CHARACTERIZATION AND COMPARATIVE ASSESSMENT OF TEN ADVANCED LINES OF AUS RICE (*Oryza sativa*)

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CERTIFICATE

This is to certify that thesis entitled, **"CHARACTERIZATION AND COMPARATIVE ASSESSMENT OF TEN ADVANCED LINES OF AUS RICE (*Oryza sativa*)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN GENETICS AND PLANT BREEDING**, embodies the result of a piece of bona fide research work carried out by **ALIYA ADIBA KHANAM**, Registration No. 12-04977 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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TO

MY BELOVED PARENTS

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CHARACTERIZATION AND COMPERATIVE ASSESSMENT OF TEN ADVANCED LINES OF AUS RICE (*Oryza sativa*)

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ABSTRACT

The present study was conducted at the experimental farm, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka during Aus season, 2017. The experiment was carried out to characterize and compare ten advanced Aus lines (F_8) based on qualitative and quantitative traits. The lines were evaluated in RCBD with three replications. Thirty five qualitative and quantitative traits were used to characterize the advanced lines. Variation was observed in the traits like leaf pubescence, shape of the ligule, attitude of the blade of flag leaf, days to heading, days to maturity, 1000-grain weight, grain length (without dehulling), sterile lemma length, decorticated grain length (after dehulling), decorticated grain shape, culm length, panicle length and no. of effective tiller per plant among the lines. Maximum no. of effective tiller was found in L10 (12.10). Minimum days to heading was found in L1, L2, L3, L4, L5, and L10. Early maturity was found in L1, L2, L3, L4, L5, and L10. 1000 grain wt. was highest in L2, L4, L6, L7, and L8. Six lines (L1, L2, L3, L4, L5, and L10) showed early time of heading, early maturing and medium type of culm length. Five lines (L2, L3, L4, L6, and L10) were observed more effective tiller per plant (more than 10). Two lines (L7, L9) were observed having long panicle (26-30 cm). Highest total no. tiller per plant, no. of effective tiller per plant, yield per plant were observed in the line L10. It was concluded that the lines L10, L5, L3 and L4 can be selected for further study.

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SOME COMMONLY USED ABREVIATIONS

Full word	**Abbreviation**
Percent	%
Degree Celsius	^0C
At the rate	@
Phenotypic variance	$\sigma^2{}_p$
Genotypic variance	$\sigma^2{}_g$
Environmental variance	$\sigma^2{}_e$
Heritability in broad sense	$h^2{}_b$
Agro Ecological Zone	AEZ
Agriculture	Agric.
Agricultural	Agril.
Analysis of variance	ANOVA
Bangladesh Bureau of Statistics	BBS
Bangladesh	BD
Centimeter	Cm
Percentage of coefficient of variation	CV%
Cultivars	cv.
Degrees of freedom	Df
And others	*et al.*
Etcetera	etc.
The sixth generation of a cross between two dissimilar homozygous parents	F_6
Food and Agriculture Organization	FAO
Gram	G
Genotype	G
Genetic advance	GA
Genotypic coefficient of variation	GCV
Harvest Index	HI
Journal	J.
Kilogram	Kg
Meter	M
Distinctness ,Uniformity and Stability	DUS

SOME COMMONLY USED ABREVIATIONS (Continued)

Full word	**Abbreviation**
Mean sum of square	MS
Molecular	Mol.
Biotechnology	Biotechnol.
Science	Sci.
Murate of Potash	MoP
Ministry of Agriculture	MoA
Square meter	m^2
Phenotypic coefficient of variation	PCV
Randomized Complete Block Design	RCBD
Sher-e-Bangla Agricultural University	SAU
Triple Super Phosphate	TSP

CHAPTER I
INTRODUCTION

Rice is a self-pollinated cereal crop belonging to genus *Oryza* of family Poaceae under the order Cyperales and class Monocotyledon having chromosome number 2n = 24 (Hooker, 1979). The genus Oryza has twenty three wild and two cultivated species viz., *Oryza sativa* and *Oryza glaberrima* (Vaughan *et al*., 2003; Linscombe *et al*., 2006). It is a major food crop, ranking second after wheat (the most cultivated cereals in the world) (USDA, 2017). It is the staple food crop of more than half of the world's population. Rice provides 21% energy and 15% of per capita protein of global human (Maclean *et al*., 2002). The world dedicated 162.3 million hectares in 2012 for rice cultivation and the total production were about 738.1 million tons (Anonymous, 2012). By 2030, the world must have to produce 60% more rice than it produce in 1995 to meet the demands (Virmani *et al*., 1997).

The total cultivable area in Bangladesh is about 8.52 M ha and net cultivated area is 7.45 M ha and 0.47 M ha cultivable areas are unplanted. The contribution of agriculture sector in GDP is 19.29 percent. The crop sub-sector dominates with 13.44% from which rice contributes 46%. Almost 47.5% of manpower is directly involved in agriculture. In Bangladesh almost 66% of the labour force depends on agriculture for employment (BBS, 2012). Of all crops, rice plays the leading role by contributing 91% of total food grain production. More than 99% of the people consume rice as their main food @416 gm/person/day. Rice occupies about 76% of total cropped area from where modern varieties cover 84.67% and local varieties cover 15.33%. The present status of area and production of rice is 11.42 million ha and 34.43 million MT (BBS, 2012). The projected population is expected to be 189.85 M by 2030 and it would require 28 million MT of clean rice or 42.50 million MT of paddy (BBS, 2012).

Three major rice crops namely, Aus, Aman and Boro constitute 100% of total rice production and grow in three different seasons. Aus is typically planted in March-

April and harvested in June-July and practically harmonized with the climatic season hot summer (March-May). Aus rice occupies about 8.97% of total cropped area from where modern varieties cover 6.65% and local varieties cover 2.32%. The present status of total area and production of Aus rice is 1.02 million ha and 2.37 million MT (BBS, 2012). The Aus rice area and production is decreasing continuously comparing to Boro, which is dominated rice crop in Bangladesh. Boro rice cultivation fully depends on irrigation and the pressure on ground water is increasing day by day and ground water level is going down but Aus rice requires only 5% supplement irrigation and the pressure on ground water is required to be low for Aus than Boro. (Rahman *et al*, 2016.) It is necessary to transfer Boro cultivated area to Aus and also to assure the food security of the country. So a need worthy aus rice variety should be developed in order to face the ground water crisis. In department of Genetics and plant Breeding, some crosses has been done between Aus and Boro rice to get the early maturity from Aus and high yielding characters from Boro rice. From the progeny of the crosses better lines were selected. Materials of F8 generations are brought under study to select more eligible lines suitable for Aus season.

In order to select a genotype or line, plant characterization is an indispensable tool based on agronomical, morphological, genetic or physiological characters (Ndour,1998). Therefore, in this study, some characterization techniques was used to select the elite lines.

The objectives of this study were to:

1. To characterize of Aus rice lines based on morphology and quality traits.
2. To compare the variation among 10 lines of Aus rice.
3. To select suitable lines for further study and release

CHAPTER II

REVIEW OF LITERATURE

About half of the world's population depends upon rice as food and it accounts for 20% of the global human per capita energy and 15% per capita protein. Besides its importance as food, rice is also the most important crop to millions of small farmers who grow it on millions of hectares and to the many landless workers who obtain income from working on these farms (Maclean *et al.*, 2002).

Characterization is a critical step to be carried out to identify accessions to find genetic relationships among genotypes. A flourishing plant breeding programme heavily relies upon existence of variability in the base population for various traits, and information on genetic control of concerned character is useful for effective execution of any breeding programme. Systematic study and characterization of high quality germplasm is not only important for utilizing the appropriate attribute based donors, but also essential in the present era for protecting the unique rice. The present study has aimed at studying the characterization and genetic variability analysis among characters and yield related characters among the ten Aus rice lines. The morphological characterization of plant is the basic criteria in order to provide fundamental information.

Evaluation of any genetic material collections is essential to ensure the principles of conservation and utilization of germplasm hence characterization of morphological traits of rice is important (Riley *et al.*, 1995). According to Thimmanna *et al.* (2000) the characters such as leaf length and width, pubescence of leaf, leaf angle, ligule shape and colour, panicle type, secondary branching, exertion, awning, seed length and width and 1000 grain weight can be used in differentiating the parental lines of rice cultivar.

The available information relevant to the present study has been reviewed in this chapter.

2.1 Characterization

2.1.1 Characterization on leaf

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.

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.

2.1.2 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.

2.1.3 Characterization on lemma, palea and spikelet

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.

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.

Zanis (2007) 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.

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.

2.1.4 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.

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.

2.1.5 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) 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.

2.1.6 Characterization on panicle

Duan *et al*. (2004) 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 al*. (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.

2.1.7 Characterization on awn

Gross and Zhao (2014), 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.

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.

2.1.8 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.

Ghosh *et al*. (2004) 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.

2.2 Variability and comparison

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) 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.

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.

2.2.1 Plant height (cm)

Yang (1998) observed that plant height is 95-98 cm while 1000- seed weight is 28 g. The rate of seed set was over 90%. Taste and grain appearance is better than Akihikari.

Sathya *et al.* (1999) reported that productive tillers per plant, plant height and harvest index are the principal character, which is responsible for grain yield per plant as they had also positive and significant association with yield.

Wang (2000) reported that plant height was 88-89 cm directly related to yields.

Mrityunjay (2001) concluded that hybrids, in general, gave higher values for plant height at harvest, panicle length and number of filled grains per panicle, performed better compared to the others in terms of yield and yield components.

De *et al.* (2002); experimented that plant height ranged from 80.00 to 132.00 cm, whereas panicle length ranged from 22.00 to 29.00 cm. which is responsible for grain yield per plant.

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and observed that Mukti gave the longest plant compared to the others.

Bhuiyan *et al.* (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of plant growth and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on plant height at maturity.

2.2.2 Number of effective tillers per plant

Mishra *et al.* (1996) concluded that number of tillers per hill and number of grains per panicle exhibited positively high significant correlation with yield.

Padmavathi *et al.* (1996) and Jiang *et al.* (2000) observed the importance of number of tillers/plant which influencing yield.

Nuruzzaman *et al.* (2000) concluded that tiller number varied widely among the varieties and the number of tillers per plant at the maximum tiller number stage ranged between 14.3, 39.5, and 12.2, 34.6.

Nehru *et al.* (2000) suggested that increased yield might be due to increased numbers of tillers and spikelets fertility percentage and test weight.

Nehru *et al.* (2000) observed that the number of productive tillers directly correlated with yield and thus improved yields.

Laza *et al.* (2001) concluded that the early vigor of hybrid rice (*Oryza sativa*) developed in temperate areas has been mainly attributed to its higher tillering rate. However, the tillering rate of hybrids was significantly lower than or equal to that of conventional varieties.

2.2.3 Panicle length (cm)

Wang *et al.* (1991) reported that the length of panicle varied from 26.30 cm to 27.50 cm among the jaixmica hybrids.

Ramalingam *et al.* (1994) observed that varieties with long panicles, a greater number of filled grains and more primary rachis would be suitable for selection because these characters have high positive association with grain yield and are correlated among themselves.

Sawant *et al.* (1995) concluded that panicle length was negatively correlated with flowering time and positively correlated with tiller height.

Oka and Saito (1999) said that there were relationships with parental values for panicle length, grain number/panicle and panicle emergence date. The hybrid MH 2005 gave a yield of 6.09 t/ha compared with 4.36 t/ha from cv. Hitomebore.

Ganesan (2001) conducted that panicle length (0.167) had the highest significant positive direct effect on yield/plant followed by number of tillers/plant (0.688), panicle exertion (0.172), and plant height (0.149).

Guimara (2002) indicate that the plants with cooperatively large panicles tend to have a high number of filled gains. However, most of the cases a positive correlation were observed between number of panicle/plant and panicle length.

2.2.4 Filled grain per panicle

Oka and Saito (1999) experimented that among F1 hybrids from crosses of rice cv. Sasanishiki with other cultivars there were relationships with parental values for grain number/panicle, panicle length, and panicle emergence date.

Mani *et al.* (1997) investigate the extent of genetic variation and interrelationship among them. A wide range of variation was recorded for all the traits. A high estimate of heritability coupled with high genetic advance for number of filled grains/panicle suggested the predominance of additive gene action for this character.

Liu *et al.* (1997) evaluated 24 *indica* x *japonica* hybrids where, filled grain/panicle (FSP) spikelets/panicle (SP), and 1000-grain weight was positively correlated with GWP. Filled grain/panicle (FSP) had the highest effect on GWP.

Mishra *et al.* (1996) concluded that phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) estimates were higher no. of tillers per hill and number of grains per panicle exhibited positively high significant correlation with yield.

Padmavathi *et al.* (1996) concluded that number of filled grains/panicle, plant height 1000-grain weight, dry matter production, spikelets sterility, days to 50% flowering had positive direct effects on grain yield.

Lin (1995) studied the relationship among filled grains/panicle, grain size, yield components and quality of grains. The percentage of filled grains/panicle was the most important factor affecting grain yield.

Mahajan (1993) indicated that filled grains/panicle, grain yield/plant was positively and significantly correlated with straw yield/plant.

Yang and Song (1994) observed that heterosis was highest for number of effective panicles (59.06%) and high for total filled grain number/main panicle (42.44%). Number of effective grains/ panicles was correlated with 100-grain weight and 10-grain length.

Rajesh and Singh (2000) reported that in hybrids, yield was primarily influenced by effective tillers per plant and fertile grains per panicle, whereas in parents it was panicle length, maturity and effective tillers per plant. Number of effective tillers per plant and fertile grains per panicle remained constant and common in explaining heterosis for yield of most of the hybrids.

Mrityunjay (2001) studied the performance of 4 rice hybrids and 4 high yielding rice cultivars and reported that hybrids, in general, gave higher values for number of filled grains per panicle.

Ganesan (2001) conducted that an experiment of 48 rice hybrids. Filled grains/panicle (0.895) had the highest significant positive direct effect on yield/plant followed by number of tillers/plant (0.688, panicle length (0.167) and plant height (0.149).

Liu and Yuan (2002) studied the relationships between high yielding potential and yielding traits. Filled grains per panicle was positively correlated with biomass, harvest index and grain weight per plant.

Chaudhary and Motiramani (2003) filled grain yield per panicle showed significant positive correlation with effective tillers per plant, spikelets density and biological yield per plant.

Parvez *et al.* (2003) reported that yield advantage for the hybrid rice is mainly due the proportion of filled grains per panicle, heavier grain weight (35%) and increased values than the control (28%).

Ismachin and Sobrizal (2006) reported that In hybrids, yield was primarily influenced by effective tillers per plant and fertile grains per panicle, whereas in parents it was panicle length, maturity and effective tillers per plant.

2.2.5 Total grains per panicle

Sarkar *et al.* (2005) studied the number of grains/panicle was negatively associated with number of panicle.

Yuan *et al.* (2005) studied the variation in the yield components of 75 high-quality rice cultivars. Among the yield components, the greatest variation was recorded for number of grains per panicle in *indica* rice, and number of panicles in *japonica* rice.

Ma *et al.* (2001) examined under 20 x 10 cm spacing, producing 142 grains/panicle, and with more than 90% spikelet fertility. The hybrid recorded the highest grain yield 11.4 t/ha..

Oka and Saito (1999) experimented that among F1 hybrids crosses with rice cv. Sasanishiki. Plant height, panicle length and number of grains/panicle were higher in the hybrid than in Sasanishiki, but the 1000-grain weight was lower.

Dhananjaya *et al.* (1998) most variation was observed for productive tillers/plant, number of fertile spikelets and total grain yield/plant. Grain yield was positively correlated with harvest index, panicle density; number of fertile spikelets, 1000-grain weight, number of grains and plant height.

