow-3, light purple-4 and purple-5. All lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were observed white color of stigma. Light green, yellow, light purple and purple color of stigma were not observed (Table 17).

4.1.14 Stigma Exertion

Data was observed at anthesis period using a hand lens or magnifying glass and the rice lines were classified into five groups with codes according to guided descriptors as no or a few (>5%)-1, low (5-20%)-3, medium (21-40%)-5, high (41-60%)-7 and very high (>61%)-9. In this case no lines were no or few type, 3 lines (L6, L9 and L10) were low type, 2 lines (L4 and L5) were medium type, 2 lines (L1 and L8) were high type and rest 3 lines (L2, L3 and L7) were very high type for exertion of stigma (Table 18). A pictorial view of stigma exertion of rice is present in Plate 8.

4.1.15 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 codes according to guided descriptors as absent-1 and present-9. In this case all lines (L1, L2, L3, L4, L6, L7, L8, L9 and L10) were observed no anthocyanin coloration of nodes (Table 19). A pictorial view of anthocyanin coloration of nodes is present in Plate 9.

4.1.16 Stem: Intensity of anthocyanin coloration of nodes

Data was collected after flowering to near maturity stage. The rice lines were classified as per guided descriptors as weak-3, medium-5, strong-7 and very strong-9. No anthocyanin coloration of nodes on the stem present in all the lines (L1, L2, L3, L4, L6, L7, L8, L9 and L10). So intensity of anthocyanin coloration of nodes on the stem of all lines was not present.

Table 17. Categorization and grouping based on color of stigma

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

Table 18. Categorization and grouping based on stigma exertion

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

Table 19. 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 and L10
Present	9	Nil

Plate 8. Stigma exertion of rice

Plate 9. Anthocyanin coloration of nodes

4.1.17 Stem: Anthocyanin coloration of internodes

Data was collected at near coloration maturity stage on stem anthocyanin coloration of internodes and the rice lines were classified into five groups with codes according to guided descriptors as absent or very weak-1, weak-3, medium-5, stronL-7 and very stronL-9. In this case all lines (L1, L2, L3, L4, L6, L7 and L8) were observed no anthocyanin coloration of internodes (Table 20). Pictorial view of anthocyanin coloration of internodes presented in Plate 10.

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

Data were collected at near maturity stage and the rice lines were classified into four groups with codes according to guided descriptors as absent or very weak (upright)-1,weak (semi-upright)-3, medium (slightly drooping)-5 and strong (strongly dropping)-7. In this case two lines (L2 and L7) were observed strong (strongly dropping) type of panicle curvature of main axis and 8 lines (L1, L3, L4, L5, L6, L8, L9 and L10) were observed medium type of panicle curvature of main axis (Table 21). Pictorial view of panicle curvature of main axis is present in Plate 11 and 12. Duan *et al*. (2004); Ma *et al*. (2004) and Khush (2000) found that characteristics such as semi-dwarfism, strong lodging resistance, and large panicles were considered the most important traits in super rice breeding.

4.1.19 Spikelet: Pubescence of lemma and palea

Data were collected after anthesis to hard dough stage or pre-ripening stage on spikelet with pubescence of lemma and palea and the rice lines were classified into five groups with codes according to guided descriptors as absent or very weak-1, weak-3, medium-5, stronL-7 and very stronL-9. In this case medium type pubescence of lemma and palea of the spikelet were observed in all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) (Table 22). Clifford (1987) found that the establishment of the lemma/palea morphology might play a pivotal biological role in grass.

Table 20. Categorization and grouping based on stem anthocyanin coloration of internodes

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

Table 21. Categorization and grouping based on panicle curvature of main axis (i.e.recurrent main axis)

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

Table 22. Categorization and grouping based on pubescence of lemma and palea of the spikelet

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

Plate 10. Anthocyanin coloration of internodes

Plate 11. Panicle curvature of main axis of L1

Plate 12. Panicle curvature of main axis of L7

4.1.20 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 tip of lemma and the rice lines were classified into six groups with codes according to guided descriptors as white-1, yellowish-2, brownish-3, red-4, purple-5 and black-6. In this case all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were found of yellowish color type. Red, purple, brownish and black coloration of the tip of lemma were not observed (Table 23).

4.1.21 Panicle: Awns in the spikelet

It was observed at flowering to maturity and normally a character of wild species of rice and grouped as absent-1 and present-9. But all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were not observed awns in the spikelet (Table 24). According to Doebley *et al*. (2006) series of morphological and physiological characteristics distinguish the wild and cultivated species, such as seed shattering, stem growth habit, awn length, and hull or seed color.

4.1.22 Panicle: Length of the longest awn

It was observed at maturity stage and normally a character of wild species of rice and grouped as per descriptors such as very short (<2 mm)-1, short (2-5 mm)-3, medium (5-10 mm)-5, long (11-20 mm)-7 and very long (>20 mm)-9. In this case there was no awns in the spikelet present in all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10). So length of the longest awn in the spikelet of all lines was not present. According to Doebley *et al.* (2006) series of morphological and physiological characteristics distinguish the wild and cultivated species, such as seed shattering, stem growth habit, awn length, and hull or seed color.

Table 23. 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 and L10
Brownish	3	Nil
Red	4	Nil
Purple	5	Nil
Black	6	Nil

Table 24. Categorization and grouping based on awns in the spikelet

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

4.1.23 Panicle: Distribution of awns

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

4.1.24 Panicle: Color of awns

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

4.1.25 Panicle: Attitude of branches

The compactness of the panicle was classified according to its mode of branching, angle of primary branches, and spikelet density in 3 groups as erect (compact panicle)-1, semi-erect (semi-compact panicle)-3 and spreading (open panicle)-5 type panicle where all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) showed semi-erect type panicle. Erect and spreading type panicles were not found among the lines (Table 25). Pictorial view of attitude of branches of panicle is present in Plate 13 and 14.

4.1.26 Panicle: Exertion

Extent to which the panicle is exerted above the flag leaf sheath is known as panicle exertion. Data were collected at near maturity stage and the rice lines were classified into five groups with codes according to guided descriptors as enclosed-1, partly exerted-3, just exerted-5, moderately exerted-7 and well exerted-9. In this case two lines (L7 and L10) were moderately exerted type, seven lines (L1, L2, L3, L4, L5, L6 and L8) were observed just exerted type where one line (L9) observed well exerted. Enclosed, partly exerted and well exerted type of panicle exertion were not found (Table 26).

Table 25. Categorization and grouping based on panicle attitude of branches

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

Table 26. Categorization and grouping based on panicle exertion

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

Plate 13. Attitude of branches (L5)

Plate 14. Attitude of branches (L7)

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

Data were collected at harvest and the rice lines were classified into three groups with codes according to guided descriptors as per follows. Late and slow (2 or more leaves retain green color at maturity)-1, intermediate-5 and early and fast (leaves are dead at maturity)-9 where eight lines (L1, L2, L3, L4, L5, L6, L7 and L9) showed intermediate type and two lines (L8 and L10) showed late and slow (2 or more leaves retain green color at maturity) type of leaf senescence. Early and fast (leaves are dead at maturity) type of leaf senescence was not found among the lines (Table 27). Buchanan-Wollaston *et al*. (2003) stated that leaf senescence was a key developmental step in the life of plants.

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

Data were collected at the time of harvest and the rice lines were classified into five groups with codes according to guided descriptors as per follows round (L:W<1.5)-1, bold (L:W=1.5-2.0)-3, medium (L:W=2.1-2.5)-5, medium slender (L:W=2.6-3.0)-7 and slender (L:W>3.0)-9 where nine lines (L1, L3, L4, L5, L6, L7, L8, L9 and L10) showed slender type and one line (L2) showed bold type grain shape. Round, medium and medium slender type decorticated grain were not found among the lines (Table 28).

4.1.29 Decorticated grain (Bran): Color

Data were collected at the time of harvest and the rice lines were classified into seven groups with codes according to guided descriptors as per follows white-1, light brown-2, variegated brown-3, dark brown-4, red-5, variegated purple-6 and purple-7 where six lines (L2, L3, L5, L6, L7 and L8) showed light brown colored decorticated grain and rest four lines (L1, L4, L9 and L10) showed white decorticated grain color (Table 29). Variegated brown, dark brown, red, variegated purple and purple decorticated grain (bran) coloration were not found among the lines. Pictorial view of decorticated grain (bran) color is present in Plate 15 and 16.

Table 27. Categorization and grouping based on leaf senescence of penultimate leaves are observed at the time of harvest

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

Table 28. Categorization and grouping based on decorticated grain shape

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

Table 29. Categorization and grouping based on decorticated unpolished grain color

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

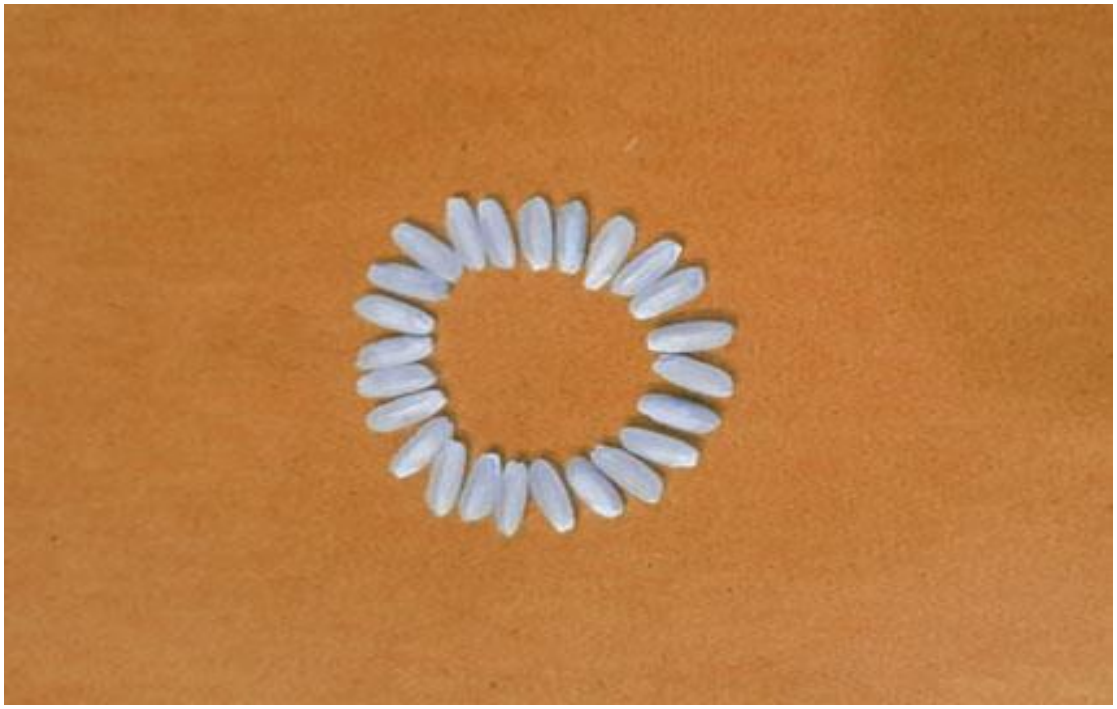


Plate 15. Decorticated grain (White colored)

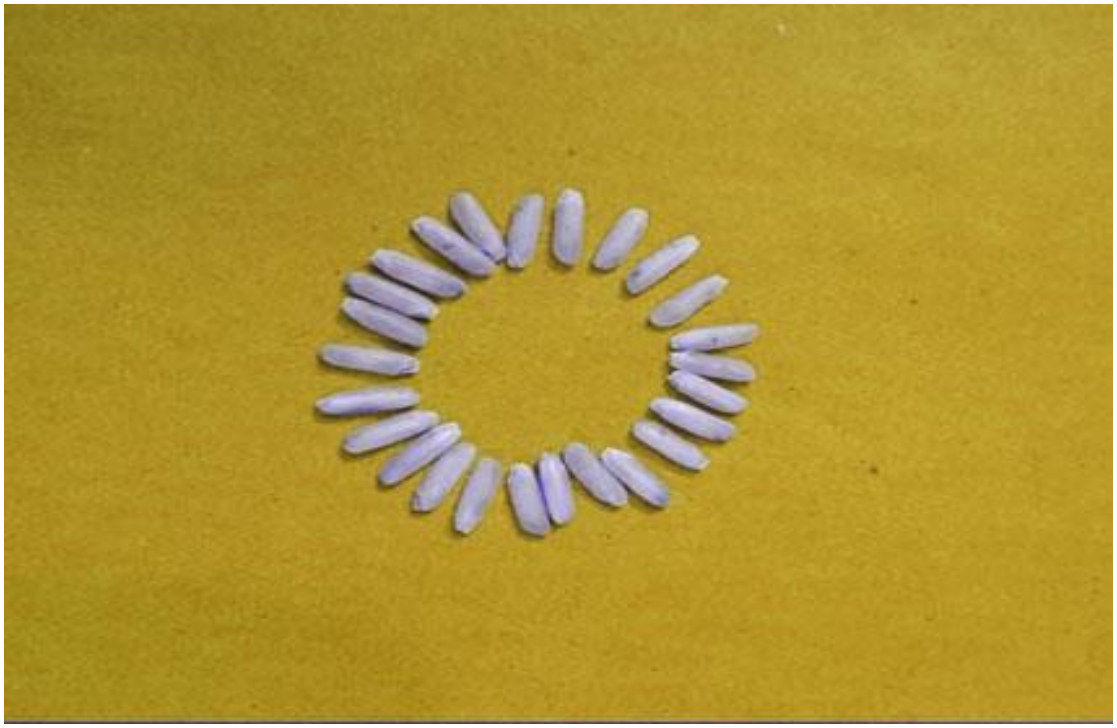


Plate 16. Decorticated grain (Light brown colored)

4.1.30 Endosperm: Content of amylose (nonwaxy type varieties)

Data were collected at the time of harvest and the rice lines were classified into three groups with codes according to guided descriptors as per follows low (>20%)-1, intermediate (21-25%)-3 and high (>25%)-5. In this case all ten lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were observed intermediate content of amylose present in endosperm (Table 30). According to Hehenberger *et al*. (2012) for most of the higher plants, endosperm and cellularization was the key event during early seed development.

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

Data were recorded at the time of harvest and the rice lines were classified into four groups with codes according to guided descriptors as per follows absent or very small-1, small (<10%)-3, medium (11-20%)-5 and large (11-20%)-7 where all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) showed absent or very small size of white core or chalkiness (% of kernel area) of polished grain. Small, medium and large size of white core or chalkiness (% of kernel area) of polished grain were not found among the lines (Table 31).