Mishra *et al.* (1996) concluded that phenotypic coefficient of variation and genotypic coefficient of variation estimates were high for grains per panicle. Number of tillers per hill and total number of grains per panicle exhibited positively high significant correlation with yield.

Xiao *et al*. (1996) indicated that heterosis in F_1 hybrids for spikelets/panicle showed a positive and significant correlation with genetic distance in indica × indica but not in indica × japonica crosses.

Lin (1995) studied the relationship among the grain size, yield components and quality, the percentage of filled grains was the most important factor affecting grain yield.

2.2.6 1000-grain weight (g)

Sarkar *et al.* (2005); said that the highest heritability value was registered for 1000-grain weight, followed by brown kernel length and grain length.

Tahir *et al.* (2002) reported highly significant variation among different traits and observe that these traits are under the control of genotypic difference among the genotypes. Other factors like: adapyibility, temperature, soil fertility, transplantation season and time might also be responsible for thousand seed weight.

Ma *et al.* (2001); experimented that ADTRH1 is a rice hybrid. 1000-grain weight is 23.8 g. In different trials, ADTRH1 showed 26.9 and 24.5% higher yield over CORH1 and ASD18.

Iftekharuddaula *et al.* (2001) reported that genotypic correlation co-efficient were higher than the corresponding phenotypic correlation coefficient in most of the traits. Days to flowering, days to maturity, grains per panicle, 1000-grain weight and harvest index showed significant positive correlations with grain yield.

Sathya *et al.* (1999) reported that 1000-grain weight, days to 50% flowering, plant height and harvest index as they had positive and significant association with yield.

Yang (1998) studied that Chao Chan-l hybrid rice was 1000-seed weight is 28 g. which is directly related with yield.

Ashvani *et al.* (1997) stated that 1000 grain weight and total biological yield/plant may be considered for further improvement of rice.

Huang *et al.* (1997) reported negative association of 1000 grain weight and yield per plant in traditional varieties.

Padmavathi *et al.* (1996) concluded that number of tillers/plant, number of panicles/plant, panicle length and 1000-grain weight was positively associated with grain yield.

Marekar and Siddiqui (1996) observed that positive and significant correlations between yield per plot and plant height, length of panicle, days to maturity, 1000-grain weight, length of grain and L/B ratio.

Kim and Rutger (1988) observed positive yield predominantly in 1000- grain weight and no. of spikelets per plant. They also observed high correlation between 1000-grain weight and grain yield.

2.2.7 Grain yield/plant

Geetha *et al.* (1994) studied those six hybrids for grain characters. ADRH4 was the highest yielding (19.7 g/plant).The increased yield in this hybrid was due to a higher number of grains per plant. Correlation analysis revealed that only grains per plant had a strong positive association with grain yield.

Ashvani *et al.* (1997) observed that grain yield/plant showed significant and positive correlation at genotypic and phenotypic levels with number of effective tillers/plant, grain yield/panicle, 1000 grain weight and total biological yield/plant.

Dhananjaya *et al.* (1998) evaluated that grain yield was positively correlated with harvest index, panicle density, number of fertile spikelets, 1000-grain weight, number of productive tillers and plant height.

Thakur *et al.* (1999) stated that high heritability coupled with high genetic advance were estimated for biological yield, panicle-weight, branches per panicle and grains per plant, and indicated the major contribution of additive gene action for expression of these characters.

Pushpa *et al.* (1999) evaluated fifty genotypes of upland rice for 10 quantitative traits. The genotypic coefficient of variation was highest for grain yield/plant and also high for spikelets/panicle and grain yield/panicle.

Oka and Saito (1999) experimented that among F1 hybrids from crosses of rice cv. Sasanishiki. The hybrid MH 2005 gave a yield of 6.09 t/ha compared with 4.36 t/ha from cv. Hitomebore. Plant height, panicle length and number of grains/plant were higher in the hybrid than in Hitomebore, but the 1000-grain weight was lower.

Chaudhary and Motiramani (2003) reported that grain yield per plant showed significant positive correlation with effective tillers per plant, spikelets density and biological yield per plant. Almost all characters exhibited high heritability coupled with high genetic advance, except harvest index.

Bisne and Sarawgi (2008) characterized 32 aromatic rice accessions of Badshah bhog group from IGKV, Raipur, Chhattisgarh germplasm for 22 morphological, six agronomical and eight quality characters. They identified genotypes viz., B: 1340, B: 2039, B: 2495, B: 2816, B: 16930, B: 2354, B: 1639, B: 2094 for quality and agronomical characteristics which may be used in hybridization programme to achieve desired segregants for good grain quality with higher yield.

In addition, based on the study done by Mehla and Kumar (2008) on various morphological characters responsible for identification of rice cultivars, they concluded that there exists wide variation among the rice cultivars in respect to morphological characters viz. awn length, panicle length, leaf blade colour and leaf sheath colour, node base colour, awning, distribution of awns, stigma colour, anthocyanin colouration of stem nodes and internodes, hence, these characters can be used for identification of rice cultivars.

Jing *et al.* (2010) studied the performance of five rice genotypes derived from different germplasm in terms of yield, harvest index (HI) and grain quality at eight agro-ecological sites of the tropics and subtropics across Asia.

Das and Ghosh (2011) characterized thirty one qualitative traits of four hundred thirty one traditional rice cultivars from germplasm collection of Rice Research Station, Chinsurch. Among the qualitative traits considerable variability was recorded for basal leaf sheath colour, awning and auricle colour. Maximum variability was observed for grains per panicle followed by spikelet per panicle.

Mathure *et al.* (2011) characterized 69 genotypes for agronomic traits and found 36 exquisite genotypes out of them that possessed one or more superior traits such as early flowering, dwarf stature, higher number of productive tillers per plant, long panicles, higher number of filled grains per panicle and strong aroma.

Moreover, when Ashfaq *et al.* (2012) associated various morphological traits with yield, there was a strong association revealed between the plant yield and the other yield component traits namely panicle length, number of seeds per panicle, productive tillers per plant and seed weight per panicle. The yield component traits were associated with other traits that also had a great contribution to the improvement of yield. For instance, panicle length was associated with flag leaf area, number of primary branches per panicle, number of spikelets per panicle, number of seeds per panicle and grain weight per panicle were directly or indirectly associated with the plant yield, leading to increased rice yield.

Sarawgi *et al.* (2012); characterized forty six aromatic rice accessions of Dubraj group. These germplasm accessions were evaluated for twenty morphological six agronomical and eight quality characters. The specific accessions D: 1137, D: 812, D: 950, D: 959, D: 925, D: 1008, D: 939, D: 6661 and D: 1090 were identified for quality and agronomical characteristics. These may be used in hybridization programs to achieve desired segregants for good grain quality with higher yield.

Sarawgi *et al.* (2014); on the basis of frequency distribution for eighteen qualitative traits of 408 rice germplasm accessions reported that majority of genotypes possessed green basal leaf sheath colour (87.25 %), green leaf blade colour (89.70 %), pubescent leaf (48.03 %), well panicle exertion (57.10 %), white stigma colour (65.93 %), straw apiculus colour (78.18 %), compact panicle type (55.63 %), awnless (88.48 %), white seed coat (82.84 %), straw hull colour (70.34 %), intermediate threshability (47.30 %), erect flag leaf angle (57.59 %), medium leaf senescence (67.15 %) and straw sterile lemma (97.05 %).

Singh *et al.* (2014); evaluated forty eight upland rice germplasm accessions and characterized for fourteen quantitative and fifteen qualitative traits. The accessions PKSLGR-16, PKSLGR-23, PKSLGR-43 and PKSLGR-45 were found to be most promising for yield and two to four of its component traits.

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

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

2.2.8 Quality characterization

Rice grain quality is an important criterion in most rice breeding programs because it exerts large effects on market value and consumer acceptance. According to Traore (2005), rice grain quality is considered second most important problem following yield. However, in several cases, even varieties with high yield are rejected by consumers because of their poor appearance, cooking and eating qualities. As such development of cultivars with good grain qualities is an important objective to emphasize in rice improvement programmes (Lapitan *et al.*, 2007).

Grain appearance and culinary grain quality (milling, cooking and eating qualities) are the major criteria considered in evaluation of grain quality in a breeding programme.

Chaudhary *et al.* (2004); studied 17 quality and plant traits viz., kernel length, kernel length: breadth ratio, kernel length after cooking, length: breadth ratio of cooked rice, elongation ratio, elongation index, alkali spreading value, head rice recovery, milling percentage of 54 aromatic rice accessions.

Singh and Singh (2007), analyzed for various cooking and physical qualities. The cultivars varied considerably with regard to quality parameters. The hulling varied from 68.9 to 82.9%, milling from 56.1 to 74.2%, head rice recovery from 19.7 to 49.4%, kernel length (KL, uncooked) from 5.1 to 7.1 mm, kernel breadth (KB, uncooked) from 1.7 to 2.4 mm, KL/KB ratio from 2.31 to 3.94, KL (cooked) from 9.5 to 12.7 mm, KB (cooked) from 2.5 to 3.6 mm, kernel elongation ratio from 1.39 to 1.98, alkali score from 2.6 to 6.6, volume expansion from 2.78 to 3.12, water uptake number from 390 to 500, amylose content from 15.15 to 41.62, gel consistency from 30 to 100, and aroma absent to strong.

Singh *et al*. (2011); studied thirty eight rice germplasm accessions out of which HUBR 40 and Adamchini had good grain quality and cooking properties, indicating their potential for consumer preferences.

Grain appearance consists of size and shape of the kernel, translucency and chalkiness of endosperm. Size and shape is a stable varietal property that can be used to identify a variety and are among the first criteria of rice quality that breeders consider in developing new varieties (Traore *et al.*, 2011). Rice varieties with little or no chalkiness in their endosperm are more preferred by consumers, because percentage grain chalkiness is closely related to milling quality. Chalky grains have a lower density of starch granules and are therefore more prone to breakage during milling, hence end up with poor quality rice and low milling recovery (Hai-mei *et al*., 2011). When the rice grains are more broken, consumers do not prefer them and they fetch low market prices. Grain appearance is therefore essential as it attracts the attention of the consumer, and although it has no effect on cooking and eating quality, it is the first basis on which a consumer accepts or rejects a variety.

The aim of milling rice is to remove the husk, the bran layers and the germ with minimum breakage to the grain hence to produce an edible, white rice kernel that is sufficiently milled and free of impurities (IRRI, 2009a). It is also one of the most important criteria of rice quality and a crucial step in post-production of rice. The degree of milling is another quality characteristic of rice and it is defined as a measure of the percentage bran removed from the brown rice kernel. Apart from the amount of white rice recovered, it influences the color and the cooking behavior of rice (IRRI, 2009b). The accurate measurement of the amounts and classes of broken grains is very important to consumers and breeders (Mutters, 2003).

Bhonsle and Sellappan (2010), evaluated the grain quality of traditionally cultivated rice varieties of Goa and concluded that some of the traditional rice varieties were with high grain quality characteristics, which could be used in rice breeding programmes and biotechnological research for further improvement of rice.

Subudhi *et al.* (2012); evaluated forty one rice varieties of different ecologies to find out those with better grain quality characters and yield, for use in varietal development programme and were further popularized among farmers.

Moreover, a study was conducted by Kanchana *et al.* (2012) to know the physical qualities of 41 rice varieties and seven varieties were found to be the best according to the length, breadth, bulk density and 1000 grains weight.

Bhonsle and Sellappan (2012), studied on the physiochemical characteristics such as hulling, head rice recovery, broken rice, grain classification, chalkiness, alkali spreading value, amylose content, gel consistency, aroma and cooking characteristics such as volume expansion, elongation ratio, water uptake were studied for 22 traditionally cultivated rice varieties from Goa, in comparison with high yielding rice varieties Jaya, Jyoti and IR8.

Parikh *et al.* (2012); evaluated 36 rice genotype, out of which Rajim-12 and Rajabhog were found superior genotype for grain yield, kernel length, L: B ratio and kernel length after working and Bikoni were found superior for head rice recovery, elongation ratio, elongation index and intermediate alkali values.

CHAPTER III

MATERIALS AND METHODS

The present investigation “Characterization and comparative assessment of ten advanced lines of Aus rice (*Oryza sativa*)” was carried out during the Aus season 2017. The techniques followed and materials used during the course of investigation are presented below:

3.1 Experimental Site

The experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University, Dhaka-1207, during April to August 2017. The location of the site was situated at 23°41’ N latitude and 90°22’ E longitude with an elevation of 8.6 meter from the sea level.

3.2 Climate and Soil

The experimental site was 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 and olive gray with common fine to medium distinct dark yellowish brown mottles. The 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 Experimental materials

The healthy seeds of ten advanced lines of Aus rice collected from the Dept. of Genetics and Plant Breeding, Sher-E-Bnalga Agricultural University, Dhaka which were used as experimental materials. The materials used in that experiment is shown in Table 1.

Table 1. Pedigree of advanced lines used in the experiment

Lines	Pedigree	Source
L1	21 x 29 $S_6P_1P_1S_2$	Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University
L2	21 x 29 $S_6P_6P_4S_1$	
L3	21 x 29 $S_6P_1P_1S_1$	
L4	21 x 29 $S_6P_2P_4S_2$	
L5	21 x 29 $S_6P_1S_3$	
L6	21 x 28 $S_5P_4P_2$	
L7	21 x 28 $S_5P_1P_2S_2$	
L8	21 x 28 $S_5P_1P_2S_3$	
L9	21 x 28 $S_5P_7P_6S_1$	
L10	21 x 29 $S_6P_2P_4S_2$	

3.4 Design and Layout

The experiment was laid out in Randomized Complete Block Design (RCBD). The field was divided into three blocks; each block was sub-divided into 10 plots where lines were randomly assigned in total 30 plots. The experimental field size was 26 m x 29 m = 754 m^2 where 1m boarder was maintained surrounding the field in every block. The unit plot size was 6 m x 2 m. Ten advanced lines were distributed randomly in the plot in each block.

3.5 Germination of Seed

Seeds of all collected rice lines were soaked separately for 24 hours in cloth bags on 5 April 2017. Soaked seeds were picked out from water and wrapped with straw and gunny bag to increase the temperature for facilitating germination (Plate 1). Seeds were sprouted properly after 72 hours.

3.6 Seedbed Preparation and Seedling Raising

The seed bed was prepared by puddling the wetland with repeated ploughing followied by laddering. Germinated seeds were sown on 11 April 2017 in the seed bed separately and proper tags were maintained (Plate 2). Beds were protected from birds and other pest.

3.7 Preparation of Main Field

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

Plate 1: Germination of experimetal rice seeds

Plate 2: Preparation of seedbed and raising seedling of rice

3.8 Application of Fertilizers

The fertilizers N, P, K were applied in the form of urea, TSP and MP, respectively. The entire amount of cow dung, TSP and MP were applied during final preparation of field. The dose and method of application of fertilizer are sown in Table 2. The entire cow dung, TSP and half of MoP were applied at the time of final land preparation on 3 May 2017. The total urea and remaining MoP were applied in three installments, at 15 days after transplanting (DAT), 30 DAT and 45 DAT recommended by BRRI ,(2014).

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

Fertilizers	**Dose (per ha)**	**Application (%)**			
		Basal	**1st installment**	**2nd installment**	**3rd installment**
Cow dung	6 ton	100	--	--	--
Urea	135 Kg	--	33.33	33.33	33.33
TSP	55 Kg	100	--	--	--
MP	85 Kg	50	16.67	16.67	16.67

3.9 Transplanting of Seedling

Healthy seedlings of 25 days old were transplanted on 5 May 2017 in separate strip of experimental field. Water level was maintained properly after transplanting. The distance between row to row was 20 cm and plant to plant was 10 cm. (Plate 3)

3.10 Intercultural Operation

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

Plate 3: Transplanting of rice seedling

3.10.1 Gap filling

Necessary gap filling was done within seven days of transplanting on 12 May 2017.