4.1.32 Decorticated grain: Aroma

Data were taken at the time of harvest and the rice lines were classified into three groups with codes according to guided descriptors as per follows absent-1, lightly present-5 and strongly present-9. In this case no aroma was found in decorticated grains of the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) (Table 32).

4.1.33 Other Distinct Special Character (if any)

In this experiment there were no other distinct special characters found.

Table 30. Categorization and grouping based on content of amylose present in endosperm

Types	Code	Lines
Low (>20%)	1	Nil
Intermediate (21-25%)	5	L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10
High (>25%)	9	Nil

Table 31. Categorization and grouping based on size of white core or chalkiness (% of kernel area) of polished grain

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

Table 32. Categorization and grouping based on aroma of decorticated grain

Types	Code	Lines
Absent	1	L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10
Lightly present	5	Nil
Strongly present	9	Nil

4.2 Characterization based on Quantitative Characters

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

Date on which 50% of panicle emergence is done of the rice fields known as heading. It is specified either as the number of days from seed sowing date to 50% heading date. Time of 50% heading of the observed lines ranged from 129.333 days to 118.667 days with a mean value of 121.9 days (Appendix-IV). 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). Five lines (L2, L4, L6, L7 and L8) showed late, five lines (L1, L3 L5, L9 and L10) showed very late but no lines were found as very early, early and medium type for 50% heading formation (Table 33). A pictorial view of time of heading is shown in Plate 17. Figure 11 showed bar graph of time of heading of different lines.

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

Culm diameter of the stem was measured in millimeter scale at the lowest internode of the stem during flowering or late reproductive stage. Culm diameter of observed lines ranged from 7.93 mm to 5.18 mm with a mean value of 6.38 mm (Appendix-II). On the basis of this character, the lines were categorized into 4 groups as small (<5.0 mm), medium (5.1-6.0 mm), large (6.1-7.0 mm) and very large (>7.0 mm) as the guided descriptors where there were no small and very large type lines, on the other hand seven medium type lines (L1, L3, L4, L5, L6, L7 and L8) and three large type lines (L2, L9 and L10) were found (Table 34). According to Chen *et al*. (2005) and Xu *et al*. (2005) morphological characteristics, including stem thickness, leaf size, leaf angle, neck stem vascular bundle abundance, and plant height during the heading stage were important indices in super rice breeding.

Table 33. Categorization and grouping based on time of heading (50%)

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

Table 34. Categorization and grouping based on culm diameter

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

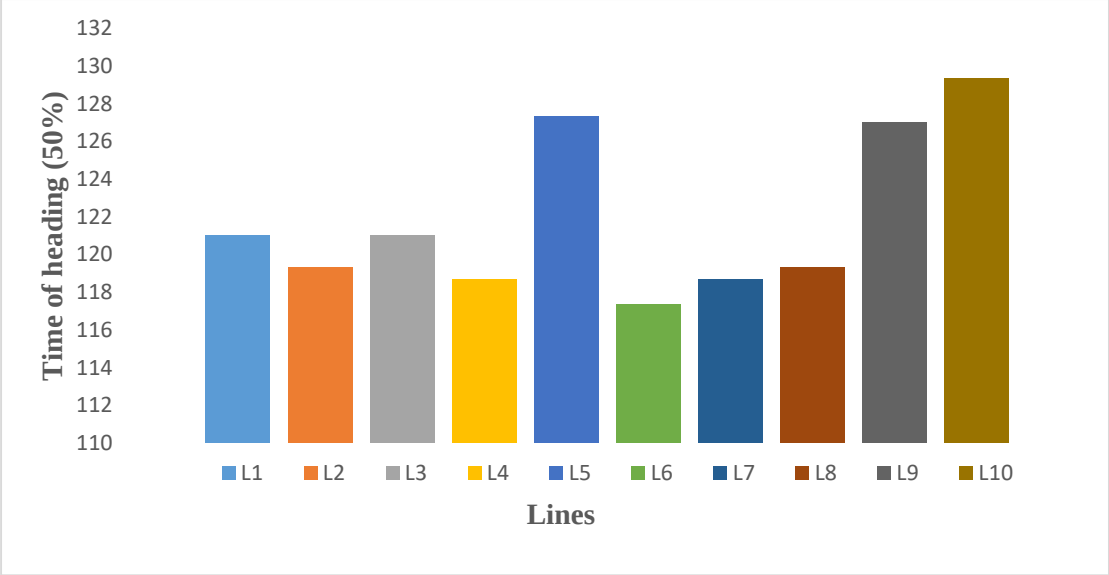


Figure 11. Different time of heading (50%) of the observed lines

Plate 17. Time of heading (50% of plants with heads)

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

Culm length means the length of a stem from ground level to panicle base. Stem length (culm length) was measured from the base of the plants to the neck of the panicles after flowering to maturity stage. Culm lengths of observed lines ranged from 79.31 cm to 64.35 cm with a mean value of 69.83 cm (Appendix-V). On the basis of this character, the lines were categorized into 5 groups as very short (<40 cm), short (41–60 cm), medium (61–80 cm), long (81-110 cm) and very long (>110 cm) as the guided descriptors where there were no very short type, short type, long type and very long type lines on the other hand, all were medium type lines (L1, L2, L3, L4, L6, L7, L8, L9 and L10) were found (Table 35). From the Figure 12 we also can distinguish different groups of observed lines based on culm length. According to Ookawa *et al*. (2010) and Chen *et al*. (2005) morphological characteristics such as plant height at the heading stage have been considered important traits in breeding both super rice and bioenergy crops.

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

Panicle length was measured from neck to the tip of the panicle of main tiller without awn in centimeters. Data were collected at 7 days after anthesis or full panicle exertion stage. On the basis of this character, the lines were categorized into 4 groups as short (<20 cm), medium (21-25 cm), long (26-30 cm) and very long (>30 cm) as the guided descriptors where there were no short type, long type and very long type lines. On the other hand all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) were found as medium type (Table 36). From the Figure 13 we also can distinguish different groups of observed lines based on panicle length. Chakraborty *et al.* (2010) found that Panicle length determines how many spikelets will be found in a panicle and therefore filled spikelets and consequently final grain yield.

Table 35. Categorization and grouping based on culm length

Groups	Scale	Code	Lines
Very short	<40 cm	1	Nil
Short	41-60 cm	3	Nil
Medium	61-80 cm	5	L1, L2, L3, L4, L6, L7, L8, L9 and L10
Long	81-110 cm	7	Nil
Very long	>110 cm	9	Nil
Range	(L5) 79.31 cm – (L7) 64.35 cm		
Average	69.83 cm		

Table 36. Categorization and grouping based on panicle length

Groups	Scale	Code	Lines
Short	<20 cm	1	Nil
Medium	21-25 cm	5	L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10
Long	26-30 cm	7	Nil
Very long	>30 cm	9	Nil
Range	(L6) 24.32 cm – (L1) 21.68 cm		
Average	23.06 cm		

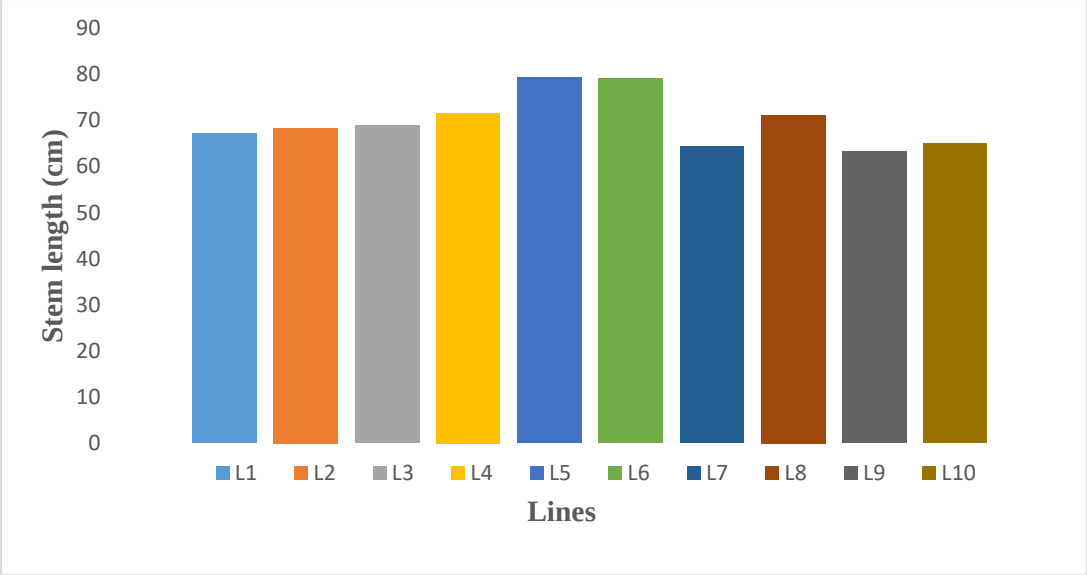


Figure 12. Different stem length (cm) up to neck of the observed lines

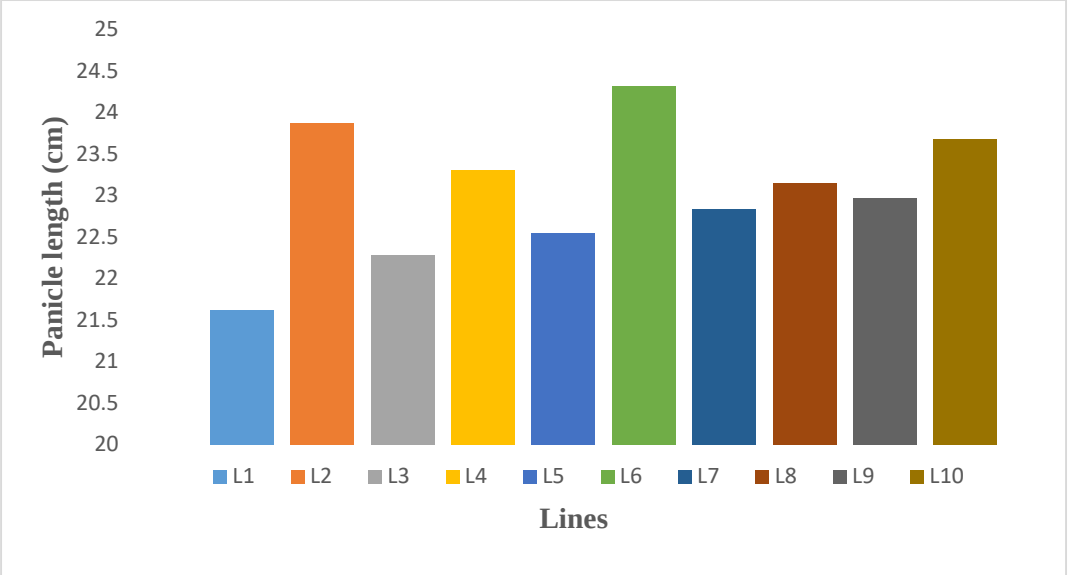


Figure 13. Different panicle length (cm) of the observed lines

4.2.5 Panicle: Number of the effective tillers per plant

The number of effective tillers per plant of the observed lines ranged from 12.93 to 10 with a mean value of 11.15 (Appendix-V) and considering this character, the observed lines were categorized as few (>6), medium (6-10) and many (>10) effective tillers per plant. There was no line showed few and medium type of effective tillers per plant. On the other hand all lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) showed many type of effective tillers per plant (Table 37). From the Figure 14 we also can distinguish different groups of observed lines based on effective tiller plant^{-1}. Hasanuzzaman *et al.* (2008) reported that the number of effective tillers rests on the number of tillers produced and this was directly proportional to the panicles produced per unit area and finally depends on variety.

4.2.6 Time of Maturity

Time of maturity was calculated as days required from sowing to maturity. Time of maturity of the observed lines ranged from 145 days to 133 days with a mean value of 137.13 days (Appendix-IV). On the basis of this character, all the lines were classified into 5 groups as very early (>100 days), early (101-115 days), medium (116-135 days), late (136-150 days) and very late (>150 days). There was no line showed very early, early and very late type of maturity. Five lines (L1, L3, L5, L9 and L10) showed late type maturity of plants (Table 38). Other five lines (L2, L4, L6, L7 and L8) showed medium type maturity of plants. This grouping based on time of maturity also shown in bar graph for more easy perception by the following Figure 15. According to Mostajeran and Rahimi-Eichi (2009) those that flowered earlier matured early while those that flowered late had a delay in their maturity. Early flowering indicated short life cycle and was considered a positive character for rice improvement.

Table 37. Categorization and grouping based on number of effective tillers per plant

Groups	Scale	Code	Lines
few	<6 tillers	3	Nil
medium	6-10 tillers	5	Nil
many	>10 tillers	7	L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10
Range	(L10) 12.93 tillers – (L8) 10 tillers		
Average	11.15 tillers		

Table 38. 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	L2, L4, L6, L7 and L8
Late	136-150	7	L1, L3, L5, L9 and L10
Very Late	>150	9	Nil
Range	(L10) 145 – (L6) 133		
Average	137.13		

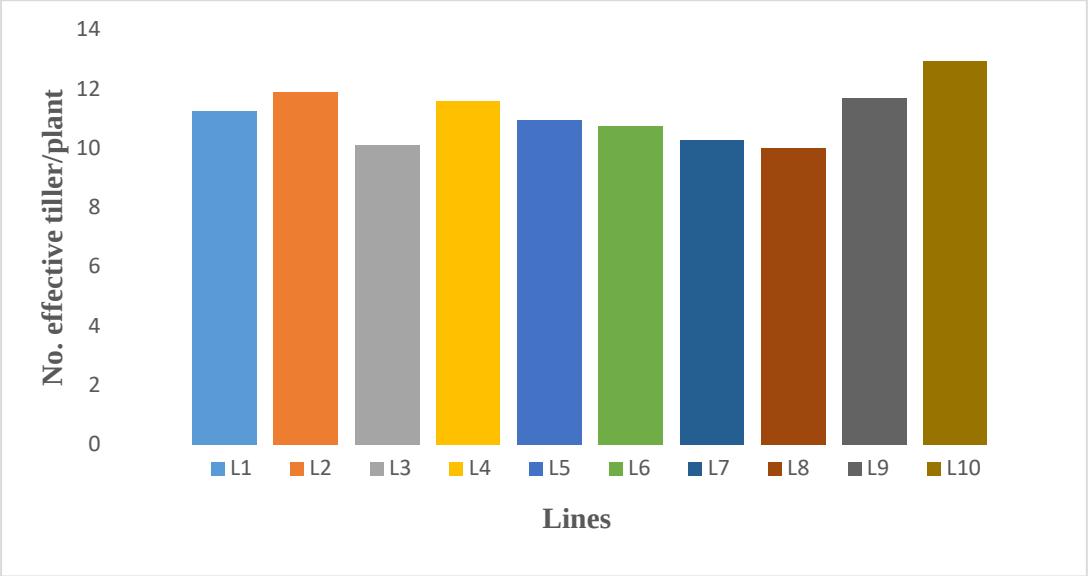


Figure 14. Total no. of effective tiller plant^{-1} of the observed lines

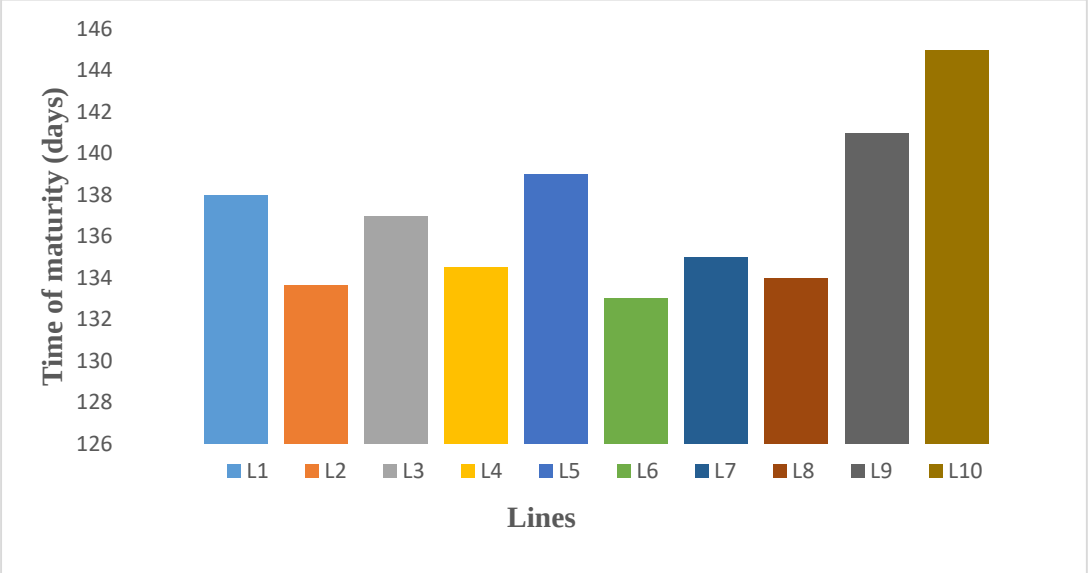


Figure 15. Time of maturity of the observed lines

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

Thousand grain weight of the observed lines ranged from 25.43g (L1) to 24.02g (L8) with a mean value of 24.76g. Considering this character, the lines were grouped as 4 types such as very low (<l5 g), low (l6-19 g), medium (20-23 g), high (24-27 g) and very high (>27 g). In this situation, there was no line showed very low, low, medium and very high type of 1000 grain weight. All ten lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) showed high type of 1000 grain weight (Table 39). From the Figure 16 we also can distinguish different groups of observed lines based on thousand grain weight (adjusted of 12% of moisture). Aidei and Beighly (2006) reported that cultivation methods didn't have much effect on 1000-grain weight.

4.2.8 Grain: Length (without dehulling)

Grain length was measured in mm and a digital caliper was used for clear visualization. Grain length of the observed rice lines ranged from 10.33 mm to 7.96 mm with a mean value of 8.78 mm. On the basis of grain length, the observed lines were grouped as very short (<6.0 mm), short (6.1-7.0 mm), medium (7.1-8.0 mm), long (8.1-9.0 mm) and very Long (>9.0 mm). One line (L2) was recorded medium, six lines (L1, L3, L5, L6, L9 and L10) were recorded as long and three lines (L4, L7 and L8) were recorded as very long (Table 40). No line was found as very short and very short. Pictorial view of grain length is presented in Plate 18. From the Figure 17 we also can distinguish different groups of observed lines based on grain length.

Table 39. Categorization and grouping based on thousand grain weight (adjusted of 12% of moisture)

Groups	Scale	Code	Lines
Very Low	<15 g	1	Nil
Low	16-19 g	3	Nil
Medium	20-23 g	5	Nil
High	24-27 g	7	L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10
Very High	>27 g	9	Nil
Range	(L10) 25.45 g- (L2) 24.28 g		
Average	24.92 g		

Table 40. 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	L2
Long	8.1-9.0 mm	7	L1, L3, L5, L6, L9 and L10
Very Long	>9.0 mm	9	L4, L7 and L8
Range	(L8) 10.33 mm – (L2) 7.96 mm		
Average	8.78 mm		

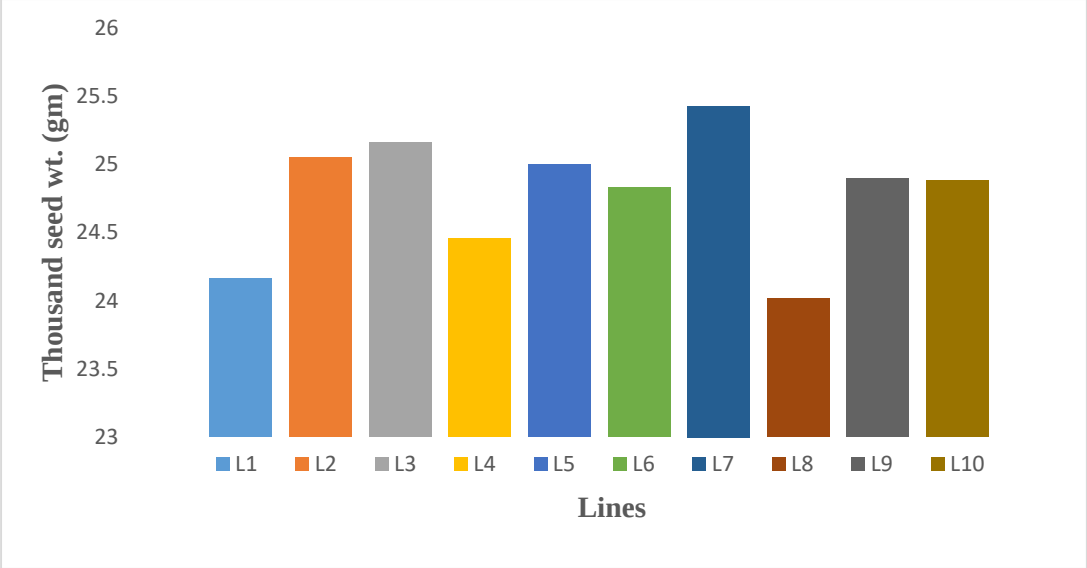


Figure 16. Thousand seed weight (g) of the observed lines

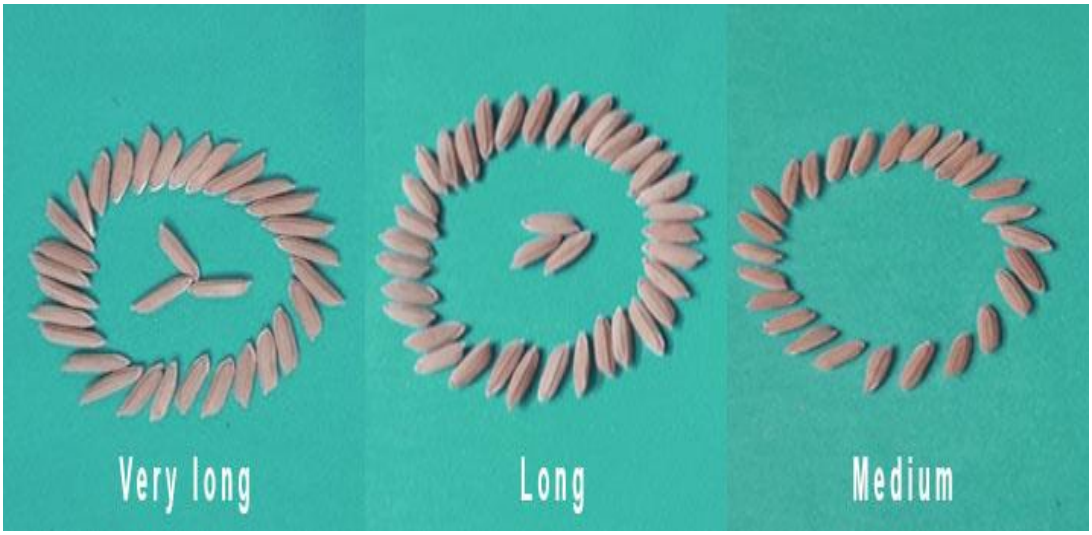


Plate 18. Various size of grain

4.2.9 Sterile Lemma Length: Measure at postharvest stage

Sterile lemma 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. Sterile lemma length of the rice lines ranged from 2.87 mm to 2.41 mm with a mean value of 2.6 mm. On the basis of sterile lemma length, the observed lines were grouped as short (<1.5 mm), medium (1.5-2.5 mm), long (2.6-3.0 mm) and very Long (>3.0 mm). Two lines (L1 and L2) were recorded as medium and rest eight lines (L3, L4, L5, L6, L7, L8, L9 and L10) as long (Table 41). No lines were found as short and very long type. From the Figure 17 we also can distinguish different groups of observed lines based on sterile lemma length.

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

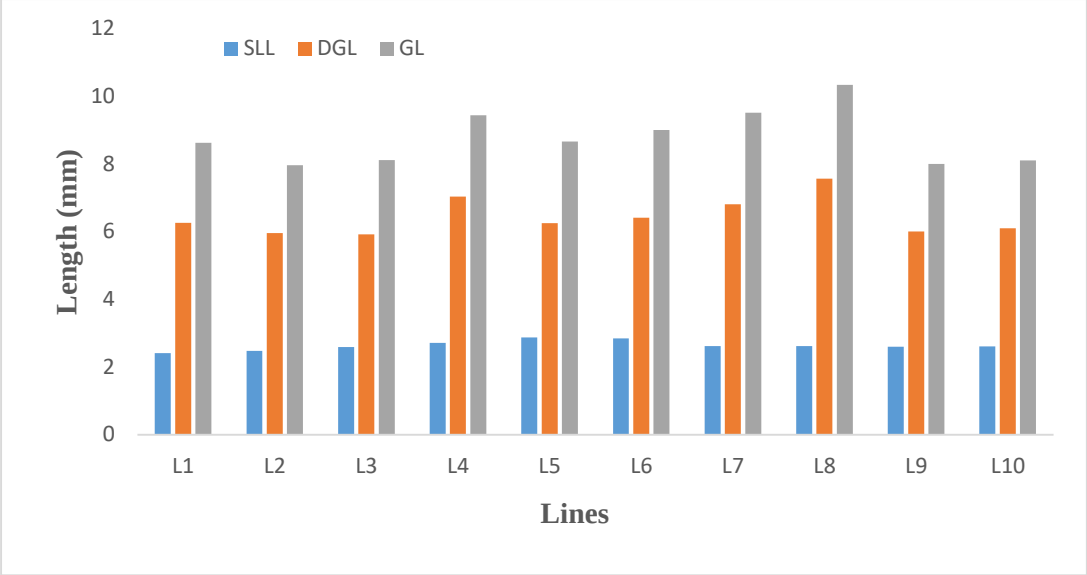
Decorticated grain length was measured in mm and a digital caliper was used for clear visualization. Ten grains from every lines were measured and the mean value was recorded. On the basis of decorticated grain length, the observed lines were grouped as short (<5.5 mm), medium (5.6-6.5 mm), long (6.6-7.5 mm) and very long (>7.5 mm). Seven lines (L1, L2, L3, L5, L6, L9 and L10) were recorded as medium, two lines (L4 and L7) as long and one line (L8) was recorded as very long. (Table 42). No lines were found as short and very long type. From the Figure 17 we also can distinguish different groups of observed lines based on decorticated grain length. Plate 19 showing the measurement procedure of decorticated grain length by digital caliper.

Table 41. Categorization and grouping based on sterile lemma length

Groups	Scale	Code	Lines
Short	<1.5 mm	1	Nil
Medium	1.5-2.5 mm	3	L1 and L2
Long	2.6-3.0 mm	5	L3, L4, L5, L6, L7, L8, L9 and L10
Very long	>3.0 mm	7	Nil
Range	(L5) 2.87 mm – (L1) 2.41 mm		
Average	2.64 mm		

Table 42. Categorization and grouping based on decorticated grain length

Groups	Scale	Code	Lines
Short	<5.5 mm	1	Nil
Medium	5.5-6.5 mm	3	L1, L2, L3, L5, L6, L9 and L10
Long	6.6-7.5 mm	5	L4 and L7
Very long	>7.5 mm	7	L8
Range	(L8) 7.56 mm – (L3) 5.92 mm		
Average	6.4 mm		



SLL = Sterile lemma length, DGL = Decorticated grain length, GL = Grain length

Figure 17. Different sterile lemma length, decorticated grain length and grain length (mm) of the observed lines

Plate 19. Measurement of decorticated grain length

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 (114.76*), studied for plant height at 5% level of probability (Appendix III). The highest plant height was observed in L6 (107.1 cm) followed by L5 (104.68 cm) .The lowest plant height was observed in L7 (88.24 cm). The mean value of plant height was 96.69 cm (Table 43). Plant height showed phenotypic variance (48.77) and genotypic variance (32.99) with relatively high differences between them which indicating considerable environmental influences on this trait (Table 44). Values of PCV and GCV were 7.22 and 5.94, respectively (Table 44). The moderate difference between PCV and GCV indicated that the genetic variation was minimal among the genotypic variation and environment had medium influence on this character expression. Figure 25 showing genotypic, phenotypic and environmental variability of the boro rice lines with their check varieties for plant height. Figure 18 showing variation in plant height of different lines. According to Ookawa *et al*. (2010) and Chen *et al*. (2005) plant height at the heading stage have been considered important traits in breeding both super rice and bioenergy crops.