3.10.2 Irrigation and drainage

Flood irrigation was given to maintain a constant level of standing water up to 2 cm in the early stages to enhance tillering, proper growth and development of the seedlings and 10-12 cm in the later stage to discourage late tillering. The field was finally dried out 15 days before harvesting.

3.10.3 Weeding

The crop was kept weed free throughout the growth period. The newly emerged weeds were uprooted carefully at tillering stage and at panicle initiation stage by mechanical means. Hand weeding was done at 25 and 40 days after transplanting. 1st weeding and mulching was done on 15 May 2017.

3.10.4 Tagging

The tagging was placed in every plot on 13 May 2017.

3.10.5 Plant protection

Proper control measures were taken against rice stem borer during tillering and heading stage of rice. Diazinon 50EC was applied for controlling stem borer on 14 June 2017. Furadan 5G @ l kg per bigha was applied at active tillering stage and panicle initiation stage of rice for controlling rice yellow stem borer on 22 June 2017. Cupravit 80 WP @ 2.5 g per liter water was applied against bacterial leaf blight of rice.

3.10.6 Harvesting, Threshing and Cleaning

The rice are harvested manually according to their maturity. Harvested crop from each crop are bundled separately and tagged were properly maintained.

3.11 Method of Recording of Observations

To study the stable diagnostic characteristics data on the morphological and quality characters were collected from ten randomly selected hills from each replicated plots. Yield and yield contribution traits were also measured for comparative analysis. The plants were selected from middle to avoid border effect and portion of the plot. Thirty five qualitative traits were observed based on BIOVERSITY INTERNATIONAL, IRRI and WARDA-2007 guidelines presented in Table 3. Fourteen quantitative traits were estimated. The observations for characterization were recorded under field condition as follows.

3.11.1 Qualitative Traits Evaluation Methods

The experimental plots were visited frequently and required data were collected as per schedule. An appropriate data record book was used for keeping records of data related to identification of the genotypes. According to Rice Descriptors data collection and recording was used. The photographs of specific trait considered to be helpful for identification of the genotypes were taken from the experimental field at appropriate times for different traits to compare the distinctness among the Aus rice genotypes. Photographs and data related to distinctness in morphological traits were taken on each of the ten Aus rice genotypes. This was done particularly to find out the expression of the qualitative traits of the genotypes irrespective of ecotypes when grown under constant environment.

3.11.1.1 Leaf sheath anthocyanin color

Data was collected at early vegetative stage on leaf sheath anthocyanin color at early boot stage by visual assessment in a group of plant. The rice lines were classified into two groups with codes according to guided descriptors as per follows (Table 3). Absent-1 and Present-9.

3.11.1.2 Leaf color

Observations with respect to leaf coloration 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). The seven groups are Pale green-1, Green-2, Dark green-3, Purple tip-4, Purple margins-5, Purple blotch-6 and Purple-7.

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

3.11.1.3 Penultimate leaf pubescence

The leaf blade pubescence was recorded at late vegetative stage by visual assessment of individual plants. The observed lines were categorized in five groups as per descriptors by following way (Table 3) like 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

3.11.1.4 Penultimate leaf anthocynin coloration of auricles & collar

The anthocyanin colouration of auricle i.e. absent and present in auricles was recorded at late vegetative stage with visual assessment by observation of individual plant. 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 and 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 and very strong-9
4	Penultimate leaf anthocynin coloration of auricles & collar	absent-1, present-9
5	Penultimate leaf: ligule	absent-1, present-9
6	Penultimate leaf: Shape of the ligule	Truncate-1, Acute-2 and 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	Time of heading	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
9 (a)	Male sterility	Absent-1, CMS-3, TGMS-5, PGMS-7 and (T)GMS-9
9 (b)	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%)- 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 and Very strong-9
11	Lemma: anthocyanin coloration of area below apex	Absent or very weak-1, Weak-3, Medium-5, Strong-7 and Very strong-9.
12	Lemma: anthocyanin coloration of apex	Absent or very weak-1, Weak-3, Medium-5, Strong-7 and Very strong-9.
13(a)	Color of stigma	White -1, Light green-2, Yellow-3, Light purple-4 and Purple-5
13(b)	Stigma exertion	No or few (<5%)-1, Low (5-20%)-3, Medium (21-40%)-5, High (41-60%)-7, Very high (>61%)-9
14	Stem: culm diameter	Small (<5.0 mm)-1, Medium (5.1-6.0 mm)-3, Large (6.1-7.0 mm)-5, Very large (>7.0 mm)
15	Stem:Anthocyanin coloration nodes	Absent-1, Present-9

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

Table 3. Descriptors with codes for qualitative characteristics (Continued.)

Sl N	Characteristics	Descriptors with Codes
16	Stem: Anthocyanin coloration of internodes	Absent or very weak-1, Weak-3, Medium-5, Strong-7 and Very strong-9.
17	Panicle: curvature of main Axis	Absent or very weak-1, Weak-3, Medium-5 Strong-7
18	Spikelet: pubescence of lemma & palea	Absent or very weak-1, Weak-3, Medium-5, Strong-7
19	Spikelet: color of the tip of Lemma	White-1, Yellowish-2, Brownish-3, Red-4, Purple-5, Black-6
20	Spikelet: awn in the spikelet	Absent-1, Present-9
21	Panicle: attitude of branches	Erect-1, Semi erect-3, Spreading-5
22	Panicle: exertion	Enclosed-1, Partly enclosed-3, Just exerted-5, Moderately exerted-7, Well exerted-9
23	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
24	Grain: length (without dehulling) (mm)	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, Very long (>9.0 mm)-9
25	Sterile lemma length	Short (<1.5 mm)-1, Medium (1.5-2.5 mm)-3, Long (2.6-3 mm)-5, Very long (>3.0 mm)-7
26	Decorticated grain length (after dehulling)	Short (<5.5 mm)-1, Medium (5.6-6.5 mm)-3, Long (6.6-7.5 mm)-5, Very long (>7.5 mm)-7
27	Leaf senescence	Late and slow-1, Intermediate-5, Early and fast-9
28	Decorticated grain shape	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, 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, Large (>20%)-7
31	Decorticated grain: aroma	Absent-1, Lightly present-5, Strongly present-9

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

3.11.1.5 Penultimate leaf: ligule

Presence or absence of papery membrane at the inside juncture between the leaf sheath and blade called ligule was recorded at early boot stage by observation of individual plant or parts of plant. The rice lines were classified into two groups with codes according to guided descriptors as per follows (Table 3).

Absent-1 and Present-9.

3.11.1.6 Penultimate leaf: Shape of the ligule

Shape of the penultimate leaf ligule was observed and the lines were categorized according to guided descriptor **(**Table 3) which is also shown hypothetically in figure 2.

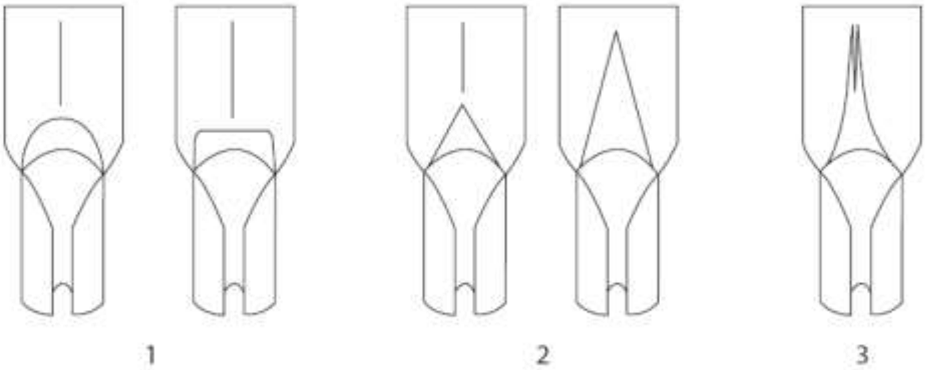

Figure 2. Ligule Shape (1-truncate, 2-acute and 3- Split or two cleft)

3.11.1.7 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. The flag leaf attitude was recorded at beginning of anthesis through visual assessment and categorized into following four groups according to guided descriptors as per follows (Table 3). Figure 3 showing the flag leaf attitude.

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.

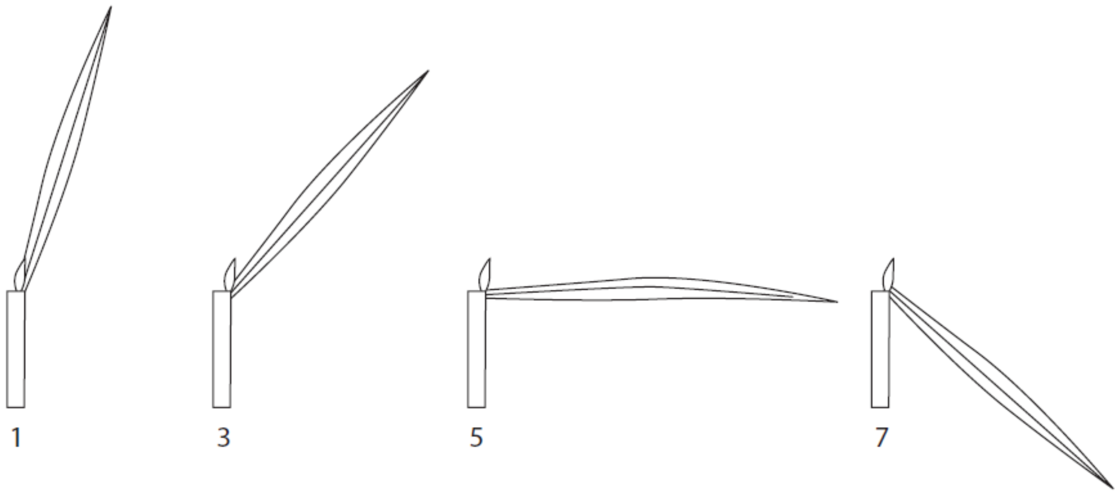

Figure 3. Flag Leaf Attitude (1-errect, 3-semi erect, 5- horizontal and 7- descending)

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

Days to heading was observed at beginning of anthesis through visual assessment and categorized into following five groups according to guided descriptors as per follows (Table 3).

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

3.11.1.9 (a) Male sterility

Presence or absence of male sterility was observed visually. 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.

3.11.1.9 (b) Microscopic observation of pollen with I_2-KI solution

Microscopic observation of pollen was observed at anthesis period of rice using I_2-KI solution and the rice lines were categorized 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

Fully fertile (0-20%)-8

3.11.1.10 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.

3.11.1.11 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.

3.11.1.12 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.

3.11.1.13a. Color of stigma

The colour of stigma i.e. the female reproductive part of the rice plant was recorded. Stigma colour is determined from blooming spikelets (between 9 am to 2pm). 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

3.11.1.13b. Stigma exertion

The stigma exertion i.e. the female reproductive part of the rice plant was recorded. Stigma exertion is determined at anthesis with 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.

3.11.1.14 Stem: culm diameter

Culm diameter of the rice plant was recorded during flowering or late reproductive stage. It was categorized into four groups (Table 3) i.e. 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).

3.11.1.15 Stem: Anthocyanin coloration of nodes

The presence or absence of anthocyanin colouration of nodes was recorded at milk filling stage through visual assessment of individual plants nodes. The rice lines were classified into two groups with codes according to guided descriptors as per follows (Table 3).

Absent-1 and
Present-9.

3.11.1.16 Stem: Anthocyanin coloration of internodes

The presence or absence of anthocyanin colouration on internodes was recorded at milk development stage through visual assessment of each landrace. 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.

3.11.1.17 Panicle: curvature of main axis

The curvature of main axis of panicle was recorded at ripening stage and grouped into absent, weak, medium, strong classes through visual assessment by observation of a group of plants.

3.11.1.18 Spikelet: pubescence of lemma & palea

The pubescence of lemma & palea was recorded at beginning of anthesis to dough development stage through visual assessment and grouped in to absent, medium and strong categories by visual observation of individual plants.

3.11.1.19 Spikelet: color of the tip of lemma

The colour of tip of lemma was recorded visually as white, yellowish, brown, red, purple and black.

3.11.1.20 Spikelet: awn in the spikelet

The awn in the spikelet was recorded at ripening stage through visual assessment by observation of individual plants and grouped into presence of awns and absent. Figure 5 represented the rice grain with awn.

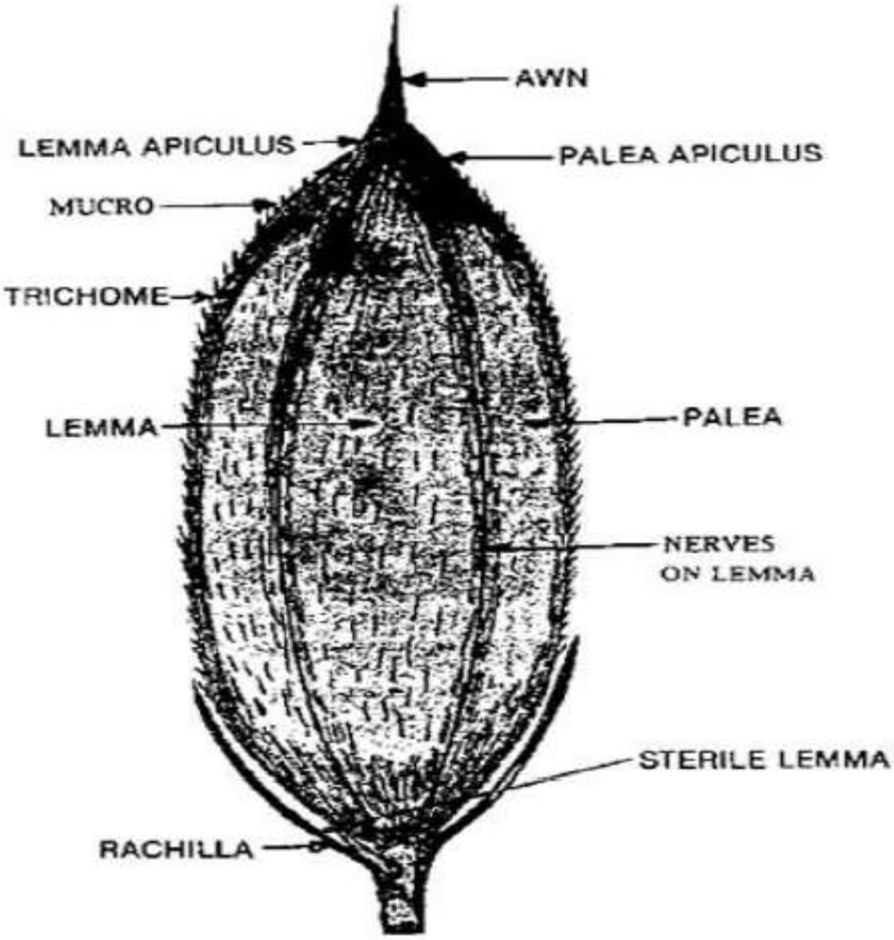

Figure 4: Rice grain showing different parts

3.11.1.21 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, Drooping-9. Figure 6 showing the attitude of different panicle branching.