4.3.2 Total no. of tillers per plant

Analysis of variance for total no. of tillers per plant exhibited non-significant mean sum of square (2.011) (Appendix III). The highest number of total tillers per plant was observed in L10 (12.53) followed by L2 (12.26). The lowest number of total tillers per plant was observed in L8 (10.23) and the mean value of total no. of tillers per plant was 11.48 cm (Table 43). Number of total tillers per plant showed phenotypic variance (1.96) and genotypic variance (0.02)

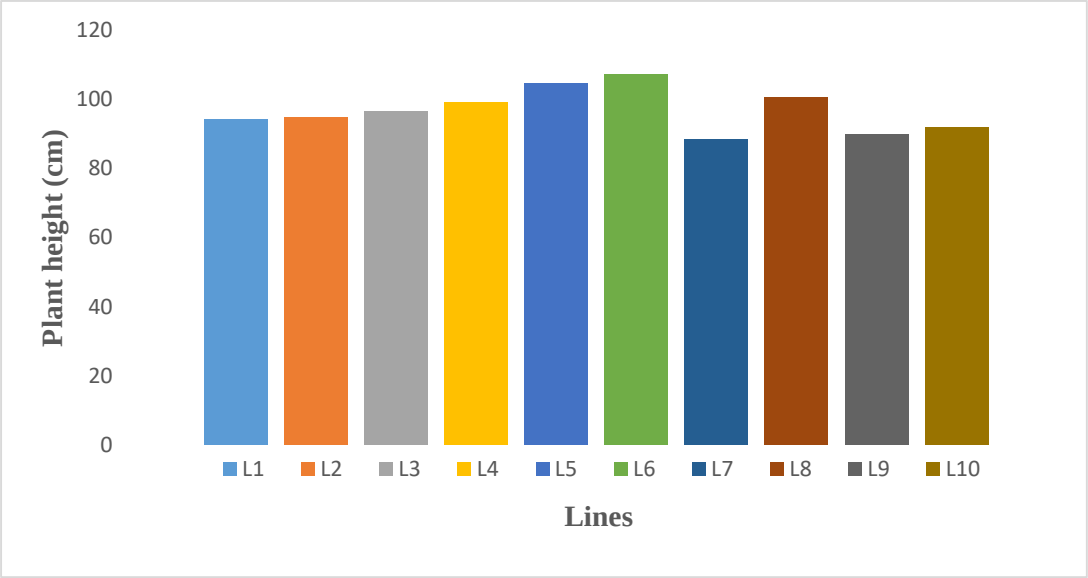


Figure 18. Significant variation in plant height (cm) of the observed lines

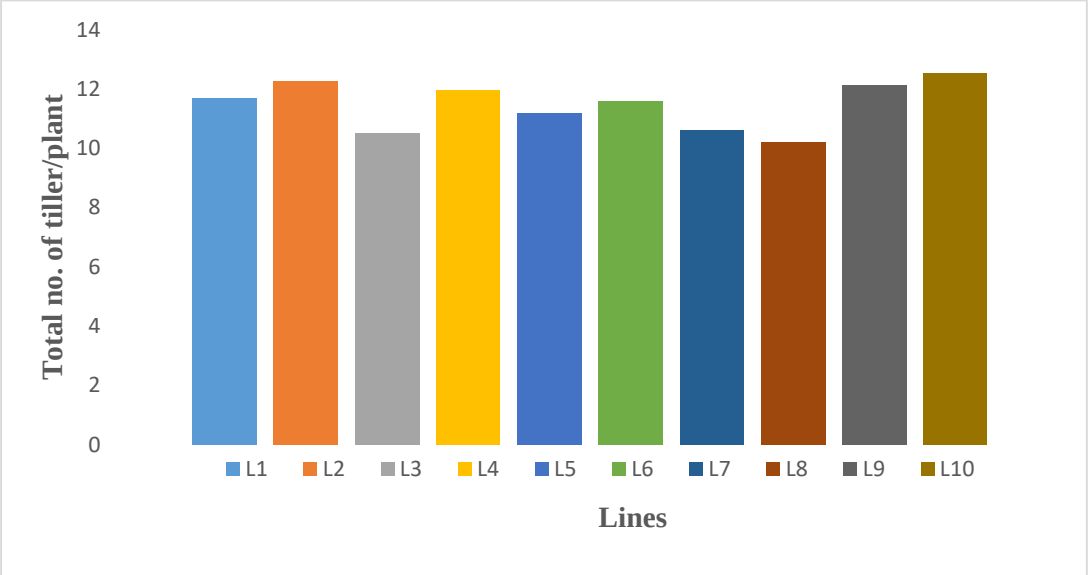


Figure 19. Non-significant variation in total no. of tiller plant^{-1} of the observed lines

Table 43: Maximum, minimum, mean and CV of fifteen parameters of boro rice lines

Parameters	Minimum	Maximum	Mean	CV (%)
PH	88.24	107.1	96.69	4.11
NTP	10.23	12.53	11.48	12.64
ETP	10	12.93	11.15	11.99
PL	21.68	24.32	23.05	4.43
PBP	8.1	10	8.93	7.60
SBP	22.56	29.96	26.15	11.33
SP	131.1	170.83	152.69	9.07
FLP	72.8	160.63	131.64	11.36
UFLP	9.23	58.3	22.62	35.96
TSW	24.02	25.43	24.79	1.87
YP	17.9	34.92	29.45	14.46
SL	63.21	79.31	69.84	5.98
TH	117.33	129.33	121.9	0.98
DM	133	145	137.13	1.53
YH	4.13	8.79	7.32	5.76

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

Table 44. Estimation of genetic parameters of different characters of the rice lines

	σ^2p	σ^2g	$\sigma^2 e$	PCV	GCV	ECV
Plant height (cm)	48.77	32.99	15.76	7.22	5.94	4.10
Total no. of tiller/plant	1.96	0.02	1.94	12.6	1.28	12.61
Number of effective tiller/plant	2.05	0.47	1.58	13.64	6.5	11.98
Panicle length	1.30	0.26	1.04	4.94	2.21	4.42
Number of Primary Branch per panicle	2.41	1.95	0.46	17.38	15.63	7.59
Number of secondary branch per panicle	10.75	1.95	8.77	12.53	5.34	11.32
Spikelet per Panicle	304.02	117.79	186.23	11.58	7.21	9.06
Filled grain of main tiller	853.27	637.67	215.6	22.6	19.53	11.36
Unfilled grain of main tiller	257.51	191.38	66.8	70.94	61.15	35.96
Thousand seed weight (g)	0.295	0.078	0.217	2.18	1.12	1.87
Yield per plant (g)	28.35	15.71	12.64	21.64	16.11	14.45
Stem length (cm)	43.9	26.45	17.45	9.48	7.36	5.98
Days of 50% maturity	15.22	13.42	1.8	4.105	3.005	1.10
Days of 80% maturity	20.92	17.43	3.49	3.75	3.42	1.53
Yield/ha	2.09	1.91	0.18	19.48	18.6	5.71

σ^2p = 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.

with relatively low differences between them which indicating lower environmental influences on this trait (Table 44). Values of PCV and GCV were 12.6 and 1.28, respectively (Table 44). The higher difference between PCV and GCV indicated that the genetic variation was higher among the genotypic variation and environment had much influence on this character expression. Figure 24 showing genotypic, phenotypic and environmental variability of eight F_8 lines of boro rice with their check varieties for total no. of tillers per plant. Figure 19 showing variation in tiller per plant of different lines. Pandey and Anurag (2010) stated that number of tillers plays a significant role in determining yield of the rice grain since it is directly related to panicle number.

4.3.3 No. of effective tillers per plant

Analysis of variance for total no. of tillers per plant exhibited non-significant (3.011) mean sum of square due to lines difference (Appendix III). The highest number of total effective tillers per plant was observed in L10 (12.93) followed by L2 (11.9). The lowest number of total effective tillers per plant was observed in L8 (10) and the mean value was 11.15 (Table 43). Number of total effective tillers per plant showed phenotypic variance (2.05) and genotypic variance (0.47) with relatively low differences between them which indicating lower environmental influences on this trait (Table 44). Values of PCV and GCV were 13.64 and 6.5, respectively (Table 44). The moderate difference between PCV and GCV indicated that the genetic variation was moderate among the genotypic variation and environment had medium influence on this character expression. Figure 24 showing genotypic, phenotypic and environmental variability of eight F_8 lines of boro rice with their check varieties for no. of effective tillers per plant. Hasanuzzaman *et al.* (2008) reported that the number of effective tillers rests on the number of tillers produced and this was directly proportional to the panicles produced per unit area and finally depends on variety.

4.3.4 Panicle length (cm)

Analysis of variance for panicle length (cm) exhibited non-significant mean sum of square (1.82) (Appendix III). The panicle length (cm) was observed highest in L6 (24.32) followed by L2 (23.87). The lowest panicle length (cm) was observed in L1 (21.68) and the mean value for the trait was 23.05 (Table 43). The panicle length (cm) showed phenotypic variance (1.30) and genotypic variance (0.26) with relatively minimal differences between them which indicating much lower genetic influences on this trait (Table 44). Values of PCV and GCV were 4.94 and 2.21, respectively (Table 44). The moderate difference between PCV and GCV indicated that the genetic variation was minimal among the genotypic variation and environment had minimal influence on this character expression. Figure 24 showing genotypic, phenotypic and environmental variability in eight F_8 lines of boro rice with their check varieties for panicle length (cm). Murthy et al. (2014) revealed that there were strong positive correlations of panicle length with number of spikelets per panicle, 100 seeds weight and yield per plant.

4.3.5 Number of primary branches per panicle

Analysis of variance for primary branch per panicle exhibited non-significant mean sum of square (1.11) (Appendix III). Among these observed lines the highest number of primary branches per panicle was taken in case of L6 (10) followed by L8 (9.4). The lowest number of primary branches per panicle was taken in L4 (8.1) which was close to L9 (8.23). The mean value for this trait was 8.93 (Table 43). Phenotypic variance and genotypic variance were calculated as (2.41) and (1.95), respectively (Table 44). 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 (17.38) and GCV (15.63) value suggested that the apparent variation not only due to lines but also due to the influence of environment (Table 44). Figure 24 showing genotypic, phenotypic and environmental variability of eight F_8 lines of boro rice with

their check varieties for number of primary branches per panicle. Figure 20 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.

4.3.6 Number of secondary branches per panicle

Number of secondary branches per panicle exhibited non-significant mean sum of square (14.62) (Appendix III). The highest number of secondary branches per panicle was observed in L2 (29.96) followed by L8 (28.73) .The lowest number of secondary branches per panicle was observed in L6 (22.56) and the mean value for this trait was 26.15 (Table 43). The phenotypic and genotypic variances for this number of secondary branches per panicle were (10.75) and (1.95), respectively (Table 44). 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 (12.53) and (5.34), respectively for number of secondary branches per panicle which denoted that medium variation existed among these lines (Table 44). Figure 21 showing variation in secondary branch per panicle of different lines. Figure 26 showing genotypic, phenotypic and environmental variability of eight F_8 lines of boro rice with their check varieties for number of secondary branches per panicle.

4.3.7 Total number of spikelets per panicle

Total number of spikelet per panicle exhibited highly significant mean sum of square (539.607^{*}) due to lines difference (Appendix III). Like other traits, total number of spikelet per panicle also differed significantly in different rice lines which ranged from 170.83 to 131.1. Maximum total number of spikelets per panicle was 170.83, recorded in L2 followed by L1 (169.86), L8 (161.3) and L7 (160.8) those were significantly better than rest of the F_8 lines. The minimum number of spikelets per panicle was recorded in L6 and it was 131.1 and the mean value for this traits was 152.69 (Table 43). The phenotypic and

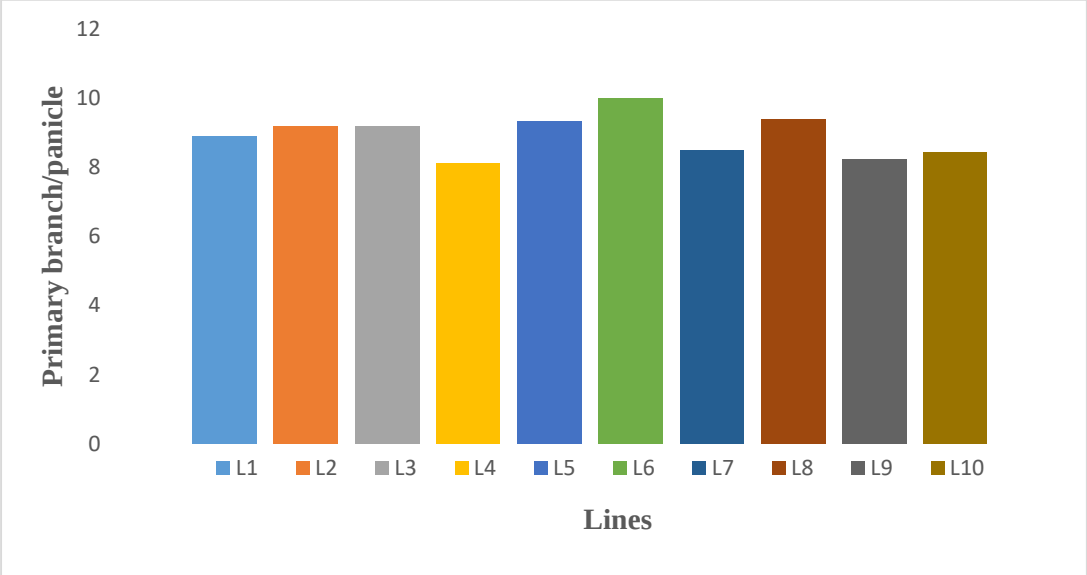


Figure 20. Non-significant variation in primary branch panicle^{-1} of the observed lines

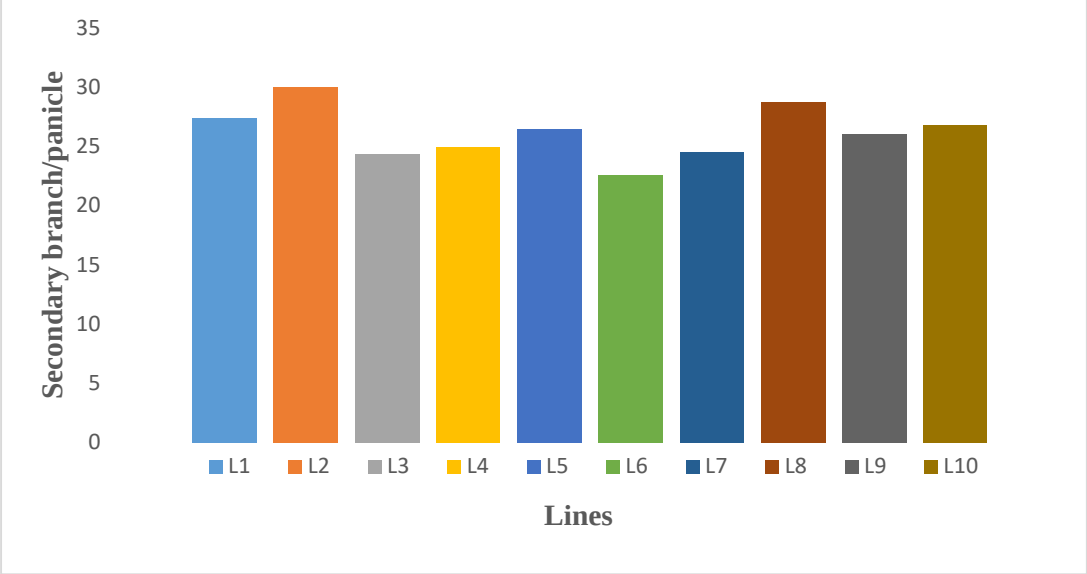


Figure 21. Non-significant variation in secondary branch panilce^{-1} of the observed lines

genotypic variances for the total number of spikelet per panicle were (304.02) and (117.79), respectively (Table 44). 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 (11.58) and (7.21), respectively for number of spikelets per panicle which denoted that medium variation existed among different these lines (Table 44). Figure 25 showing genotypic, phenotypic and environmental variability in eight F_8 lines of boro rice with their check varieties for total number of spikelets per panicle. Figure 22 showing variation in spikelets per panicle of different lines. Singh *et al.* (2013) recorded the similar findings.

4.3.8 Number of filled grains per panicle

Number of filled grains per panicle exhibited highly significant mean sum of square (2128.62^{*}) due to lines difference (Appendix III). The maximum number of filled grains per panicle was found in L1 and it was 160.63 followed by L2 (159.12) and the minimum number of filled grains per panicle was recorded in L6 and that was (72.8). The mean value for this trait was 129.24 (Table 43). The phenotypic and genotypic variances for the number of filled grains per panicle were (853.23) and (637.67), respectively (Table 44). 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 (22.6) and (19.53), respectively for number of filled grains per panicle which denoted that moderate variation existed among the different rice lines (Table 44). Figure 23 showing variation in filled grain per panicle of different lines. Figure 25 showing genotypic, phenotypic and environmental variability in eight F_8 lines of boro rice with their check varieties for number of filled grains per panicle. Akhtar *et al.* (2011) reported that Paddy yield had significant positive correlation with number of grains per panicle and 1000 grain weight.

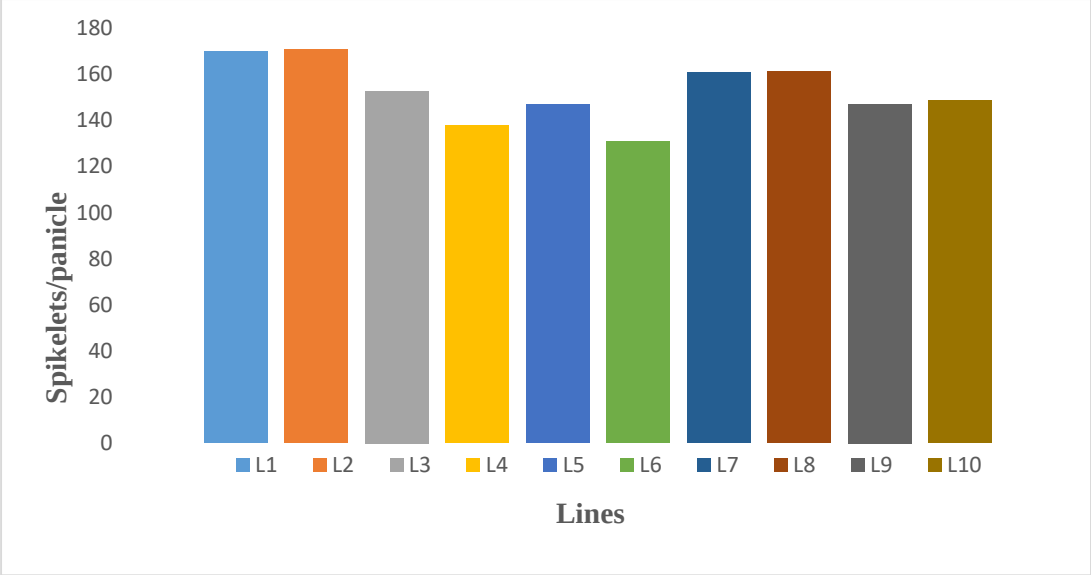


Figure 22. Significant variation in spikelets panicle^{-1} of the observed lines

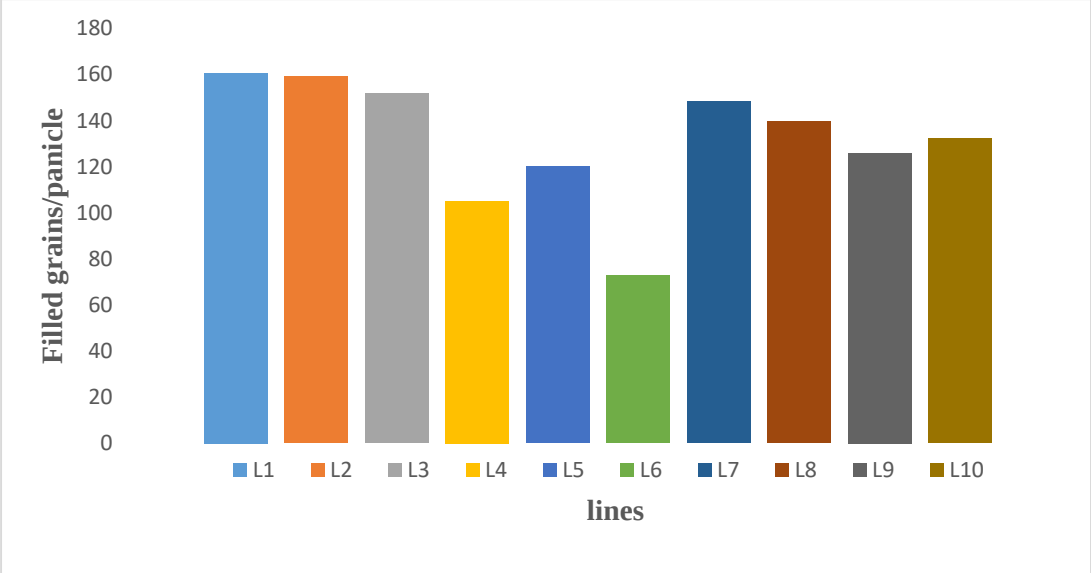
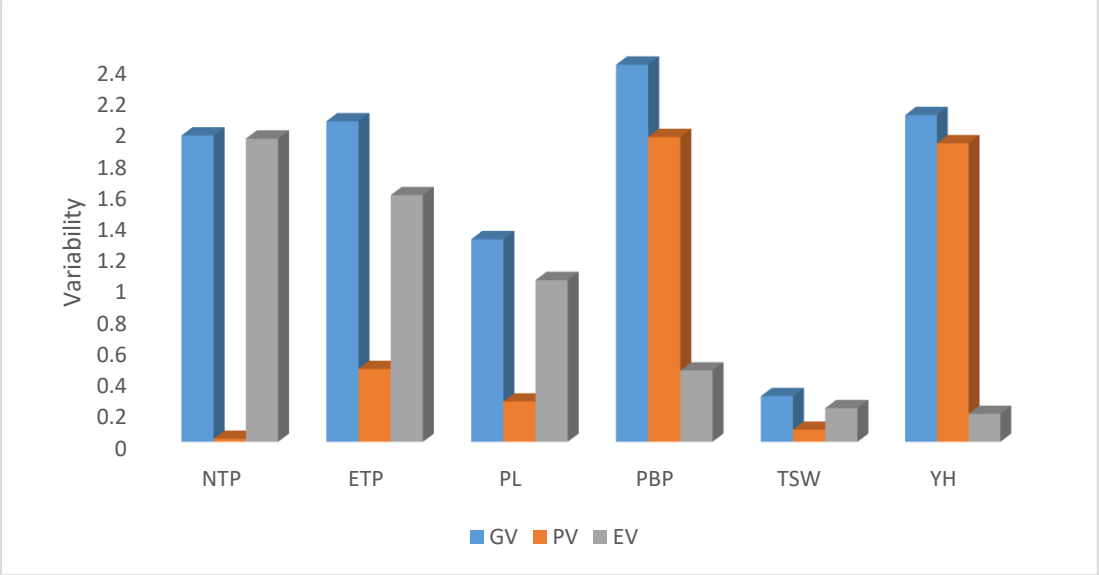
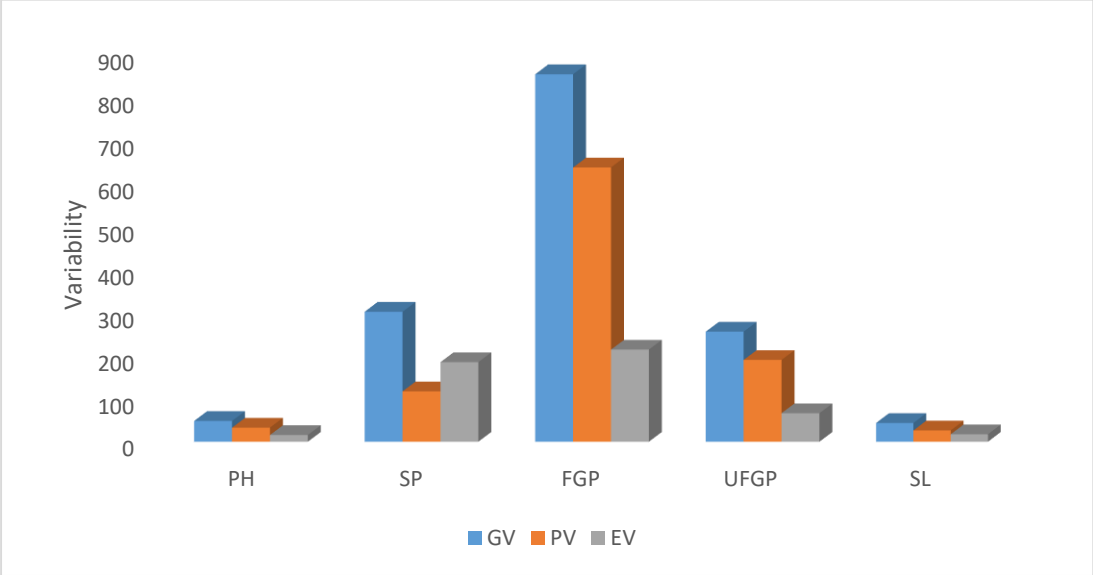


Figure 23. Significant variation in filled grain panicle^{-1} of the observed lines



NTP = no. of tiller/plant, ETP = effective tiller/plant, PL = panicle length, PBP = primary branch/panicle, TSW = thousand seed weight, YH = yield/ha, GV =genotypic variability, PV = phenotypic variability, EV = environmental variability

Figure 24. Genotypic, phenotypic and environmental variability in eight F_8 lines of Boro rice with their check verities



PH = plant height (cm), SP = spikelets/panicle, FLP = filled grain/plant, UFLP = unfilled grain/plant, SL = stem length, GV =genotypic variability, PV = phenotypic variability, EV = environmental variability

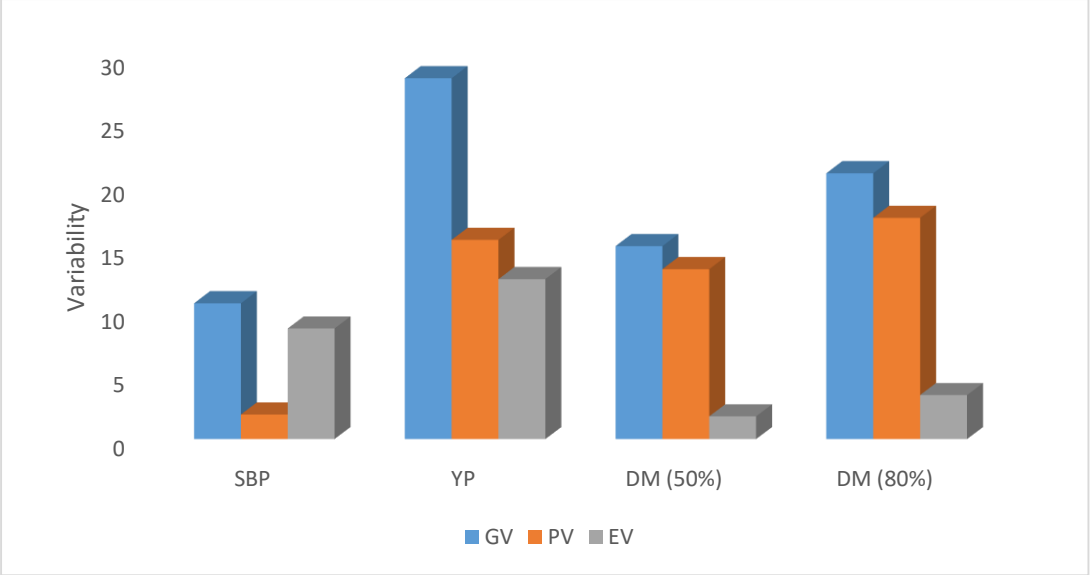
Figure 25. Genotypic, phenotypic and environmental variability in eight F_8 lines of Boro rice with their check varieties

4.3.9 Number of unfilled grains per panicle

Number of filled grains per panicle exhibited highly significant mean sum of square (640.32*) due to lines difference (Appendix III). The maximum number of unfilled grains per panicle was found in L6 and it was 58.3 and the minimum number of unfilled grains per panicle was recorded in L1 (9.23). The mean value of this trait was 22.62 (Table 43). The phenotypic and genotypic variances were (257.51) and (191.38), respectively (Table 44). The phenotypic variance is higher than the genotypic variance indicated that large influence of environment on the expression of the genes controlling this trait (Table 43). The value of PCV and GCV were (70.94) and (61.15), respectively for number of filled grains per panicle which denoted that moderate variation existed among the rice lines (Table 44). Figure 25 showing genotypic, phenotypic and environmental variability of eight F_8 lines of boro rice with their check varieties. Figure 27 showing variation in unfilled grain per panicle of different lines.

4.3.10 1000 seed weight (g)

Thousand seed weight exhibited non-significant (0.453) mean sum of square (Appendix III). The maximum 1000 seed weight (g) was found in L7 and that was 25.43 followed by L3 (25.16), L2 (25.05) and L5 (25.00). The minimum 1000 seed weight (g) was recorded in L8 and that was (24.02). The mean value for this trait was 24.79 (Table 43). Phenotypic variance and genotypic variance were measured as (0.295) and (0.078), respectively (Table 44). The phenotypic variance observed to be slightly higher than the genotypic variance indicating little influence of environment on this trait. Little difference between PCV (2.18) and GCV (1.12) value indicated that the apparent variation due to the influence of environment along with lines (Table 44). Figure 24 showing genotypic, phenotypic and environmental variability in eight F_8 lines of boro rice with their check varieties for 1000 seed weight (g). Aidei and Beighly (2006) reported that cultivation methods didn't have much effect on 1000-grain weight.