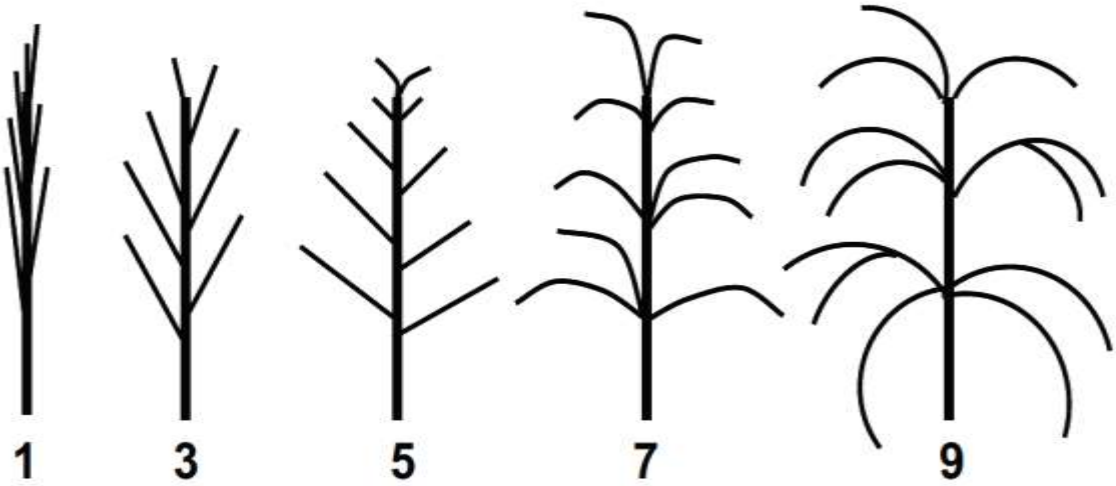

Figure 5. Attitude of panicle branches

3.11.1.22 Panicle: exertion

The panicle exertion was recorded at ripening stage, which were classified into partly exerted, exerted and well exerted classes. The classes were recorded through visual assessment of a group of plants. 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.

Figure 6 represented panicle exertion of rice lines.

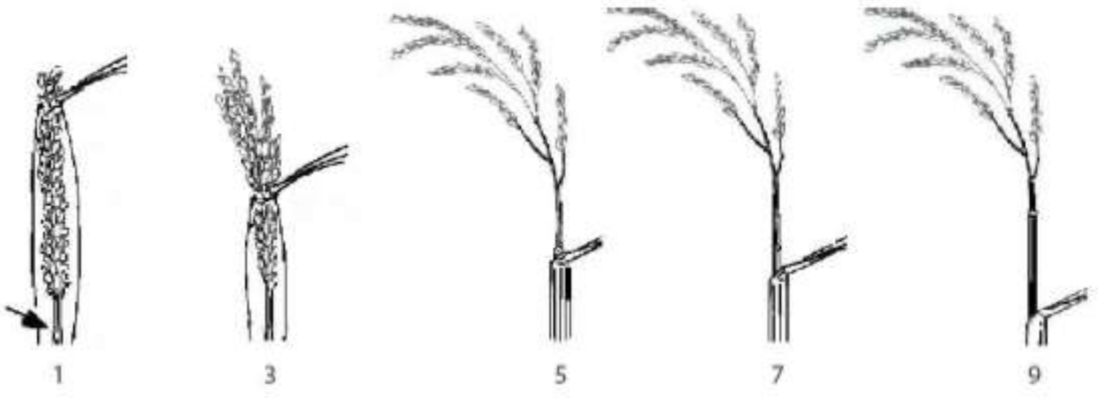

Figure 6: Panicle exertion

3.11.1.23 Time of maturity

Number of days to 80% maturity of plant and recorded as according to descriptor (Table 3). The rice lines were grouped into following

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

3.11.1.24 Grain: length (without dehulling) (mm)

Length of grain was recorded after harvest stage without dehulling through millimeter measurement of individual grain and grouped into very short, short, medium, long and very long grain.

3.11.1.25 Sterile lemma length

Length of sterile lemma was recorded after harvest stage at lab through millimeter measurement of individual grain and grouped into short, medium, long and very long sterile lemma. In Figure 7, the sterile lemma and palea is shown.

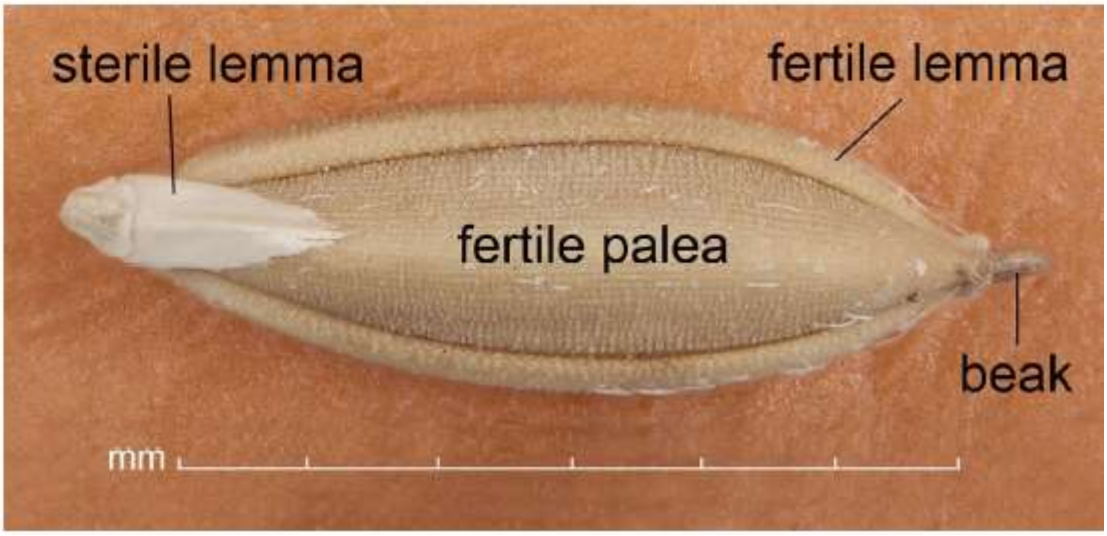

Figure 7: Lemma and palea of rice grain

3.11.1.26 Decorticated grain length (after dehulling)

Grain length was measured in mm and a stereo-microscope was used for clear visualization. Ten grains from every genotypes were measured and the mean value was recorded. The genotypes were classified as per the guided descriptors and grouped into short, medium, long and very long grain.

3.11.1.27 Leaf senescence

The leaf senescence was visually recorded at stage when caryopsis became hard on a group of plants. Senescence is categorized in to early, medium and late classes.

3.11.1.28 Decorticated grain shape

After dehulling (brown rice) or after milling (polished rice) the length and breadth of the grains are measured for computing the shape. Select minimum 10 full grains per replication with both the ends intact and measure the length and breadth by using Grain Shape Tester or Dial Micrometer. 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 8 showing the procedure measuring grain shape.

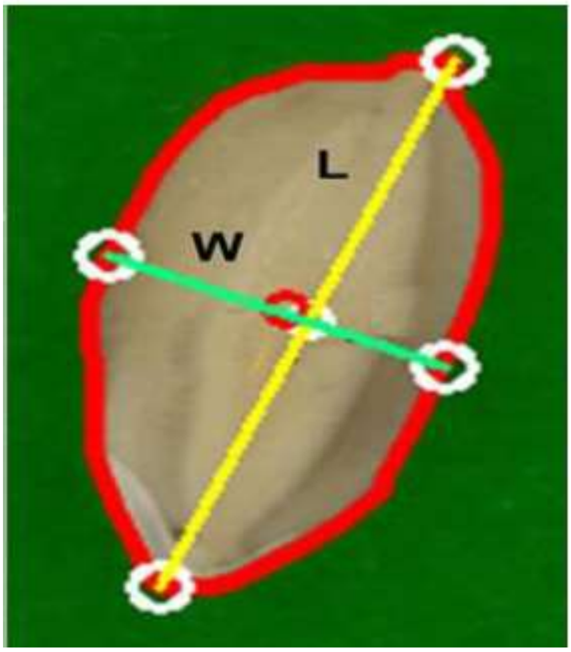

Figure 8: Grain shape measuring procedure

3.11.1.29 Decorticated grain (bran): color

The colour of seed coat was recorded after hulling. 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 9 showing bran color of rice

Figure 9: Bran color of rice

3.11.1.30 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.

3.11.1.31 Decorticated grain: aroma

Grain aroma was determined at post harvest stage. This technique was developed by International Rice Research Institute, Philippines (Jennings *et al.* 1979). According to this 20 to 30 freshly harvested milled grains were taken in a test tube with 20 ml of distilled water. Stoppers were put on the mouth of test tubes and placed in boiling water bath for 10-20 minutes. Test tubes were removed and cooled. Aroma was then detected by smelling. 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.

3.11.2 Quantitative Traits Evaluation Methods

3.11.2.1 Stem length (cm)

It was measured from ground level to the base of the panicle at maturity stage. The length of stem was measured in centimeter and categorized into following five groups **(**Table 4). Figure 10 represented the rice culm length.

Very short- < 40 cm
Short- 41-60 cm
Medium- 61-80 cm
Long- 81-110 cm
Very long- > 110 cm

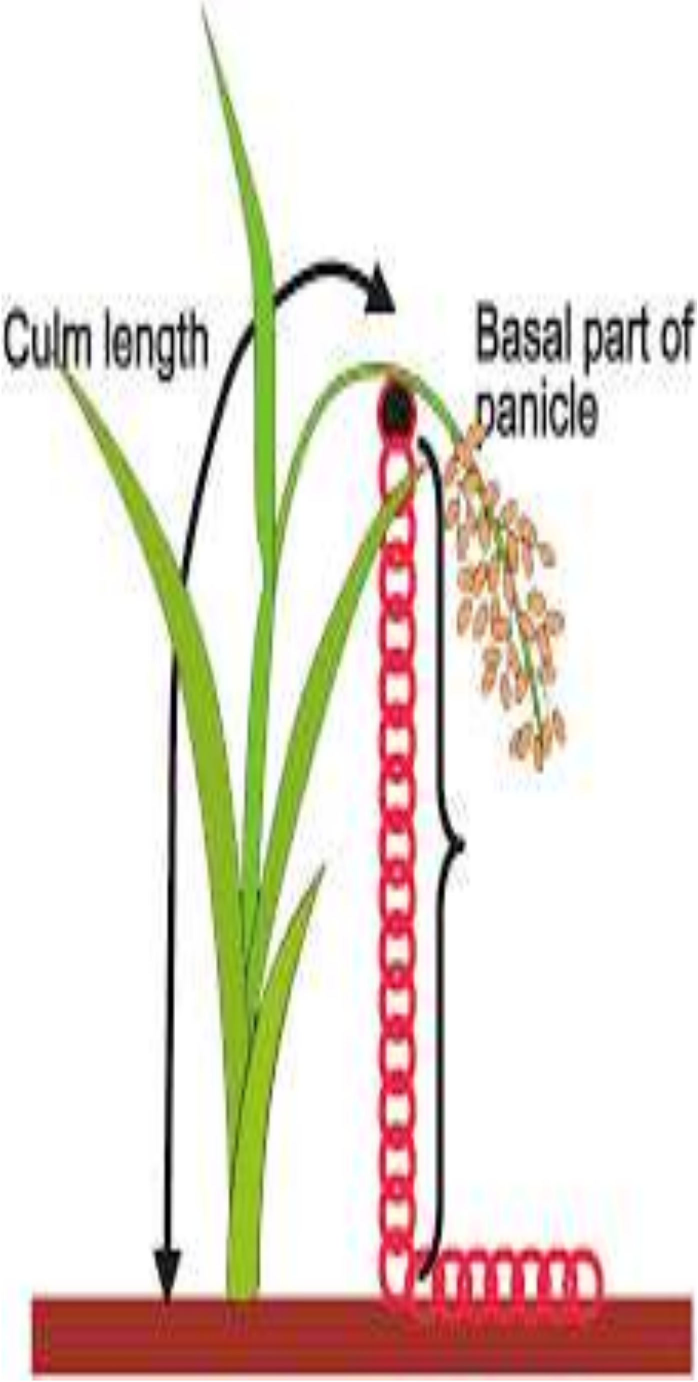

Figure 10. Culm Length

Table 4. Descriptors with codes for quantitative characteristics

SI. NO.	Characteristics	Descriptors with Codes
1	Stem length (culm length)	Very short- < 40 cm, Short- 41-60 cm, Medium- 61-80 cm, Long- 81-110 cm and Very long- > 110 cm
2	No. of effective tiller per plant	Few (>6)-3, Medium (6-10)-5 and Many (>10)-7.
3	Panicle length (cm)	Short (<20 cm)-3, Medium (21-25 cm)-5, Long (26-30 cm)-7, Very long (>30 cm)-9
4	1000-grain weight (g)	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.

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

3.11.2.2 Plant height (cm)

The average height of the 5 plants/hill in ten hills from ground level to the tip of main panicle recorded in centimeters at maturity.

3.11.2.3 Total no. tiller per plant

Total number of panicle bearing tillers was counted from each of the sample plants.

3.11.2.4 No. of effective tiller per plant

Effective tillers are the tillers which bear panicle and the number of effective tillers was counted from each of the sample plants and the average was taken. Based on this character, all the lines were grouped into following groups as per the guided descriptors as follows (Table 4).
Few (>6)-3,
Medium (6-10)-5 and
Many (>10)-7.
Figure 11 showing tiller of rice plant.

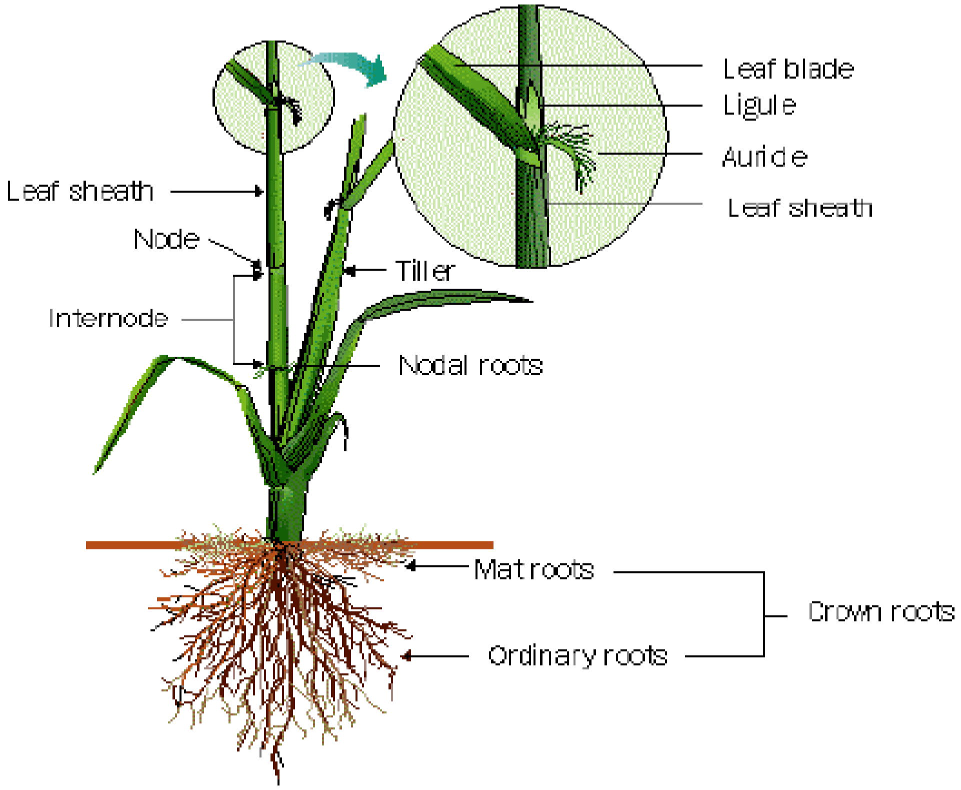

Figure 11: Morphology of a rice plant (vegetative stage)

3.11.2.5 Panicle length (cm)

Panicle length was measured in centimeters at the time of plant maturity from the base of panicle to the tip of last spikelet prior to harvesting. Panicle length was classified into four groups with codes according to guided descriptors as per follows (Table 4).

Short (<20 cm)-3
Medium (21-25 cm)-5
Long (26-30 cm)-7
Very long (>30 cm)-9

3.11.2.6 No. of primary branches per panicle

Observations with respect to number of total primary branches per panicle were recorded at maturity stage.