SBP = secondary branch/panicle, YP = yield per plant (L), DM = days of maturity, GV =genotypic variability, PV = phenotypic variability, EV = environmental variability

Figure 26. Genotypic, phenotypic and environmental variability in eight F_8 lines of Boro rice with their check varieties

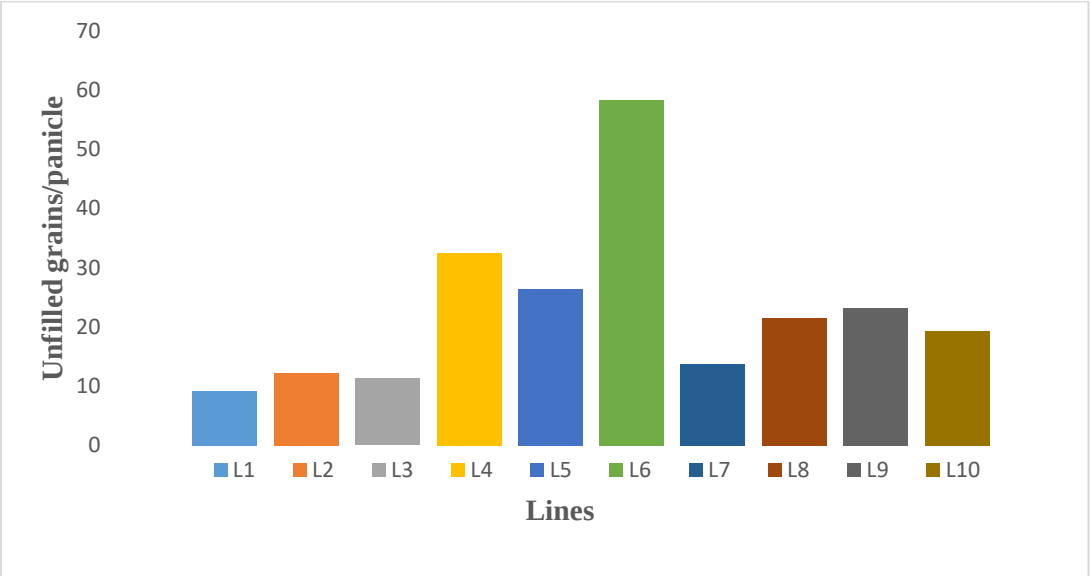


Figure 27. Highly significant variation in unfilled grain panicle^{-1} of the observed lines

4.3.11 Stem length (cm)

Stem length exhibited significant mean sum of square (96.80*) due to lines difference (Appendix III). The highest stem length (cm) was found in L5 and it was 79.31 followed by L6 (79.17). The lowest stem length (cm) was recorded in L9 and that was (63.21) (Table 43). Phenotypic variance and genotypic variance were measured as (43.9) and (26.45), respectively (Table 44). 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 (9.48) and GCV (7.36) value indicated that the apparent variation not only due to lines but also due to the influence of environment (Table 44). So there was a possibility for selection. Figure 25 showing genotypic, phenotypic and environmental variability of eight F_8 lines of boro rice with their check varieties for stem length (cm).

4.3.12 Days of 50% maturity

Days of 50% maturity exhibited highly significant mean sum of square (42.08*) due to different lines (Appendix III). The highest days of 50% maturity was found in L10 and it was 129.33. The lowest days of maturity was recorded in L6 and that was 117.333 (Table 43). Phenotypic variance and genotypic variance were measured as (15.22) and (13.42), respectively (Table 44). 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 (4.10) and GCV (3.05) value indicated that the apparent variation not only due to lines but also due to the influence of environment (Table 44). So there was a possibility for selection. Figure 26 showing genotypic, phenotypic and environmental variability of eight F_8 lines of boro rice with their check varieties for days of 50% maturity. Khush and peng (1996) reported that early maturing varieties were advantageous in areas with short rainfall duration.

4.3.13 Days of 80% maturity

Days of 80% maturity exhibited highly significant mean sum of square (55.78*) due to lines difference (Appendix III). The highest days of maturity was found in L10 and it was 145 followed by L9 (141). The lowest days of maturity was recorded in L6 and that was (133) followed by L2 (133.66). The mean value of this trait was 137.13 (Table 43). Phenotypic variance and genotypic variance were measured as (20.92) and (17.43), respectively (Table 44). 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 (3.75) and GCV (3.42) value indicated that the apparent variation not only due to lines but also due to the influence of environment (Table 44). So there was a possibility for selection. Figure 26 showing genotypic, phenotypic and environmental variability of eight F_8 lines of boro rice with their check varieties for days of 80% maturity. Murthy *et al*. (2014) revealed that there was a significant and positive co relation of grain yield per plant with days of flowering, days of maturity and leaf length.

4.3.14 Yield per plant (g)

Yield per plant exhibited significant mean sum of square (59.78*) due to lines difference (Appendix III). The highest yield per plant (g) was found in L7 and it was 34.92g followed by L2 (33.16g), L3 (32.62g) and L5 (32.4g). The lowest yield per plant (g) was recorded in L6 and that was (17.9g) followed by L4 (21.2g) (Table 43). Phenotypic variance and genotypic variance were measured as (28.35) and (15.71), respectively (Table 44). 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 little difference between PCV (21.64) and GCV (16.11) value indicated that the apparent variation not only due to the lines but also due to the influence of environment (Table 44). So there was a possibility for selection. Figure 26 showing genotypic, phenotypic and environmental variability of eight F_8 lines of boro rice with their check varieties for yield per plant (g). Figure 28 showing

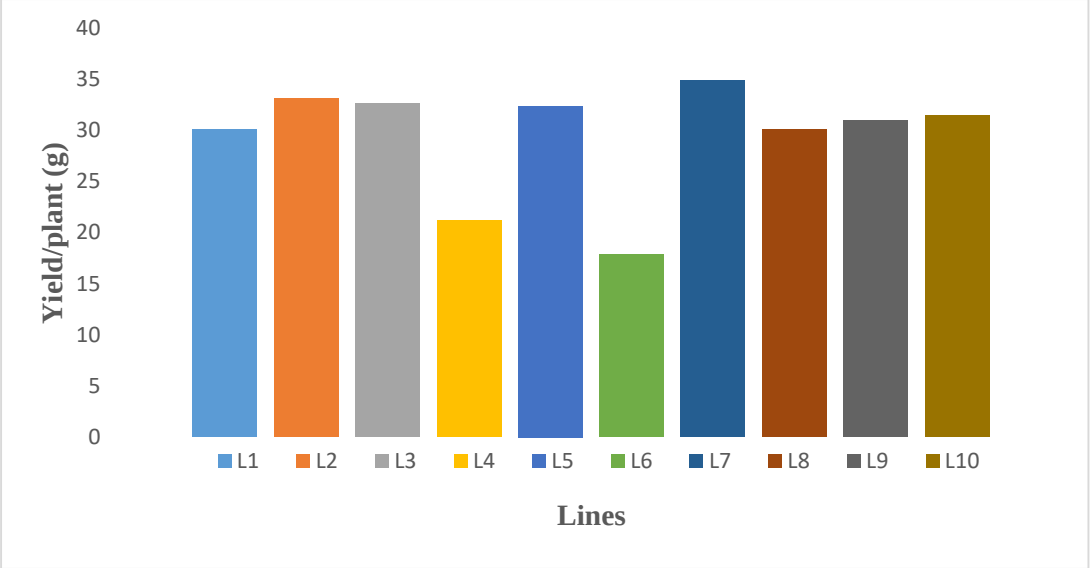


Figure 28. Significant variation in yield plant^{-1} (g) of the observed lines

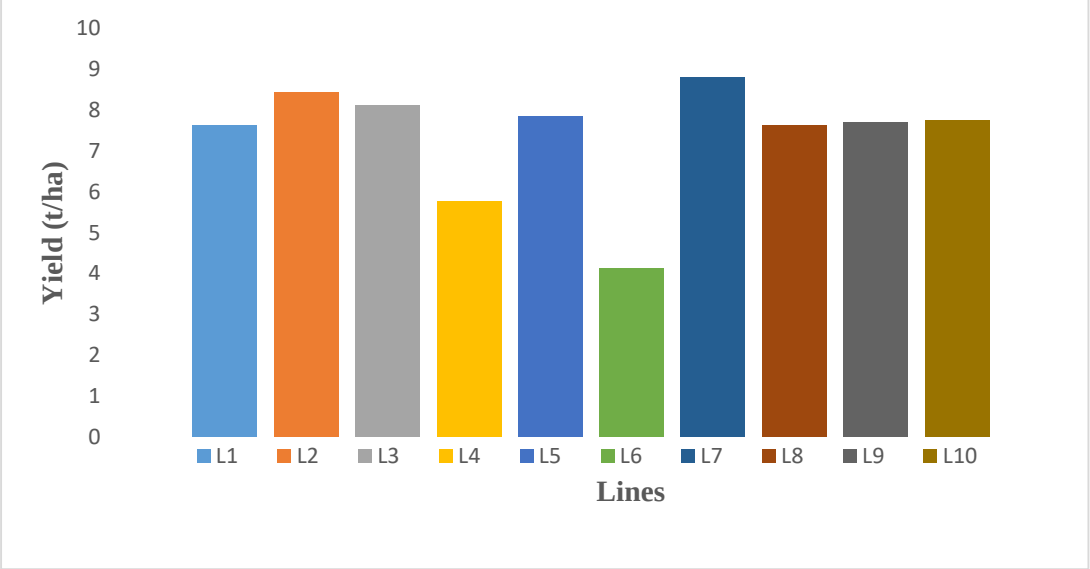


Figure 29. Significant variation in yield (t/ha) of the observed lines

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.

4.3.15 Yield (t/ha)

Yield exhibited significant mean sum of square (5.93*) due to lines difference (Appendix III). The highest yield was found in L7 and it was 8.79 t/ha followed by L2 (8.42 ton/ha), L3 (8.1 ton/ha) and L5 (7.85 t/ha) comparing with the checks L9 (7.69 t/ha) and L10 (7.75 t/ha). The lowest yield was recorded in L6 and that was 4.13 ton/ha followed by L4 (5.77 t/ha) (Table 43). Phenotypic variance and genotypic variance were measured as (2.09) and (1.91), respectively (Table 44). The phenotypic variance observed to be higher than the genotypic variance indicating influence of environment on the expression of the genes controlling this trait. Little difference between PCV (19.48) and GCV (18.6) value indicated that the apparent variation not only due to the lines but also due to the influence of environment (Table 44). So there was a possibility for selection. Figure 29 showing variation in yield/ha of different lines. Figure 24 showing genotypic, phenotypic and environmental variability of eight F_8 lines of 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.

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 eight F_8 lines of boro rice during the period of boro seasons in 2017. The experiment was designed to characterize and to variability study among these lines on the basis of morphological and quality traits. Eight rice lines were evaluated for thirty one qualitative and ten quantitative traits of morphological characters 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 inbred 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 seven qualitative characters *viz*. leaf color, penultimate leaf: pubescence of blade, panicle: curvature of main axis, panicle: exertion, leaf senescence: penultimate leaves are observed at the time of harvest, decorticated grain: shape (L/B ratio) and decorticated unpolished grain: color. No variation was observed in these lines for 24 qualitative characters *viz*. leaf sheath: anthocyanin color, penultimate leaf: anthocyanin color of auricles and collar, penultimate leaf: ligule, penultimate leaf: shape of the ligule, flag leaf: attitude of blade, male sterility, lemma and palea: anthocyanin color, lemma and palea: anthocyanin color below apex, lemma: anthocyanin coloration of apex, spikelet: color of stigma, Stem: anthocyanin coloration of nodes, stem: intensity of anthocyanin color of nodes, stem: anthocyanin coloration of internodes, spikelet: pubescence of lemma and palea, spikelet: color of tip of lemma , Panicle: awns in spikelet, panicle: length of

longest awn, color of awns, panicle: distribution of awns, panicle: attitude of branches, polished grain: size of white core or chalkiness, endosperm: content of amylose, decorticated grain: aroma.

Four quantitative characters *viz*. thousand seed weight, stem: culm length, panicle length: measured from the neck to the tip of the panicle of main tillers without awns and panicle: no. of effective tillers per plant showed no variation for these rice lines. Rest six quantitative characters *viz*. time of heading (50% of plants with heads), stem: culm diameter, time of maturity, grain: length (without dehulling), sterile lemma length: measure at post-harvest stage, and decorticated grain: length (after dehulling, before milling) showed variation among the rice lines.

In case of variability six parameters showed non-significant result *viz*. no. of tillers/plant, no. of effective tillers/plant, Panicle length (cm), primary branches/panicle, secondary branches/panicle and thousand seed weight. Rest nine parameters *viz*. plant height (cm), spikelets/panicle, filled grains/panicle, unfilled grains/panicle, yield/plant (g), stem length (cm), days to maturity (50% and 80%) and yield (t/ha) showed significant variation.

The following characters such as leaf color, panicle: curvature of main axis, panicle: exertion, leaf senescence: penultimate leaves are observed at the time of harvest, decorticated grain: shape (L/B ratio), decorticated unpolished grain: color, plant height (cm), spikelets/panicle, filled grains/plant, unfilled grains/plant, yield/plant (g), stem length (cm), days to maturity (50% and 80%) and yield (t/ha) were the important characters for selection of better rice lines. There were five types of stigma exertion such as no or a few, low, medium, high and very high. Three rice lines (L2, L3 and L7) showed very high type of stigma exertion. In case of panicle: curvature of main axis seven lines L1, L3, L4, L5, L6, L8, L9 and L10 showed medium (slightly drooping) types of curvature of panicle. Panicle length is one of the most important yield contributing character of rice. Panicle length of observed lines ranged from

(L6) 24.32 cm to (L1) 21.68 cm with a mean value of 23.05 cm where all the lines (L1, L2, L3, L4, L5, L6, L7, L8, L9 and L10) showed medium panicle length (21-25 cm). Culm length of observed lines ranged from 79.31 (L5) cm to 64.35 (L7) cm with a mean value of 71.28 cm. All lines (L1, L2, L3, L4, L6, L7, L8, L9 and L10) showed medium (21-25 cm) type of panicle length. In case of days to maturity L1, L3, L5, L9 and L10 lines showed late in maturity (136-150 days) and L2, L4, L6, L7 and L8 showed medium in maturity (116-135 days) with an average of 137.13 days.

In case of variability study total no. of spikelets/panicle showed significant variation. The maximum spikelets/panicle was 170.83 recorded in L2 followed by L1 (169.86). The phenotypic and genotypic variance were 304.02 and 117.79, respectively which showed that large influence of environment on the expression of the genes controlling this traits. The filled grains/panicle was highly significant where L1 showed highest filled grains/panicle and it was 160.63. The phenotypic and genotypic variance were 853.23 and 637.67, respectively which showed that the influence of environment on the expression of the genes controlling this traits. Significant result was obtained in yield/plant (g) in case of variability where highest yield/plant (g) was found in L7 (34.92g) followed by L2 (33.16g), L3 (32.62g) and L5 (32.4g), here the difference between phenotypic and genotypic variance was 12.64 which indicated the influence of environment on this parameter. Yield/plant (g) for the checks were 30.99g (L9) and 31.50g (L10) 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 in yield (t/ha). Here L7 showed maximum result and it was 8.79 t/ha followed by L2 (8.42 t/ha), L3 (8.1 t/ha) and L5 (7.85 t/ha). On the other hand yield (t/ha) for the check varieties were 7.69 t/ha (L9) and 7.75 t/ha (L10). So, among the eight lines L2, L3, L5 and L7 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.