3.11.2.7 No. of secondary branches per panicle

Observations with respect to number of total number of secondary branches per panicle was counted at maturity stage.

3.11.2.8 Total no. of spikelets per panicle

Total number of spikelets per panicle was measured by adding filled and unfilled grains per panicle.

3.11.2.9 No. of filled grain of main tiller

The number of filled grains of ten randomly selected panicles of main tillers from ten hills was recorded and then averaged.

3.11.2.10 No. of unfilled grain of main tiller

The number of unfilled grains of ten randomly selected panicles of main tillers from ten hills was recorded and then averaged.

3.11.2.11 1000 seed weight (g)

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.

3.11.2.12 Dry weight (g) in 1 sqm

After threshing and recording the net yield, total yield was counted fully grown from 1 square meter of land and weighed at 12% moisture content.

3.11.2.13 Yield per plant (g)

Panicles of randomly selected plants per replication were threshed, seeds were sun dried for two days and weighed and then averaged. Seed yield was adjusted at 12% moisture content.

3.11.2.14 Yield per ha (Ton)

Yield per plant was converted into yield per hectare and denoted as ton.

3.12 Statistical Analysis

The qualitative data in relation to morphological traits are just presented in tabular form for easier description according to IBPGR-IRRI, 2007. The data were arranged as per IBPGR-IRRI formulation with the help of Microsoft-XL program. For quantitative data analysis mean data of the characters were used to statistical analyze like analysis of variance (ANOVA), mean, range (DMRT) were calculated by using MSTATC software program.

Analysis of variance (ANOVA)

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

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

Where.

r = Number of replications

l = Number of lines

d.f. = degree of freedom

MS = Mean sum of square

EMS = Expected values of M.S.

CHAPTER IV

RESULTS AND DISCUSSION

The present research work was conducted with a view to characterize and compare ten Aus advanced lines as per the guided descriptors developed by IBPGR-IRRI. Characterization was done based on thirty one qualitative and ten quantitative traits. Comparative study among the ten advanced lines was implemented based on fourteen yield contributing characters. The results of the present study have been presented and discussed in this chapter under the following headings.

- Characterization based on qualitative characters
- Characterization based on quantitative characters
- Comparative 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-9 according to descriptors. No significant differentiation was observed in the investigation. All lines were absent of leaf sheath anthocyanin color. A pictorial view of leaf sheath anthocyanin color is presented in Plate 4**.**

4.1.2 Leaf color

Pigmentation in different plant parts in any of its possible combinations does not appear to be related to crop development, pest resistance or grain yield (Jennings *et al.*, 1979) but it has been found useful in recognizing, removing off-types and maintaining the genetic purity of seed. On the basis of leaf color the observed lines were categorized in seven groups like pale green-1, green-2, dark green-3, purple-tip-4, purple margins-5, purple bloch-6 and purple-7 according to guided descriptors. But only one type of color was found in this investigation i.e. green. All ten lines showed green color. However, it will not be reliable for identification of cultivars, because the intensity of green color of many cultivars gets bleached when the plant are left in the field to dry in sun or as a result of influence of fertilizers and environmental conditions (Kooistra, 1964**)**. Pictorial view of leaf color is presented in Plate 5.

Plate 4. Leaf sheath anthocyanin color

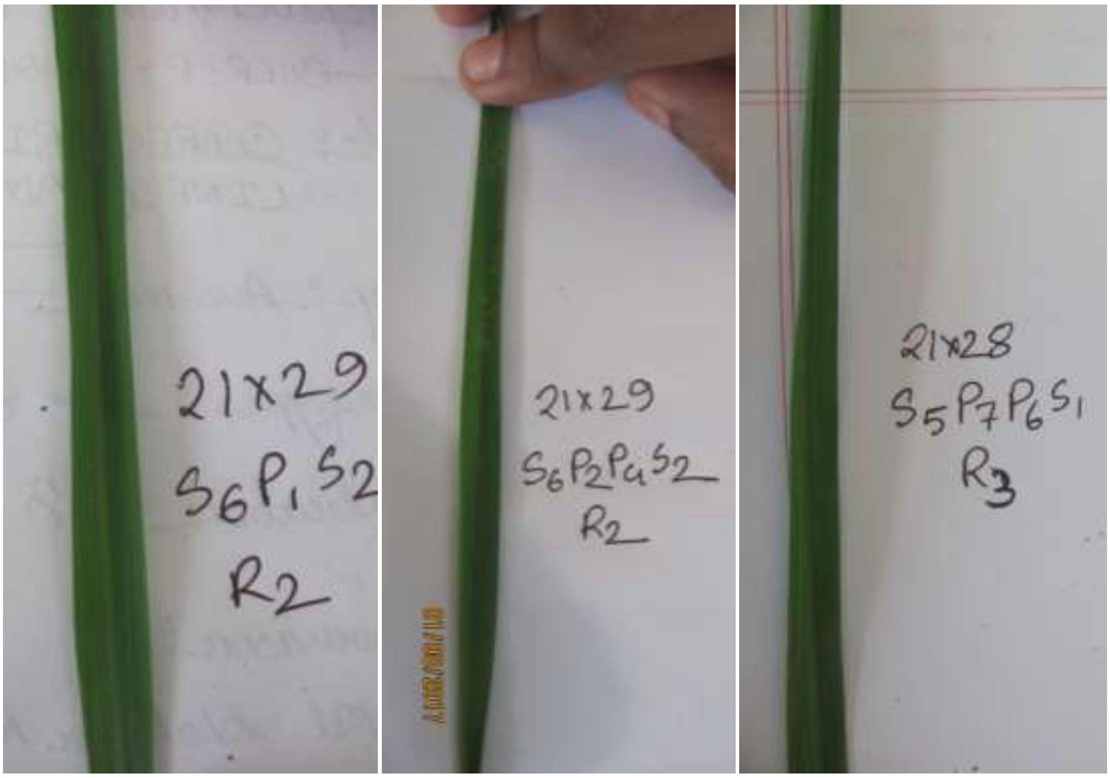

Plate 5. Green color leaf

4.1.3 Penultimate leaf pubescence

The leaves of most rice lines were pubescent but a few are weak. On the basis of penultimate leaf pubescence observed Aus rice lines were classified as absent or very weak-1, weak or only on the margins-3, medium hairs on the lower portion of the leaf-5, strong hairs on the leaf blade -7 and very strong-9. There was little variation among the lines investigated and found two types of leaf pubescence. Four lines (L4, L5, L8 and L9) represent weak or only on the margin type pubescence and rest six lines (L1, L2, L3, L6, L7 and L10) shown medium hairs on the lower portion of the leaf type pubescence (Table 5). A graphical representation of leaf pubescence was shown in Figure 12.

Table 5. Categorization and grouping based on penultimate leaf pubescence

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

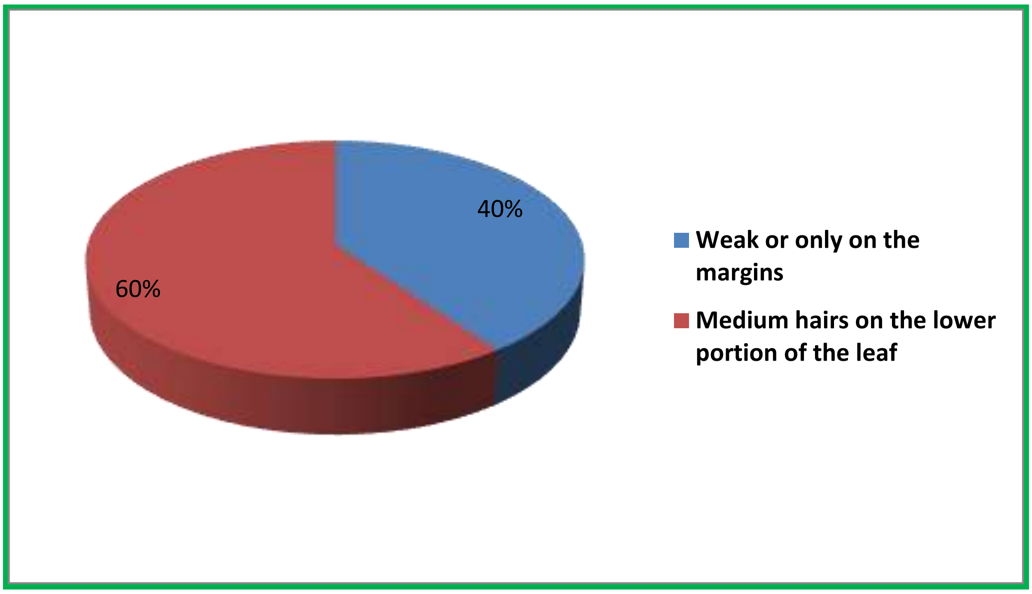

Figure 12. Penultimate leaf pubescence as observed from 10 rice lines

4.1.4 Penultimate leaf: anthocyanin coloration of auricles & collar

On the basis of anthocyanin coloration of auricles & collar the investigated lines were categorized as absent-1 and present-9 according to descriptors. No significant differentiation was observed in the tested lines for this trait. All genotypes were absent of anthocyanin coloration of auricles and collar. A pictorial view of anthocyanin coloration of auricles and color of penultimate leaf is presented in Plate 6.

L3 **L4** **L1**

Plate 6. Anthocyanin coloration of auricle and collar

4.1.5 Penultimate leaf: ligule

On the basis leaf ligule, the test lines were categorized as absent-1 and present-9 according to descriptors. No significant differentiation was observed in the tested lines for this trait. Leaf ligule was present in all lines. A pictorial view of ligule is presented in Plate 7.

4.1.6 Penultimate leaf: Shape of the ligule

On the basis of ligule shape, Aus rice lines were classified as truncate-1, acute-2 and split or two-cleft-3 type. Four lines (L1, L2, L4 and L6) were truncate type, one line (L7) acute and rest five lines (L3, L5, L8, L9, L10) were split or 2-cleft type shape of ligule. A pictorial view of shape of 2-cleft ligule of penultimate leaf is presented in Plate 7. Ligule is a thin, upright, papery membrane that lies at the junction between the sheath and the blade. It can have either a smooth or hairy-like surface (IRRI, 2009). Ligule shape can serve as a unique character in identifying lines and hence could be of importance in every rice breeding programme.

Plate 7. Split of 2-cleft type 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 test lines were categorized in four groups like erect (<30^0)-1, intermediate or semi-erect (30^0-45^0)-3, horizontal (46^0-90^0)-5 and reflexed or descending (>90^0)-7 type. Here four lines (L1, L3, L4, L6) showed erect type flag leaf and rest six lines (L2, L5, L7, L8, L9, L10) showed intermediate or semi erect type flag leaf (Table 6). Pictorial view of attitude of the blade of flag leaf is presented in Plate 8. 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.

Table 6. Categorization and grouping based on attitude of the blade of flag leaf

Types	Code	Lines
Erect (<30)	**1**	L1, L3, L4, L6
Intermediate or semi-erect (30 45)	**3**	L2, L5, L7, L8, L9, L10
Horizontal (46-90)	**5**	**Nil**
Reflexed or descending (>90)	**7**	**Nil**

L1 L3 L4

Plate 8. Attitude of flag leaf

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

Based on time of heading the test lines were categorized in five groups like 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. Two categories of time of heading were observed in the lines of this experiment. This variation might be due to genetic makeup of the lines and line with environmental interactions. Six lines (L1, L2, L3, L4, L5, and L10) showed early time of heading and rest four lines (L6, L7, L8, L9) showed late time of heading (Table 7). Flowering duration is an important character that is frequently considered before release of a variety for commercial cultivation (Shahidullah *et al.*, 2009).

Table 7. Categorization and grouping based on time of heading

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

4.1.9 Male sterility

Male sterility was observed at anthesis period of rice and grouped as per descriptors. Based on male sterility the test lines were categorized in five groups like absent-1, CMS-3, TGMS-5, PGMS-7 and P(T)GMS-9. There was no significant difference among the lines for this trait. There was absent of male sterility trait among the advanced lines. Ali *et al.* (1995) stated that the use of male sterility was the prerequisite for commercial exploitation of heterosis, as rice is a self-pollinating crop.

4.1.10 Microscopic observation of pollen with I_2-KI solution

On the basis of Microscopic observation of pollen with I_2-KI solution the test lines were categorized as 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 according to descriptors. No significant differentiation was observed in the tested lines for this trait. All lines were shown fully fertile pollen. Agbo and Obi (2005) observed that percentage of fertile spikelets had higher correlation values with yield. With good crop management and growth, high yields are obtained with normal spikelet sterility as much as 10% to 15%.

4.1.11 Lemma and Palea: anthocyanin coloration

The test lines were categorized as absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9 on the basis of lemma and palea anthocyanin coloration according to descriptors. Lemma and palea combindly indicates the seed coat anthocyanin color actually. In this case all the lines were absent of anthocyanin coloration. 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.

4.1.12 Lemma: anthocyanin coloration of area below apex

On the basis of lemma anthocyanin coloration of area below apex the test lines were categorized as absent or very weak-1, weak-3, medium-5, sstrong-7 and very strong-9 according to descriptors. No significant variation was observed in the tested lines for this trait. In this case all ten lines were no anthocyanin coloration anthocyanin coloration of area below apex of lemma.

4.1.13 Lemma: anthocyanin coloration of apex

In case of lemma anthocyanin coloration of apex the test lines were categorized as absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9 according to descriptors. No significant variation was observed in the tested lines for this trait. All the lines were absent of anthocyanin coloration of lemma of apex.

4.1.14 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. No significant variation was observed in the tested lines for this trait. All ten lines were shown white color of stigma. Light green, yellow, light purple and purple color of stigma were not observed

4.1.15 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. No significant variation was observed in the tested lines for this trait. All ten lines were shown no or few stigma exertion. A pictorial view of stigma exertion of rice is presented in Plate 9**.**

Plate 9. Stigma exertion of rice

4.1.16 Stem: culm diameter (from five mother tillers in the lowest internode)

Based on culm diameter the test lines were categorized in four groups like 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). No significant variation was observed in the tested lines for this trait. All ten lines were shown small culm diameter category.

4.1.17 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. No significant variation was observed in the tested lines for this trait. All ten lines were absent of anthocyanin coloration of nodes was absent among lines. A pictorial view of anthocyanin coloration of nodes is present in Plate 10.

Plate 10. Anthocyanin coloration of nodes

4.1.18 Stem: Anthocyanin coloration of internodes

On the basis of anthocyanin coloration of internodes the test lines were categorized as absent or very weak-1, weak-3, medium-5, strong-7 and very strong-9 according to descriptors. No significant variation was observed in the tested lines for this trait. All ten lines were absent of anthocyanin coloration of internodes.

4.1.19 Panicle: curvature of 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. There is no significant variation observed in the tested lines for this trait. All the lines were having strong of panicle curvature of main axis. Pictorial view of panicle curvature of main axis is present in Plate 11. 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.

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Plate 11. Panicle curvature of main axis

4.1.20 Spikelet: pubescence of lemma & palea

On the basis of pubescence of lemma and palea, Aus rice lines were classified as absent or very weak-1, weak-3, medium-5 and strong-7. There was no variation among the lines tested and found only one type of pubescence. All lines represent medium type pubescence of lemma and palea.

4.1.21 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. There was no variation among the tested lines and found only one type of color. All lines represent brownish color of the tip of lemma.

4.1.22 Spikelet: awn in the spikelet

This character was observed at maturity stage and based on presence of awns. The test lines were categorized into two groups as absent-1 and present-9. All lines represent absent of awn. Most breeders select awnless grains because the awns are tough, persistent and objectionable in milling and threshing. Lines with partly awned panicles, short-awned types present no problem and should not be discarded because of that character alone during cultivar development. Acharya *et al.* (1991) stated that awns appear to be equipped with physiological and biological buffers that enable them to adjust to changes in the environment although many farmers consider it a nuisance during milling.

4.1.23 Panicle: attitude of branches

Panicle type of rice refers to the mode of branching, the angle of the primary branches and the spikelet density (IRRI, 2009c). The compactness of the panicle was classified according to its mode of branching, angle of primary branches, and spikelet density in five groups as erect-1, semi-erect-3 and spreading-5 type panicle. In this study all ten lines showed spreading type panicle. Erect and semi erect panicles were not found among the lines studied. Crop breeders usually selectively breed for an erect panicle type; spreading panicle type is actively selected against, for reasons of maximizing crop grain production and harvest. Hence the genotypes with compact panicle types can be used in breeding programmes for the purpose of increasing rice production. Pictorial view of attitude of branches of panicle is presented in Plate 12.

4.1.24 Panicle: exertion

Extent to which the panicle is exerted above the flag leaf sheath is known as panicle exertion. Panicle exertion is an essential physiological process for obtaining high grain yield in rice and is mainly driven by peduncle (uppermost internode) elongation. When some of the spikelets at lower down the panicle are trapped inside the flag leaf sheath, it increases the sterility in the lower unexerted spikelets hence reduce the grain yield (Muthurajan *et al.*, 2010). The panicle was classified according to its exertion in five groups as enclosed-1, partly enclosed-3, just exerted-5, moderately exerted-7 and well exerted-9. In this study all ten lines showed well exerted panicle hence they are good for grain yield improvement. Enclosed type of panicle was not found among the genotypes studied. However, the extent of panicle exertion is largely influenced by the agro-climatic condition and cropping seasons (Hoan *et al*., 1998).

L1 L2 L3 L4 L5 L6 L7 L8 L9 L10

Plate 12. Photograph showing of attitude of branches of panicle of ten Aus rice lines

4.1.25 Time of maturity

Based on time of maturity the test lines were categorized into five groups as 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. Six lines (L1, L2, L3, L4, L5, L10) were found early maturing type and rest of the four lines (L6, L7, L8, L9) were found as late maturating type (Table 8). Minimum value for days to maturity represents that the variety has a benefit of early ripening. Early maturity genotypes could be selected for areas with short rain seasons and in areas where farmers grow a second crop to take advantage of residual water after harvesting the early rice crop. Plate 13 represented 80% maturity stage of rice lines.

Table 8. Categorization and grouping based on time of maturity

Types	**Code**	**Lines**
Very early (<100 days)	1	**Nil**
Early (101-115 days)	3	L1, L2, L3, L4, L5, L10
Medium (116-135 days)	5	**Nil**
Late (136-150 days)	7	L6, L7, L8, L9
Very late (>150 days)	9	**Nil**

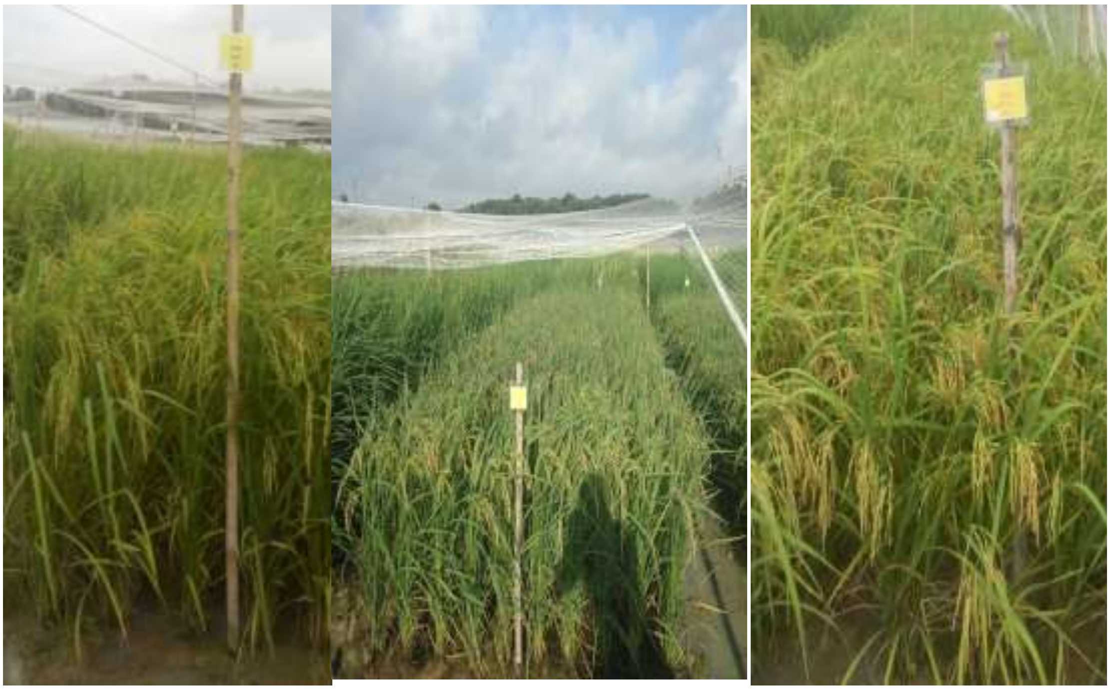


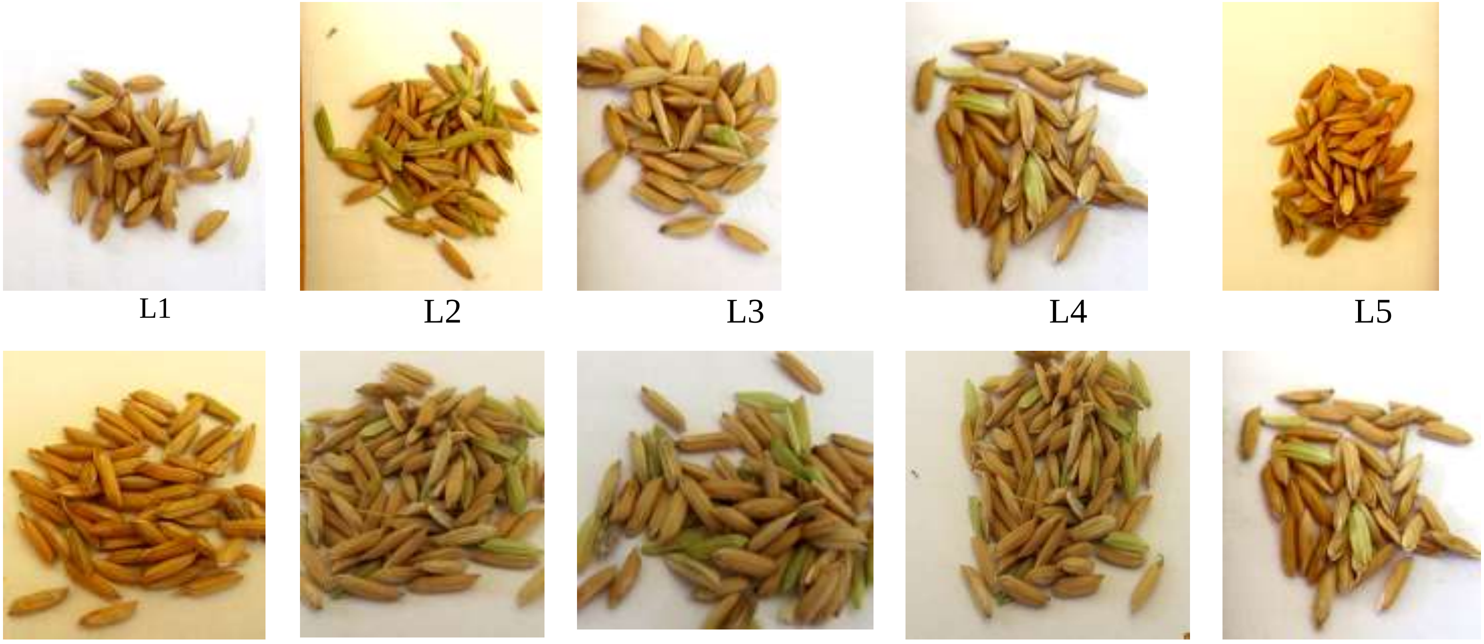
Plate 13: Rice lines showing 80% maturity

4.1.26 Grain: length (without dehulling) (mm)

Based on grain length the test lines were categorized in five groups like 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. Two category of grain length were found in present study. Here six lines (L1, L2, L3, L4, L5, L8) showed long grain length and rest four lines (L6, L7, L9, L10) showed very long category of grain length. Table 9 and plate 14 are showing the grain length variation.

Table 9. Categorization and grouping based on grain length (without dehulling)

Types	Code	Lines
Very short (<6.0 mm)	1	**Nil**
Short (6.1-7.0 mm)	3	**Nil**
Medium (7.1-8.0 mm)	5	**Nil**
Long (8.1-9.0 mm)	7	L1, L2, L3, L4, L5, L8
Very long (>9.0 mm)	9	L6, L7, L9, L10



L1 L2 L3 L4 L5

L6 L7 L8 L9 L10

Plate 14: Grains of different lines

4.1.27 Sterile lemma length: measure at post-harvest stage

Based on sterile lemma length the test lines were categorized in four groups like short (<1.5 mm)-1, medium (1.5-2.5 mm)-3, long (2.6-3 mm)-5 and very long (>3.0 mm)-7. Only long type of sterile lemma was found in present study.

4.1.28 Decorticated grain length (after dehulling)

Decorticated grain length of the test lines were categorized in four groups like 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. In this experiment there were found two types of decorticated grain length. Five lines (L1, L2, L3, L5, L9) were represented medium type of decorticated grain length and their grain length was between 5.6 mm to 6.5 mm. Rest five lines (L4, L6, L7, L8, L10) showed long type of grain length after dehulling (Table 10). Long grain length (after dehulling) was represented in Plate 15.

Table 10. Categorization and grouping based on decorticated grain length (after dehulling)

Types	**Code**	**Lines**
Short (<5.5 mm)	1	**Nill**
Medium (5.6-6.5 mm)	3	L1, L2, L3, L5, L9
Long (6.6-7.5 mm)	5	L4, L6, L7, L8, L10
Very long (>7.5 mm)	7	**Nill**

Plate 15: Decorative long type of grain length after dehulling

4.1.29 Leaf senescence

According to descriptor the test lines were categorized in three groups for the leaf senescence like late and slow-1, intermediate-5 and early and fast-9. No variation was observed for this trait in the studied lines. All ten lines showed late and slow type of leaf senescence.

4.1.30 Decorticated grain shape

Grain shape is the ratio of grain length to grain width. According to grain shape the lines were grouped as round (L: W <1.5)-1, bold (1.5-2.0)-3, medium (2.1-2.5)-5, medium slender (2.6-3.0)-7 and slender (>3.0)-9. Two categories of lines were found on basis of grain shape. Out of ten lines four lines (L1, L4, L6, L8) under the group of medium slender having their length/width ratio between 2.6 to 3.0 and rest six lines (L2, L3, L5, L7, L9, L10) were under the category of slender having their length/width ratio more than 3.0. Determining the physical dimension of rice varieties is very important, since it is produced and marketed according to grain size and shape. The length and width of rice grain are important attributes that determine the shape of the rice (IRRI, 2009b). Takoradi (2008) reported that long grain rice is highly demanded by the rice consuming populace. Hence the long grains obtained in this study can be used in breeding programmes so as to meet the consumers' need. Although the preference for rice grain characteristics varies with consumer groups, medium slender and slender grains are generally preferred and are good valuable attributes that could be exploited to improve the grain characteristics.

4.1.31 Decorticated grain (bran): color

According to descriptor decorticated bran color of grain were categorized in seven groups like white-1, light brown-2, variegated brown-3, dark brown-4, red-5, variegated purple-6 and purple-7. No variation was observed for this trait in the studied lines. All ten lines showed light brown color of bran of grain. Photograph showing the brown bran color of rice in Plate 16.

Plate 16: Light brown rice bran color

4.1.32 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 these are absent or very small-1, small (<10%)-3, medium (11-20%)-5 and large (11-20%)-7. The test lines were found in two categories like small and medium types of size of white core of polished grain. Six lines (L1, L2, L3, L4, L5, and L10) were represented small and four lines (L6, L7, L8, L9) were showed medium size of white core of polished grain.

4.1.33 Decorticated grain: aroma

Different techniques were developed to detect aroma by several scientists around the world. The technique developed by IRRI was followed here where aroma was detected by smelling (Sensory Test) after adding l.7% (0.3035N) solution of KOH. All the tested lines were not aromatic. Based on aroma the tested lines were categorized in three groups as absent-1, lightly present-5 and strongly present-9. There was no variation among all the lines tested. All studied lines were absent of aroma.

4.2 Characterization based on Quantitative Characters

4.2.1 Stem length (culm length) (cm)

Stem length (culm length) means the length of a stem from ground level to panicle base. 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. These are 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. Culm lengths of test lines ranged from 67.67 cm to 120.20 cm (Table 11**)**. Three types of lines were found viz. medium, long and very long type of culm length (Table 12). Six lines (L1, L2, L3, L4, L5, L10) were represented medium type of culm length (Table 12). Two lines (L6, L7) were represented long type of culm length. Lines (L8, L9) were represented very long type of stem length. Mean performance of stem length was presented in Figure 12.

Table 11. Mean stem length of ten lines

Sl No.	Lines	Stem length (cm)	Rank
1	L1	74.66	5
2	L2	67.67	1
3	L3	74.30	4
4	L4	70.40	2
5	L5	71.64	3
6	L6	88.53	7
7	L7	109.93	8
8	L8	117.67	9
9	L9	120.20	10
10	L10	75.23	6

Table 12. Categorization and grouping based on stem length

Types	**Code**	**Lines**
Very short- < 40 cm	1	**Nil**
Short- 41-60 cm	3	**Nil**
Medium- 61-80 cm	5	L1, L2, L3, L4, L5, L10
Long- 81-110 cm	7	L6, L7
Very long- > 110 cm	9	L8, L9

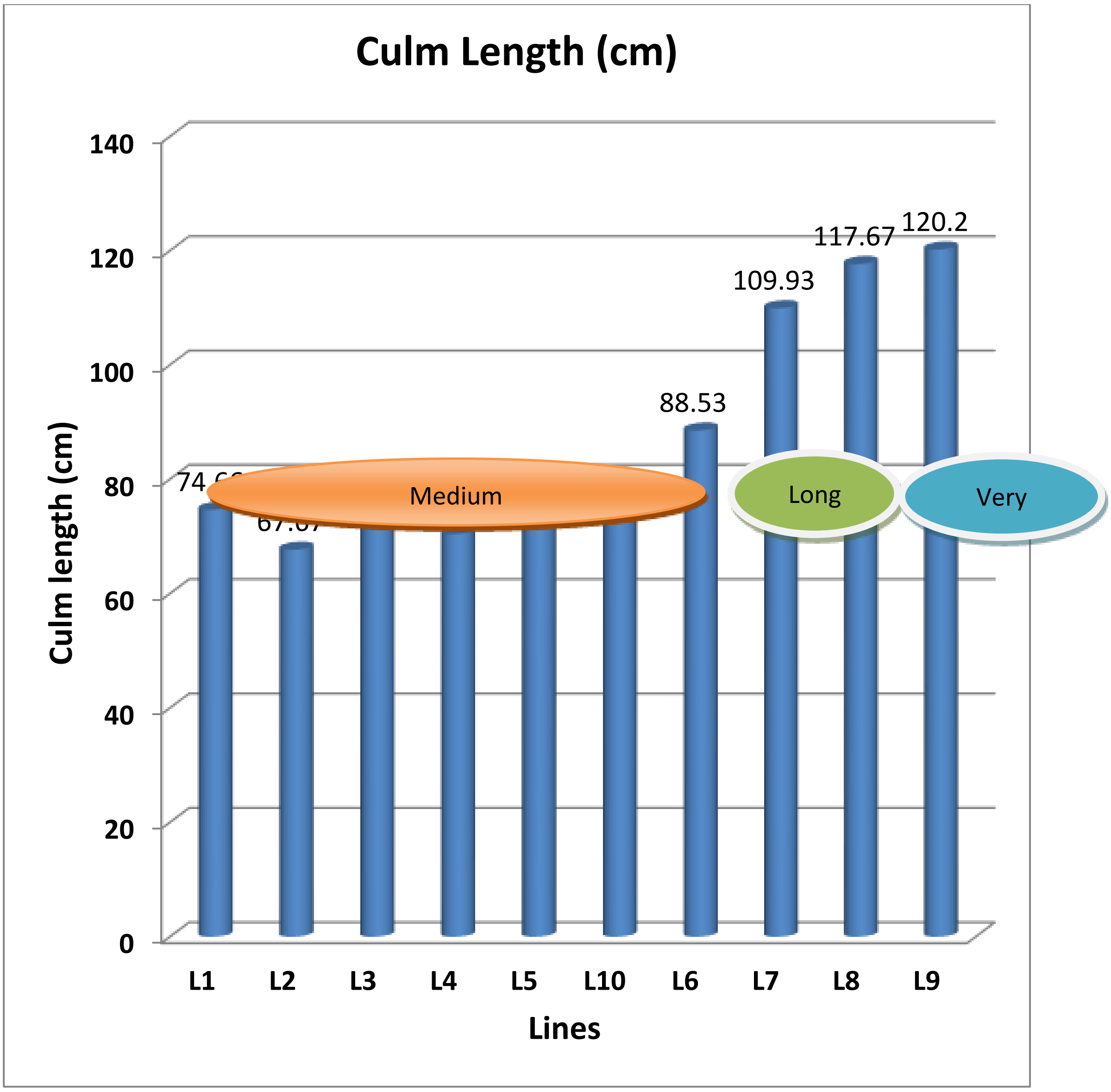


Figure 13: Culm length variation among the advanced lines.