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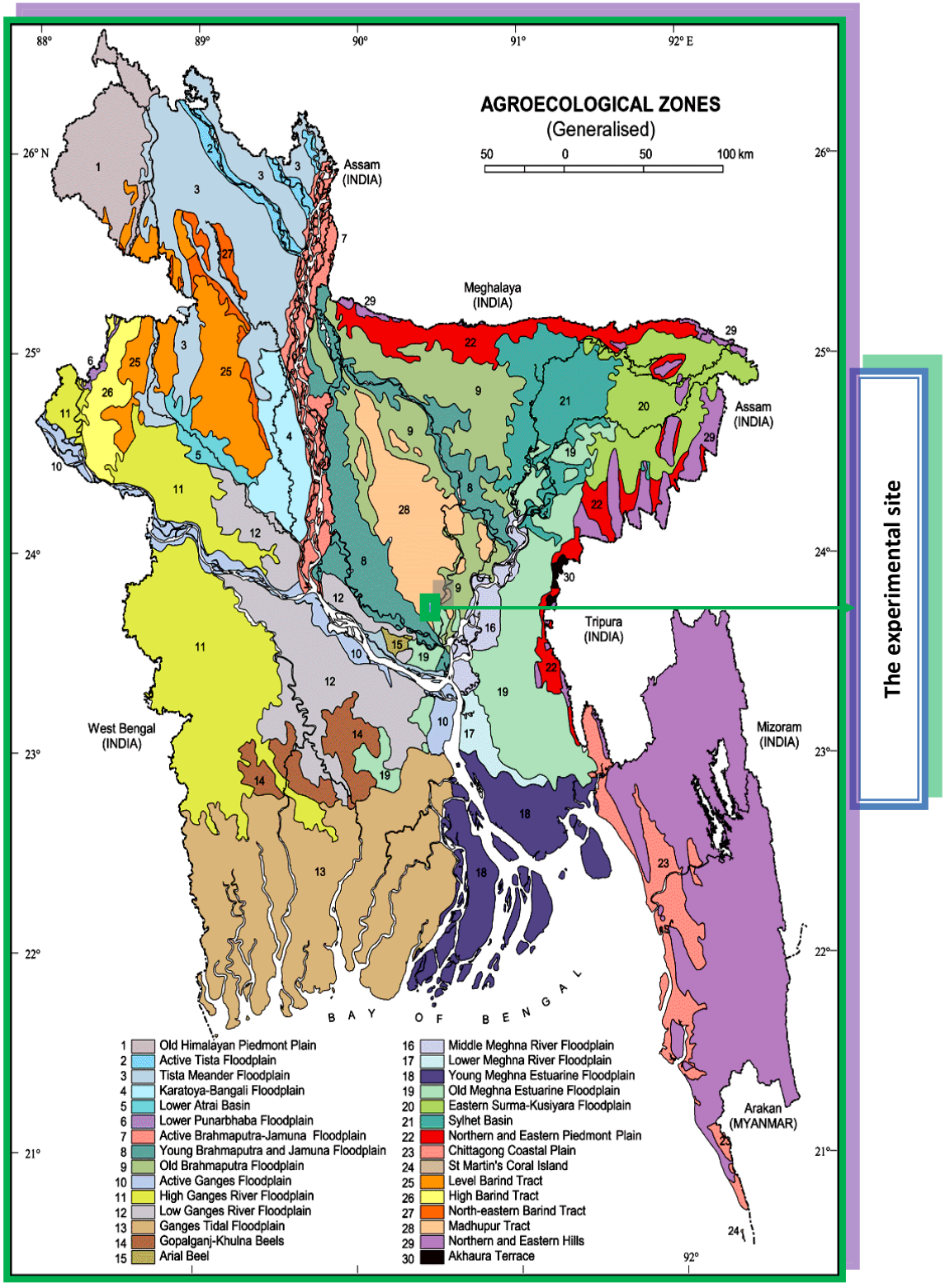
APPENDICES

Appendix I. Map showing the experimental site under study



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

DUS tests data of BRRI dhan 21 X 29 $S_6P_1P_1S_1$ (L1)

Sl. No.	Characteristics	Status	Code
1	Leaf sheath: anthocyanin color	Absent	1
2	Leaf color	Green	2
3	Penultimate leaf: pubescence of blade	Medium hair on the lower portion of the leaf	5
4	Penultimate leaf: anthocyanin color of auricles and collar	Absent	1
5	Penultimate leaf: ligule	Present	9
6	Penultimate leaf: shape of the ligule	Split or two-cleft	3
7	Flag leaf: attitude of blade	Erect (<30)	1
8	Time of heading (50% of plants with heads)	Very late (>120 days)	9
9	Male sterility	Absent	1
10	Lemma and palea: anthocyanin color	Absent or very weak	1
11	Lemma and palea: anthocyanin color below apex	Absent or very weak	1
12	Lemma: anthocyanin coloration of apex	Absent or very weak	1
13	Spikelet: color of stigma	White	1
14	Stem: culm diameter	Medium (5.1-6.0)	3
15	Stem: culm Length	Medium (61-80cm)	5
16	Stem: anthocyanin coloration of nodes	Absent	1
17	Stem: intensity of anthocyanin color of nodes	Absent	0
18	Stem: anthocyanin coloration of internodes	Absent or very weak	1
19	Panicle: length	Medium (21-25cm)	5
20	Panicle: curvature of main axis	Medium	5
21	Panicle: no. of effective tillers in plant	Many (>10)	7
22	Spikelet: pubescence of lemma and palea	Medium	5
23	Spikelet: color of tip of lemma	Yellowish	2
24	Panicle: awns in spikelet	Absent	1
25	Panicle: length of longest awn	Absent	0
26a	Color of awns	Absent	0
26b	Panicle: distribution of awns	Absent	0
27	Panicle: attitude of branches	Semi-erect	3
28	Panicle: exertion	Just exerted	5
29	Time of maturity	Late (136-150 days)	7
30	Grain: wt. of 1000 fully developed grains(at 12% MC)	High (24-27Lm)	7
31	Grain: length (without dehulling)	Long (8.1-9.0 mm)	7
32	Spikelet: sterile lemma length	Medium (1.5-2.5mm)	3
33	Decorticated grain: length (After dehulling, before milling)	Medium (5.6-6.5mm)	3
34	Leaf senescence	Intermediate	5
35	Decorticated grain: shape (L/B ratio)	Bold (L:W>3.0)	9
36	Decorticated unpolished grain: color	White	1
37	Polished grain: size of white core or chalkiness	Absent or very small	1
38	Endosperm: content of amylose	Intermediate (21-25%)	3
39	Decorticated grain: aroma	Absent	1
40	Any other character	Absent	0

DUS tests data of BRRI dhan 21 X 29 $S_6P_1P_1S_2$ (L2)

Sl. No.	Characteristics	Status	Code
1	Leaf sheath: anthocyanin color	Absent	1
2	Leaf color	Green	2
3	Penultimate leaf: pubescence of blade	Medium hairs on the lower portion of the leaf	5
4	Penultimate leaf: anthocyanin color of auricles and collar	Absent	1
5	Penultimate leaf: ligule	Present	9
6	Penultimate leaf: shape of the ligule	Split or two-cleft	3
7	Flag leaf: attitude of blade	Erect (<30)	1
8	Time of heading (50% of plants with heads)	Late (106-120 days)	7
9	Male sterility	Absent	1
10	Lemma and palea: anthocyanin color	Absent or very weak	1
11	Lemma and palea: anthocyanin color below apex	Absent or very weak	1
12	Lemma: anthocyanin coloration of apex	Absent or very weak	1
13	Spikelet: color of stigma	White	1
14	Stem: culm diameter	Large (6.1-7.0)	5
15	Stem: culm Length	Medium (61-80cm)	5
16	Stem: anthocyanin coloration of nodes	Absent	1
17	Stem: intensity of anthocyanin color of nodes	Absent	0
18	Stem: anthocyanin coloration of internodes	Absent or very weak	1
19	Panicle: length	Medium (21-25cm)	5
20	Panicle: curvature of main axis	Strong	7
21	Panicle: no. of effective tillers in plant	Many (>10)	7
22	Spikelet: pubescence of lemma and palea	Medium	5
23	Spikelet: color of tip of lemma	yellowish	2
24	Panicle: awns in spikelet	Absent	1
25	Panicle: length of longest awn	Absent	0
26a	Color of awns	Absent	0
26b	Panicle: distribution of awns	Absent	0
27	Panicle: attitude of branches	Semi-erect	3
28	Panicle: exertion	Just exerted	5
29	Time of maturity	Medium (116-135 days)	5
30	Grain: wt. of 1000 fully developed grains(at 12% MC)	High (24-27Lm)	7
31	Grain: length (without dehulling)	Medium (7.1-8.0 mm)	5
32	Spikelet: sterile lemma length	Medium (1.5-2.5mm)	3
33	Decorticated grain: length (After dehulling, before milling)	Medium (5.6-6.5mm)	3
34	Leaf senescence	Intermediate	5
35	Decorticated grain: shape (L/B ratio)	Bold (L:W=1.5-2.0)	3
36	Decorticated unpolished grain: color	Light brown	2
37	Polished grain: size of white core or chalkiness	Absent or very small	1
38	Endosperm: content of amylose	Intermediate (21-25%)	3
39	Decorticated grain: aroma	Absent	1
40	Any other character	Absent	0

DUS tests data of BRRI dhan 21 X 29 $S_2P_1P_1$ (L3)

Sl. No.	Characteristics	Status	Code
1	Leaf sheath: anthocyanin color	Absent	1
2	Leaf color	Green	2
3	Penultimate leaf: pubescence of blade	Medium hairs on the lower portion of the leaf	5
4	Penultimate leaf: anthocyanin color of auricles and collar	Absent	1
5	Penultimate leaf: ligule	Present	9
6	Penultimate leaf: shape of the ligule	Split or two-cleft	3
7	Flag leaf: attitude of blade	Erect (<30)	1
8	Time of heading (50% of plants with heads)	Late (106-120 days)	7
9	Male sterility	Absent	1
10	Lemma and palea: anthocyanin color	Absent or very weak	1
11	Lemma and palea: anthocyanin color below apex	Absent or very weak	1
12	Lemma: anthocyanin coloration of apex	Absent or very weak	1
13	Spikelet: color of stigma	White	1
14	Stem: culm diameter	Medium (5.1-6.0)	3
15	Stem: culm Length	Medium (61-80cm)	5
16	Stem: anthocyanin coloration of nodes	Absent	1
17	Stem: intensity of anthocyanin color of nodes	Absent	0
18	Stem: anthocyanin coloration of internodes	Absent or very weak	1
19	Panicle: length	Medium (21-25cm)	5
20	Panicle: curvature of main axis	Medium	5
21	Panicle: no. of effective tillers in plant	Many (>10)	7
22	Spikelet: pubescence of lemma and palea	Medium	5
23	Spikelet: color of tip of lemma	Yellowish	2
24	Panicle: awns in spikelet	Absent	1
25	Panicle: length of longest awn	Absent	0
26a	Color of awns	Absent	0
26b	Panicle: distribution of awns	Absent	0
27	Panicle: attitude of branches	Semi-erect	3
28	Panicle: exertion	Just exerted	5
29	Time of maturity	Late (136-150 days)	7
30	Grain: wt. of 1000 fully developed grains(at 12% MC)	High (24-27Lm)	7
31	Grain: length (without dehulling)	Long (8.1-9.0 mm)	7
32	Spikelet: sterile lemma length	Medium (1.5-2.5mm)	3
33	Decorticated grain: length (After dehulling, before milling)	Medium (5.6-6.5mm)	3
34	Leaf senescence	Intermediate	5
35	Decorticated grain: shape (L/B ratio)	Bold (L:W>3.0)	9
36	Decorticated unpolished grain: color	Light brown	2
37	Polished grain: size of white core or chalkiness	Absent or very small	1
38	Endosperm: content of amylose	Intermediate (21-25%)	3
39	Decorticated grain: aroma	Absent	1
40	Any other character	Absent	0

DUS tests data of BRRI dhan 21 X 28 $S_5P_1P_2S_1$ (L4)

Sl. No.	Characteristics	Status	Code
1	Leaf sheath: anthocyanin color	Absent	1
2	Leaf color	Pale green	1
3	Penultimate leaf: pubescence of blade	Medium hair on the lower portion of the leaf	5
4	Penultimate leaf: anthocyanin color of auricles and collar	Absent	1
5	Penultimate leaf: ligule	Present	9
6	Penultimate leaf: shape of the ligule	Split or two-cleft	3
7	Flag leaf: attitude of blade	Erect (<30)	1
8	Time of heading (50% of plants with heads)	late (106-120 days)	7
9	Male sterility	Absent	1
10	Lemma and palea: anthocyanin color	Absent or very weak	1
11	Lemma and palea: anthocyanin color below apex	Absent or very weak	1
12	Lemma: anthocyanin coloration of apex	Absent or very weak	1
13	Spikelet: color of stigma	White	1
14	Stem: culm diameter	Medium (5.1-6.0)	3
15	Stem: culm Length	Medium (61-80cm)	5
16	Stem: anthocyanin coloration of nodes	Absent	1
17	Stem: intensity of anthocyanin color of nodes	Absent	0
18	Stem: anthocyanin coloration of internodes	Absent or very weak	1
19	Panicle: length	Medium (21-25cm)	5
20	Panicle: curvature of main axis	Medium	5
21	Panicle: no. of effective tillers in plant	Many (>10)	7
22	Spikelet: pubescence of lemma and palea	Medium	5
23	Spikelet: color of tip of lemma	Yellowish	2
24	Panicle: awns in spikelet	Absent	1
25	Panicle: length of longest awn	Absent	0
26a	Color of awns	Absent	0
26b	Panicle: distribution of awns	Absent	0
27	Panicle: attitude of branches	Semi-erect	3
28	Panicle: exertion	Just exerted	5
29	Time of maturity	Medium (116-135 days)	5
30	Grain: wt. of 1000 fully developed grains(at 12% MC)	High (24-27Lm)	7
31	Grain: length (without dehulling)	Very long (>9.0 mm)	9
32	Spikelet: sterile lemma length	Long (2.6-3.0mm)	5
33	Decorticated grain: length (After dehulling, before milling)	Medium (5.6-6.5mm)	3
34	Leaf senescence	Intermediate	5
35	Decorticated grain: shape (L/B ratio)	Slender (L:W>3.0)	9
36	Decorticated unpolished grain: color	White	1
37	Polished grain: size of white core or chalkiness	Absent or very small	1
38	Endosperm: content of amylose	Intermediate (21-25%)	3
39	Decorticated grain: aroma	Absent	1
40	Any other character	Absent	0