L6 **L7**

Plate 17. Showing long type culm length

4.2.2 No. of effective tillers per plant

The highest number of effective tillers per plant (13.400) was recorded for L8 whereas the lowest no. of effective tiller per plant (9.400) was recorded for L1. The genotypes were grouped as Few (<6)-3, Medium (6-10)-5 and Many (>10)-7 according to descriptor. No. of effective tiller per plant of test lines ranged from 8.87 to 12.10 (Table 13).Two category of no. of effective tiller per plant was observed in these studied lines (Table 14). Five lines (L1, L5, L7, L8, L9) were observed having medium category of no. of effective tiller per plant and rest five lines (L2, L3, L4, L6, L10) were observed many category of effective tiller per plant as effective tiller number between 6-10 represent medium category and more than 10 represent many category (Table 14). From the Figure 13 we also can distinguish different groups of observed lines based on effective tiller 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.

Table 13. Mean numbers of effective tillers per plant of ten lines

Sl No.	Lines	No. of effective tillers per plant	Rank
1	L1	8.68	2
2	L2	10.43	7
3	L3	10.23	6
4	L4	11.33	9
5	L5	9.13	3
6	L6	10.63	8
7	L7	9.83	5
8	L8	8.87	1
9	L9	9.60	4
10	L10	12.10	10

Table 14. Categorization and grouping based no. of effective tillers per plant

Group	**Scale**	**Code**	**Lines**
Few	<6	3	**Nil**
Medium	6-10	5	L1, L5, L7, L8, L9
Many	>10	7	L2, L3, L4, L6, L10

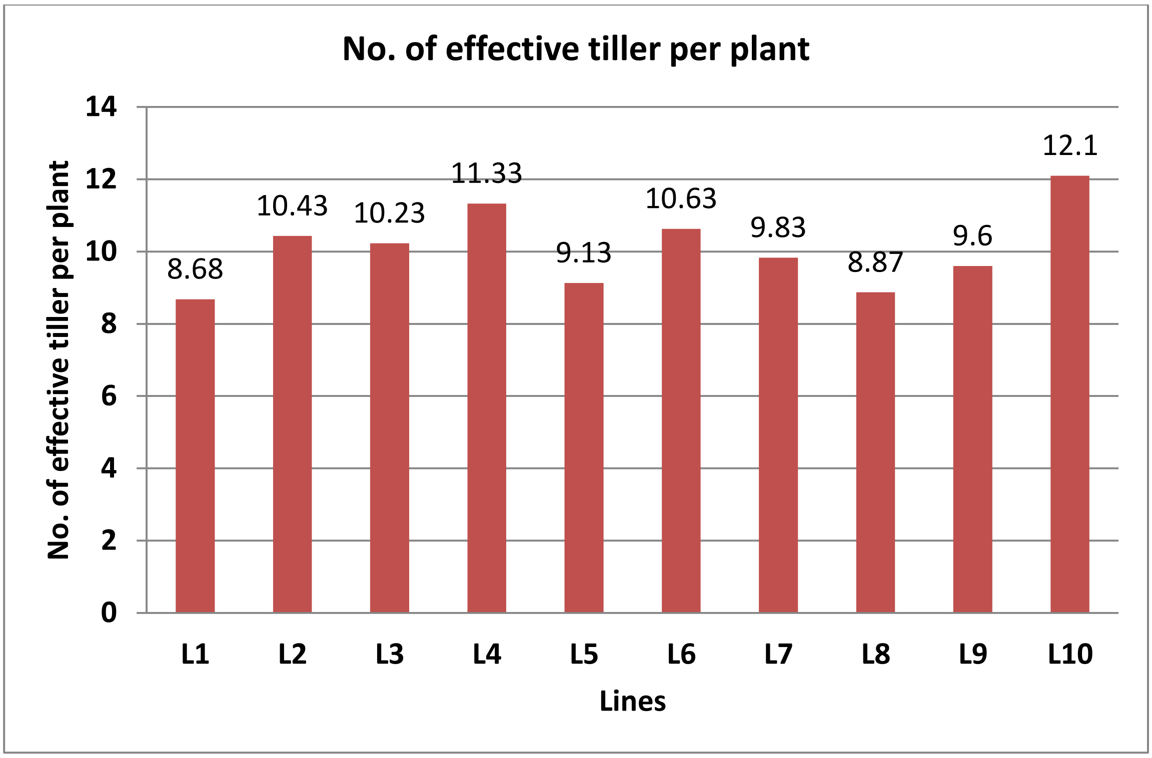


Figure 14: Total no. of effective tillers per plant of the observed lines

4.2.3 Panicle length (cm)

The shortest panicle length of 23.77 cm was recorded for L5 whereas the longest panicle length of 31.00 cm was recorded for L8. The lines were grouped as short (<20 cm)-3, medium (21-25 cm)-5, long (26-30 cm)-7 and very long (>30 cm)-9 according to descriptor. The panicle length and number of panicle per plant directly control the yield of a particular variety (Ashfaq, *et al.*, 2012). Three category of panicle length was observed in these studied lines. Seven lines (L1, L2, L3, L4, L5, L6, L10) were observed having medium panicle as length between 21-25 cm represent medium panicle. Two lines (L7, L9) were observed long panicle and between 26-30 cm long. Similar results were obtained by Sarma *et al.* (2004) and found that eight genotypes showed more than 25 cm panicle length and the remaining genotypes were recorded lesser panicle length. Only one line shown very long type of panicle length (more than 30 cm) and observed by line L8.

Table 15. Mean no. of effective tiller per plant of ten lines

Sl No.	Lines	Panicle Length (cm)	Rank
1	L1	25.42	7
2	L2	24.57	2
3	L3	25.03	5
4	L4	25.23	6
5	L5	23.77	1
6	L6	25.03	4
7	L7	29.87	9
8	L8	31.00	10
9	L9	29.73	8
10	L10	25.42	7

Table 16. Categorization and grouping based no. of effective tiller per plant

Group	**Scale**	**Code**	**Lines**
Short	<20 cm	3	**Nil**
Medium	21-25 cm	5	L1, L2, L3, L4, L5, L6, L10
Long	26-30 cm	7	L7, L9
Very long	>30 cm	9	L8

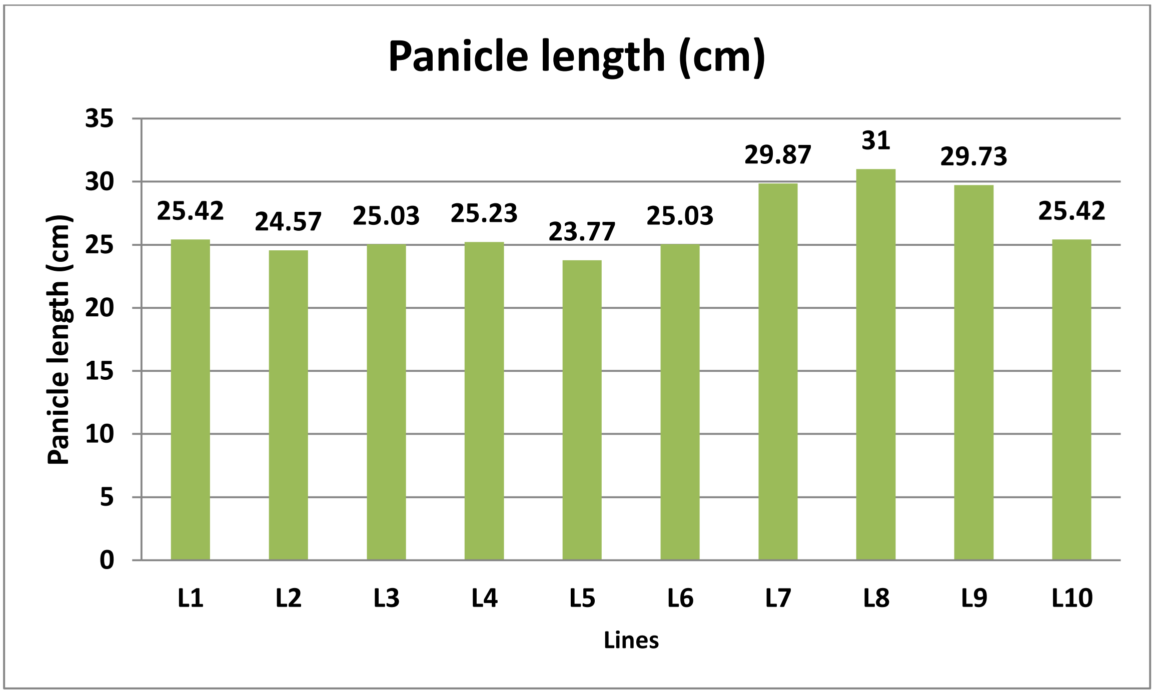


Figure 15: Panicle length of 10 Aus rice lines

4.2.4 1000-grain weight (g)

The lowest 1000 grain weight (20.50g) was recorded for L9 whereas the highest 1000 grain weight of (26.00) g was in L3 **(**Table 17). Based on 1000 seed weight the test lines were categorized into five groups like 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. Two types of category were found for 1000-seed weight. Here seven lines (L2, L4, L6, L7, L8, L9, L10) showed medium weight of 1000-seeds, three lines (L1, L3, L5) showed high category weight of 1000-seeds (Table 18). IRRI (2009b) reported that longer grains are lighter in weight than medium or bold grains.

Table 17. Mean no. of effective tiller per plant of ten lines

Sl No.	Lines	1000 grain weight (g)	Rank
1	L1	25.67	9
2	L2	21.33	2
3	L3	26.00	10
4	L4	23.33	6
5	L5	24.00	8
6	L6	22.30	4
7	L7	22.00	3
8	L8	22.60	5
9	L9	20.50	1
10	L10	23.33	7

Table 18. Categorization and grouping based no. of effective tiller per plant

Group	**Scale**	**Code**	**Lines**
Very low	<15 g	1	**Nil**
Low	16-19 g	3	**Nil**
Medium	20-23 g	5	L2, L4, L6, L7, L8, L9, L10
High	24-27 g	7	L1, L3, L5
Very high	>27 g	9	**Nil**

4.3 Comparative Study

4.3.1 Analysis of variance

The analysis of variance of different morphological traits of ten advanced Aus lines for are shown in Table 19. Analysis of variance indicated that the difference among lines for fourteen traits under study viz., stem length, plant height, no. of tiller per plant, no. of effective tillers per plant, panicle length, no. of primary branches per panicle, no. of secondary branches per panicle, total spikelets per panicle, filled grain of main tiller (no), unfilled grain of main tiller(no), 1000-grain weight (g), dry weight (g) in 1 sqm, yield per plant (g) and yield per ha (Ton) was highly significant. Result suggests the presence of variation among the lines for all these traits. Previous studies in rice also found significant variation for these traits **(** Kumar *et al.*, 2014**).**

Table 19. Analysis of variance (ANOVA) for fourteen traits in Aus rice

Characters/Variety	Mean sum of square		
	Replication (r-1) = 2	Genotype (g-1) = 9	Error (r-1)(g-1) = 18
Stem length (cm)	55.76	1,302.77**	28.20
Plant height (cm)	81.06	1,428.56**	28.49
Total no. tiller per plant	3.86	3.35*	1.20
No. of effective tiller per Plant	2.55	3.57**	0.76
Panicle length (cm)	3.93	21.06**	2.14
No. of primary branches per panicle	2.86	10.38**	0.77
No. of secondary branches per panicle	56.71	65.61**	11.56
Total no. of spikelets per Panicle	113.15	467.50**	67.22
No. of filled grain of main till	226.02	908.87**	128.25
No. of unfilled grain of main tiller	2.71	599.80**	115.30
1000 seed weight (g)	0.61	9.29**	1.37
Dry weight (g) in 1 sqm	2,254.90	34,004.49**	826.53
Yield per plant (g)	3.90	92.05**	12.86
Yield per ha (Ton)	0.31	3.27**	0.08

*= Significant at the 0.05 level ** = Significant at the 0.01 level.

4.3.2 Performance of the lines for yield and yield contributing traits

The mean performances of the 10 rice lines for their traits are shown in Table 20 and Table 21.

Plant height (cm)

Plant height ranged from 98.27 cm to 158.60 cm among the lines with a mean value of 119.91 cm. Highest plant height was observed in line L9 and it was statistically similar with the line L8 (149.80 cm) while lowest in line L2 and it was statistically similar with L4 (103.70 cm), L5 (104.07 cm) and L1 (105.05 cm).