DUS tests data of BRRI dhan 21 X 28 $S_5P_4P_1S_1$ (L5)

Sl. No.	Characteristics	Status	Code
1	Leaf sheath: anthocyanin color	Absent	1
2	Leaf color	Green	2
3	Penultimate leaf: pubescence of blade	Medium hairs on the lower portion of the leaf	5
4	Penultimate leaf: anthocyanin color of auricles and collar	Absent	1
5	Penultimate leaf: ligule	Present	9
6	Penultimate leaf: shape of the ligule	Split or two-cleft	3
7	Flag leaf: attitude of blade	Erect (<30)	1
8	Time of heading (50% of plants with heads)	Late (106-120 days)	7
9	Male sterility	Absent	1
10	Lemma and palea: anthocyanin color	Absent or very weak	1
11	Lemma and palea: anthocyanin color below apex	Absent or very weak	1
12	Lemma: anthocyanin coloration of apex	Absent or very weak	1
13	Spikelet: color of stigma	White	1
14	Stem: culm diameter	Medium (5.1-6.0)	3
15	Stem: culm Length	Medium (61-80cm)	5
16	Stem: anthocyanin coloration of nodes	Absent	1
17	Stem: intensity of anthocyanin color of nodes	Absent	0
18	Stem: anthocyanin coloration of internodes	Absent or very weak	1
19	Panicle: length	Medium (21-25cm)	5
20	Panicle: curvature of main axis	Medium	5
21	Panicle: no. of effective tillers in plant	Many (>10)	7
22	Spikelet: pubescence of lemma and palea	Medium	5
23	Spikelet: color of tip of lemma	Yellowish	2
24	Panicle: awns in spikelet	Absent	1
25	Panicle: length of longest awn	Absent	0
26a	Color of awns	Absent	0
26b	Panicle: distribution of awns	Absent	0
27	Panicle: attitude of branches	Semi-erect	3
28	Panicle: exertion	Just exerted	5
29	Time of maturity	Late (136-150 days)	7
30	Grain: wt. of 1000 fully developed grains(at 12% MC)	High (24-27Lm)	7
31	Grain: length (without dehulling)	Long (8.1-9.0 mm)	7
32	Spikelet: sterile lemma length	Medium (1.5-2.5mm)	3
33	Decorticated grain: length (After dehulling, before milling)	Medium (5.6-6.5mm)	3
34	Leaf senescence	Intermediate	5
35	Decorticated grain: shape (L/B ratio)	Bold (L:W>3.0)	9
36	Decorticated unpolished grain: color	Light brown	2
37	Polished grain: size of white core or chalkiness	Absent or very small	1
38	Endosperm: content of amylose	Intermediate (21-25%)	3
39	Decorticated grain: aroma	Absent	1
40	Any other character	Absent	0

DUS tests data of BRRI dhan 21 X 28 $S_5P_1P_2S_4$ (L6)

Sl. No.	Characteristics	Status	Code
1	Leaf sheath: anthocyanin color	Absent	1
2	Leaf color	Green	2
3	Penultimate leaf: pubescence of blade	Medium hairs on the lower portion of the leaf	5
4	Penultimate leaf: anthocyanin color of auricles and collar	Absent	1
5	Penultimate leaf: ligule	Present	9
6	Penultimate leaf: shape of the ligule	Split or two-cleft	3
7	Flag leaf: attitude of blade	Erect (<30)	1
8	Time of heading (50% of plants with heads)	Late (106-120 days)	7
9	Male sterility	Absent	1
10	Lemma and palea: anthocyanin color	Absent or very weak	1
11	Lemma and palea: anthocyanin color below apex	Absent or very weak	1
12	Lemma: anthocyanin coloration of apex	Absent or very weak	1
13	Spikelet: color of stigma	White	1
14	Stem: culm diameter	Medium (5.1-6.0)	3
15	Stem: culm Length	Medium (61-80cm)	5
16	Stem: anthocyanin coloration of nodes	Absent	1
17	Stem: intensity of anthocyanin color of nodes	Absent	0
18	Stem: anthocyanin coloration of internodes	Absent or very weak	1
19	Panicle: length	Medium (21-25cm)	5
20	Panicle: curvature of main axis	Medium	5
21	Panicle: no. of effective tillers in plant	Many (>10)	7
22	Spikelet: pubescence of lemma and palea	Medium	5
23	Spikelet: color of tip of lemma	Yellowish	2
24	Panicle: awns in spikelet	Absent	1
25	Panicle: length of longest awn	Absent	0
26a	Color of awns	Absent	0
26b	Panicle: distribution of awns	Absent	0
27	Panicle: attitude of branches	Semi-erect	3
28	Panicle: exertion	Just exerted	5
29	Time of maturity	Medium (116-135 days)	5
30	Grain: wt. of 1000 fully developed grains(at 12% MC)	High (24-27Lm)	7
31	Grain: length (without dehulling)	Long (8.1-9.0 mm)	7
32	Spikelet: sterile lemma length	Long (2.6-3.0 mm)	5
33	Decorticated grain: length (After dehulling, before milling)	Medium (5.6-6.5mm)	3
34	Leaf senescence	Intermediate	5
35	Decorticated grain: shape (L/B ratio)	Slender (L:W>3.0)	9
36	Decorticated unpolished grain: color	Light brown	2
37	Polished grain: size of white core or chalkiness	Absent or very small	1
38	Endosperm: content of amylose	Intermediate (21-25%)	3
39	Decorticated grain: aroma	Absent	1
40	Any other character	Absent	0

DUS tests data of BRRI dhan 26 X 28 $S_1P_9P_4S_1$ (L7)

Sl. No.	Characteristics	Status	Code
1	Leaf sheath: anthocyanin color	Absent	1
2	Leaf color	Green	2
3	Penultimate leaf: pubescence of blade	Weak or only on the margins	3
4	Penultimate leaf: anthocyanin color of auricles and collar	Absent	1
5	Penultimate leaf: ligule	Present	9
6	Penultimate leaf: shape of the ligule	Split or two-cleft	3
7	Flag leaf: attitude of blade	Erect (<30)	1
8	Time of heading (50% of plants with heads)	Late (106-120 days)	7
9	Male sterility	Absent	1
10	Lemma and palea: anthocyanin color	Absent or very weak	1
11	Lemma and palea: anthocyanin color below apex	Absent or very weak	1
12	Lemma: anthocyanin coloration of apex	Absent or very weak	1
13	Spikelet: color of stigma	White	1
14	Stem: culm diameter	Medium (5.1-6.0)	3
15	Stem: culm Length	Medium (61-80cm)	5
16	Stem: anthocyanin coloration of nodes	Absent	1
17	Stem: intensity of anthocyanin color of nodes	Absent	0
18	Stem: anthocyanin coloration of internodes	Absent or very weak	1
19	Panicle: length	Medium (21-25cm)	5
20	Panicle: curvature of main axis	Strong	7
21	Panicle: no. of effective tillers in plant	Many (>10)	7
22	Spikelet: pubescence of lemma and palea	Medium	5
23	Spikelet: color of tip of lemma	yellowish	2
24	Panicle: awns in spikelet	Absent	1
25	Panicle: length of longest awn	Absent	0
26a	Color of awns	Absent	0
26b	Panicle: distribution of awns	Absent	0
27	Panicle: attitude of branches	Semi-erect	3
28	Panicle: exertion	Moderately exerted	7
29	Time of maturity	Medium (116-135 days)	5
30	Grain: wt. of 1000 fully developed grains(at 12% MC)	High (24-27Lm)	7
31	Grain: length (without dehulling)	Very long (>9.0 mm)	9
32	Spikelet: sterile lemma length	Long (2.6-3.0mm)	5
33	Decorticated grain: length (After dehulling, before milling)	Long (6.6-7.5mm)	5
34	Leaf senescence	Intermediate	5
35	Decorticated grain: shape (L/B ratio)	Slender (L:W>3)	9
36	Decorticated unpolished grain: color	Light brown	2
37	Polished grain: size of white core or chalkiness	Absent or very small	1
38	Endosperm: content of amylose	Intermediate (21-25%)	3
39	Decorticated grain: aroma	Absent	1
40	Any other character	Absent	0

DUS tests data of BRRI dhan 24 X 36 $S_8P_1P_1S_1$ (L8)

Sl. No.	Characteristics	Status	Code
1	Leaf sheath: anthocyanin color	Absent	1
2	Leaf color	Green	2
3	Penultimate leaf: pubescence of blade	Medium hairs on the lower portion of the leaf	5
4	Penultimate leaf: anthocyanin color of auricles and collar	Absent	1
5	Penultimate leaf: ligule	Present	9
6	Penultimate leaf: shape of the ligule	Split or two-cleft	3
7	Flag leaf: attitude of blade	Erect (<30)	1
8	Time of heading (50% of plants with heads)	Very late (>120 days)	9
9	Male sterility	Absent	1
10	Lemma and palea: anthocyanin color	Absent or very weak	1
11	Lemma and palea: anthocyanin color below apex	Absent or very weak	1
12	Lemma: anthocyanin coloration of apex	Absent or very weak	1
13	Spikelet: color of stigma	White	1
14	Stem: culm diameter	Medium (5.1-6.0)	3
15	Stem: culm Length	Medium (61-80cm)	5
16	Stem: anthocyanin coloration of nodes	Absent	1
17	Stem: intensity of anthocyanin color of nodes	Absent	0
18	Stem: anthocyanin coloration of internodes	Absent or very weak	1
19	Panicle: length	Medium (21-25cm)	5
20	Panicle: curvature of main axis	Medium	5
21	Panicle: no. of effective tillers in plant	Many (>10)	7
22	Spikelet: pubescence of lemma and palea	Medium	5
23	Spikelet: color of tip of lemma	Yellowish	2
24	Panicle: awns in spikelet	Absent	1
25	Panicle: length of longest awn	Absent	0
26a	Color of awns	Absent	0
26b	Panicle: distribution of awns	Absent	0
27	Panicle: attitude of branches	Semi-erect	3
28	Panicle: exertion	Just exerted	5
29	Time of maturity	Medium (116-135 days)	5
30	Grain: wt. of 1000 fully developed grains(at 12% MC)	High (24-27Lm)	7
31	Grain: length (without dehulling)	Very Long (>9.0 mm)	9
32	Spikelet: sterile lemma length	Long (2.6-3.0 mm)	5
33	Decorticated grain: length (After dehulling, before milling)	Very long (>7.5mm)	7
34	Leaf senescence	Late and slow (2 or more leaves retain green color at maturity)	1
35	Decorticated grain: shape (L/B ratio)	Slender (L:W>3.0)	9
36	Decorticated unpolished grain: color	Light brown	2
37	Polished grain: size of white core or chalkiness	Absent or very small	1
38	Endosperm: content of amylose	Intermediate (21-25%)	3
39	Decorticated grain: aroma	Absent	1
40	Any other character	Absent	0

Appendix III. Analysis of variance of fifteen important characters of rice lines

Source of variation	D.F.	PH	NTP	ETP	PL	PBP	SBP	SP	FLP	UFLP	TSW	YP	SL	DM (50%)	DM (80%)	YH
Replication	2	17.46	0.401	0.528	0.959	0.343	10.43	413.47	272.75	52.58	0.206	16.58	1.67	4.13	0.900	0.040
Lines	7	114.76*	2.011	3.01	1.82	1.11	14.62	539.60*	2128.62*	640.32*	0.453	59.78*	96.80*	42.08*	55.78*	5.93*
Error	14	15.76	1.94	1.58	1.04	0.46	8.77	186.23	215.60	66.18	0.217	12.64	17.45	1.80	3.49	0.183

* Significant at 5% level of significance

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

Appendix IV. Mean performance of various growth parameter and yield components (quantitative character) of eight F_8 boro rice lines with their check varieties

Lines	PH	NTP	ETP	PL	PBP	SBP	SP	FLP	UFLP	TSW	YP	SL	TH	DM	YH
L1	94.27	11.7	11.26	21.68	8.9	27.36	169.86	160.63	9.23	24.16	30.08	67.06	121	138	7.62
L2	94.79	12.26	11.9	23.87	9.2	29.96	170.83	159.16	12.16	25.05	33.16	68.37	119.33	133.66	8.42
L3	96.62	10.53	10.13	22.28	9.2	24.3	152.8	151.9	11.3	25.16	32.62	68.98	121	137	8.1
L4	99.03	11.96	11.6	23.3	8.1	24.9	137.73	105.16	32.53	24.46	21.2	71.7	118.667	134.66	5.77
L5	104.68	11.2	10.96	22.56	9.3	26.4	147	120.23	26.43	25.00	32.4	79.31	127.333	139	7.85
L6	107.1	11.6	10.76	24.32	10	22.56	131.1	72.8	58.3	24.83	17.9	79.17	117.333	133	4.13
L7	88.24	10.63	10.26	22.84	8.5	24.46	160.8	148.27	13.7	25.43	34.92	64.35	118.667	135.66	8.79
L8	100.57	10.23	10	23.05	9.4	28.73	161.3	139.57	21.46	24.02	30.11	71.20	119.333	134.33	7.63
L9	89.88	12.13	11.7	22.97	8.23	26.00	147.1	125.86	23.16	24.90	30.99	63.21	127	141	7.69
L10	91.76	11.53	12.93	23.68	8.43	26.80	148.6	132.17	19.30	24.88	31.50	64.97	129.333	145	7.75

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

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

A. Physical composition of the soil

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

B. Chemical composition of the soil

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

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

Appendix VI. Monthly recorded the average air temperature, rainfall, relative humidity and sunshine of the experimental site during the period from October 1, 2016 to April 2017

Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)	Sunshine (hr.)
	Maximum	Minimum			
October, 2016	32.6	23.8	78	172.3	5.2
November, 2016	29.6	19.2	77	34.4	5.7
December, 2016	26.4	14.1	69	12.8	5.5
January, 2017	25.4	12.7	68	7.7	5.6
February, 2017	28.1	15.5	68	28.9	5.5
March, 2017	32.5	20.4	64	65.8	5.2
April, 2017	33.7	23.6	69	165.3	5.9

Source: Sher-e-Bangla Agricultural University Weather Station