Table 20. Range, mean, CV (%) of 14 traits in Aus rice

Parameters	Range		Mean	CV (%)
	Min	Max		
Stem length (cm)	67.67	120.20	87.02	6.10
Plant height (cm)	98.27	158.60	119.91	4.45
Total no. tiller per plant	9.38	12.33	10.74	10.22
No. of effective tiller per plant	8.68	12.10	10.09	8.66
Panicle length (cm)	23.77	31.00	26.45	5.54
No. of primary branches per panicle	7.90	12.87	10.04	8.78
No. of secondary branches per panicle	23.97	36.10	28.40	11.97
Total no. of spikelets per panicle	120.21	153.87	133.80	6.13
No. of filled grain of main tiller	92.73	137.17	112.62	10.06
No. of unfilled grain of main Tiller	9.17	58.47	24.03	44.68
1000 seed weight (g)	20.50	26.00	23.11	5.07
Dry weight (g) in 1 sqm	196.33	434.33	322.82	8.91
Yield per plant (g)	8.60	24.77	16.39	21.89
Yield per ha (Ton)	1.96	4.40	3.25	8.74

Min : minimum
Max : maximum
CV (%) : coefficient of variation

Table 21. Mean performance of 14 characters of 10 Aus lines

Genotype	Stem length (cm)	Plant height (cm)	Total no. tiller per plant	No. of effective ti per plant	Panicle length (cm	No. of primary branches per panic	No. of secondary branches per panic	Total no. of spikel per panicle	No. of filled grain main tiller	No. of unfilled gra of main tiller	1000 seed weight (	Dry weight (g) in sqm	Yield per plant (g)	Yield per ha (Ton)
L1	74.66d	105.05de	9.38d	8.68e	25.42b	9.38c-e	25.15c	125.55c	108.09bc	18.32bc	25.67a	394.33ab	18.75a	3.94b
L2	67.67d	98.27e	11.13a-d	10.43b-d	24.57b	7.90e	23.97c	122.60c	98.40c	25.67bc	21.33cd	434.00a	18.53a	4.08b
L3	74.30d	111.17cd	11.17a-d	10.23b-e	25.03b	9.63cd	27.57bc	122.37c	96.17c	23.87bc	26.00a	390.33ab	20.47a	4.34a
L4	70.40d	103.70de	11.97ab	11.33ab	25.23b	8.23de	24.70c	126.47c	92.73c	34.13b	23.33bc	417.67a	19.60a	4.18b
L5	71.64d	104.07de	9.67cd	9.13c-e	23.77b	8.60de	24.34c	120.21c	105.17bc	15.38bc	24.00ab	434.33a	20.40a	4.32a
L6	88.53c	119.50c	11.63a-c	10.63a-c	25.03b	10.70bc	27.63bc	141.50ab	129.50a	12.70c	22.30b-d	196.33c	9.93b	1.96c
L7	109.93b	141.40b	10.40a-d	9.83b-e	29.87a	12.87a	33.40ab	149.90a	124.37ab	25.63bc	22.00b-d	206.40c	11.97b	2.06c
L8	117.67ab	149.80ab	9.53cd	8.87de	31.00a	12.70a	36.10a	153.87a	137.17a	17.00bc	22.60b-d	206.92c	10.83b	2.25c
L9	120.20a	158.60a	10.17b-d	9.60c-e	29.73a	11.77ab	35.13a	144.37ab	136.17a	9.17c	20.50d	200.50c	8.60b	2.00c
L10	75.23d	107.50de	12.33a	12.10a	24.80b	8.57de	26.03c	131.15bc	98.40c	58.47a	23.33bc	347.33b	24.77a	4.40a

Total no. of tillers per plant

Total no. of tillers per plant was performed with the ranged from 9.38 to 12.33 **(Table 20)**. The average total no. of tiller per plant was 10.74. Line L10 was showed highest significant number of total tiller per plant which was statistically similar with L4 (11.97), L6 (11.63), L3 (11.17) while line L1 represented the lowest value of this trait which was statically similar with L8 (9.53) and L5 (9.67) **(**Table 21).

Number of effective tillers per plant

The range for the effective no of tillers per plant from 8.68 to 12.10 were found for number of effective tiller per plant with an average of 10.09. The most significant number of effective tiller per plant was exhibited by line L10 while line L1 showed the lowest number for this trait.

Panicle length (cm)

Panicle length was exhibited the variation with the ranged from 23.77 cm to 31.00 cm with an average of 26.45 cm. The line L8 represented the longest panicle which was statistically similar with L7 (29.87 cm) and L9 (29.73 cm). While the shortest panicle length was observed by the line L5 which was statistically similar with L10 (24.80 cm) and L2 (24.57 cm).

Number of primary branches per panicle

Number of primary branches/panicle was varied from 7.90 to 12.87. The average of number of primary branches per panicle was 10.04. The line L7 produced the highest number of primary branches/panicle which was similar in statistically with L8 (12.70) and L9 (11.77). The lowest number of primary branches per panicle was observed by the line L2.

Number of secondary branches/panicle

The important yield contributing trait number of secondary branches/panicle was ranged from 23.97 to 36.10 with a mean value of 28.40. The highest and lowest number of secondary branches/panicle was exhibited by the lines L8 and L2, respectively.

Total no. of spikelets/panicle

High variation in total no. of spikelets/panicle in the present study was observed with minimum 120.21 to maximum 153.87. The average of total no. of spikelts/panicle was 133.80. Highest total no. of spikelets/panicle was observed by the line L8 while L5 showed the lowest no. of spikelets/panicle. A graphical presentation of total no. of spikelets/panicle was shown in Figure 15.

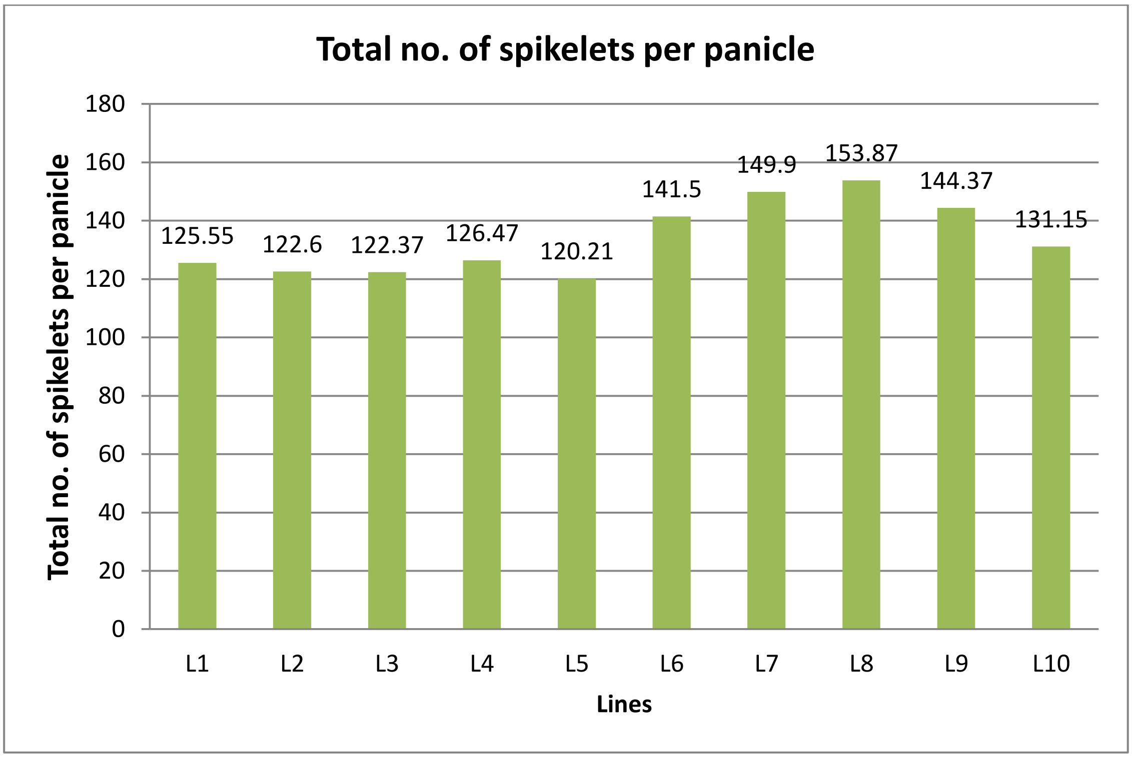


Figure 16. Variation in mean performance of 10 lines of total spikelets per panicle of rice

Number of filled grains of main tiller

In case of number of filled grains of main tiller, advanced lines exhibited high range of variation from 92.73 to 137.17 and the mean value was 112.62. The maximum number of filled grains of main tiller was observed in L8 which was statistically similar with L9 (136.17) and L6 (129.50) and while minimum number of filled grains of mail tiller was observed in line L4 which was similar in statistical as 5% level of provability with L3 (96.17) and L2 (98.40). Since, greater number of filled grains per panicle is one of the major criteria which contribute to higher seed yield and it could be utilized in further program.

Number of unfilled grain of main tiller

Number of unfilled grain of main tiller was varied from 9.17 to 58.47 with a mean of 24.03. The lowest number of unfilled grain of main tiller was observed by line L9 while the highest number of this trait in L10.

Thousand seed weight (g)

The thousand seed weight was ranged from 20.50 g to 26.00 g with a mean value of 23.11 g. The maximum value of thousand seed weight was observed in line L3 which was statistically similar with L1 (25.67 g) while minimum value of thousand grain weight was observed in line L9. Ten lines were shown in graphically for the mean data of thousand seed weight in Figure 17.

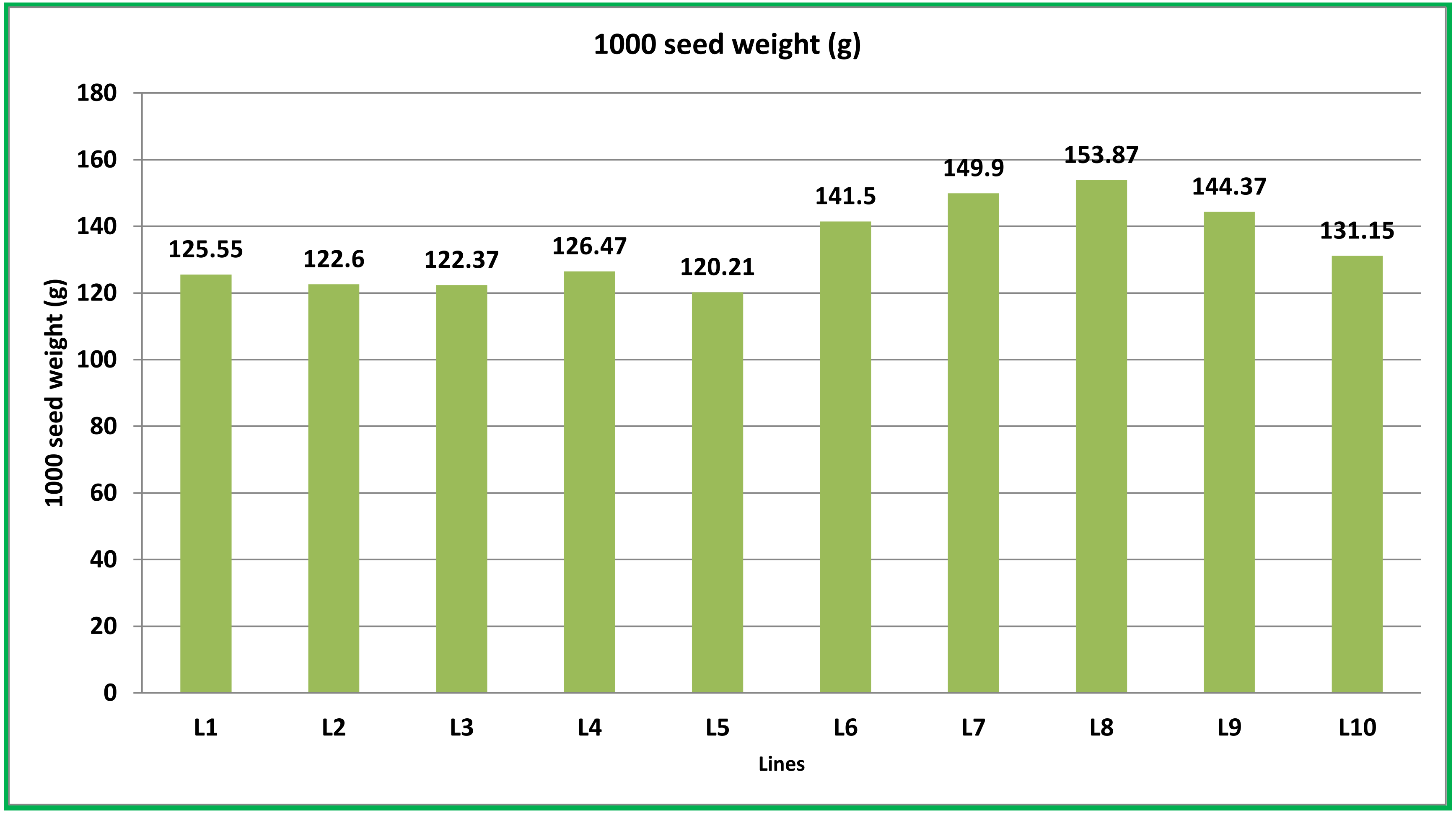


Figure 17. Variation in mean performance of 10 lines of 1000 seed weight of rice

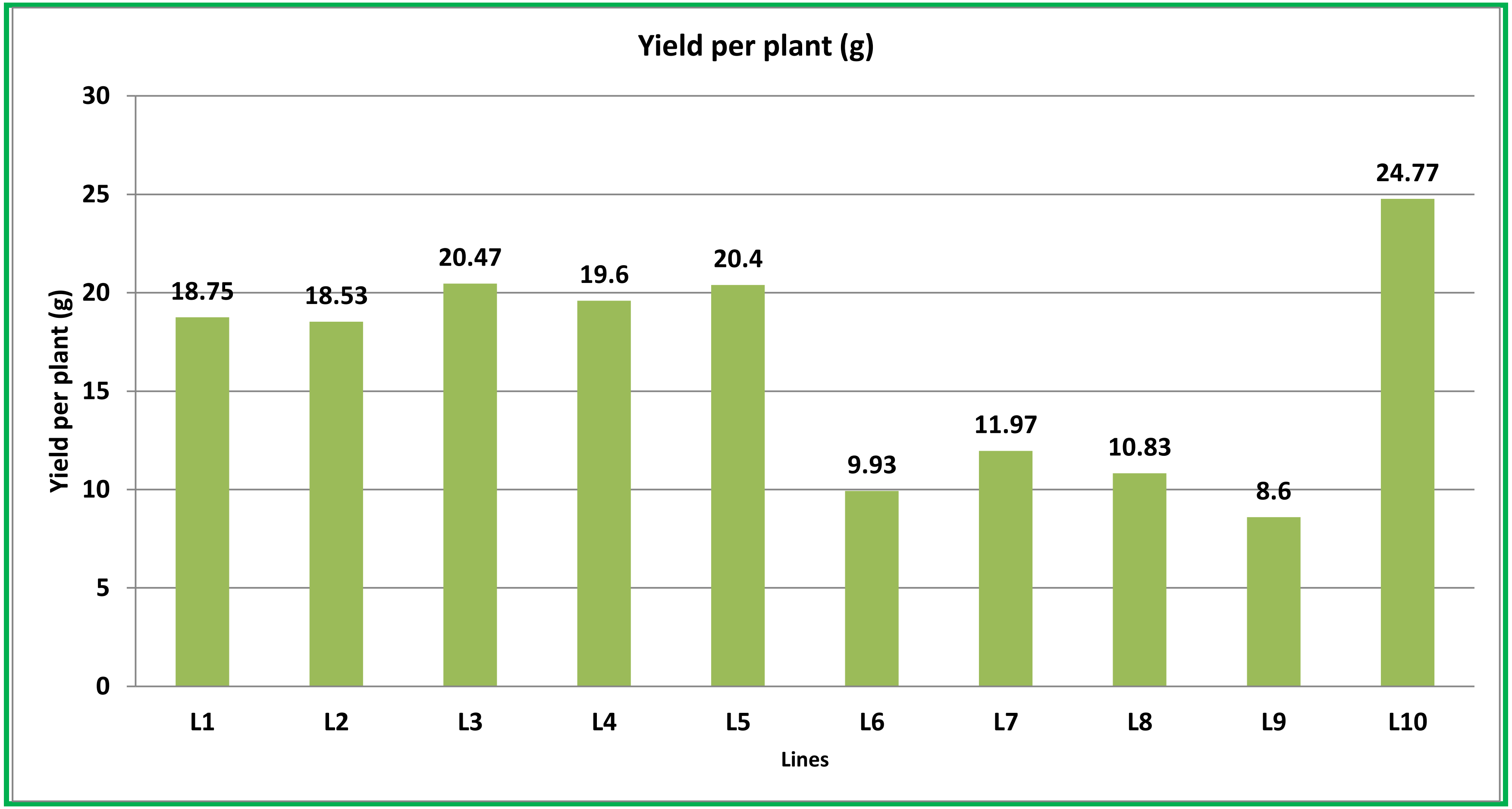


Figure 18. Variation in mean performance of 10 lines of yield per plant of rice

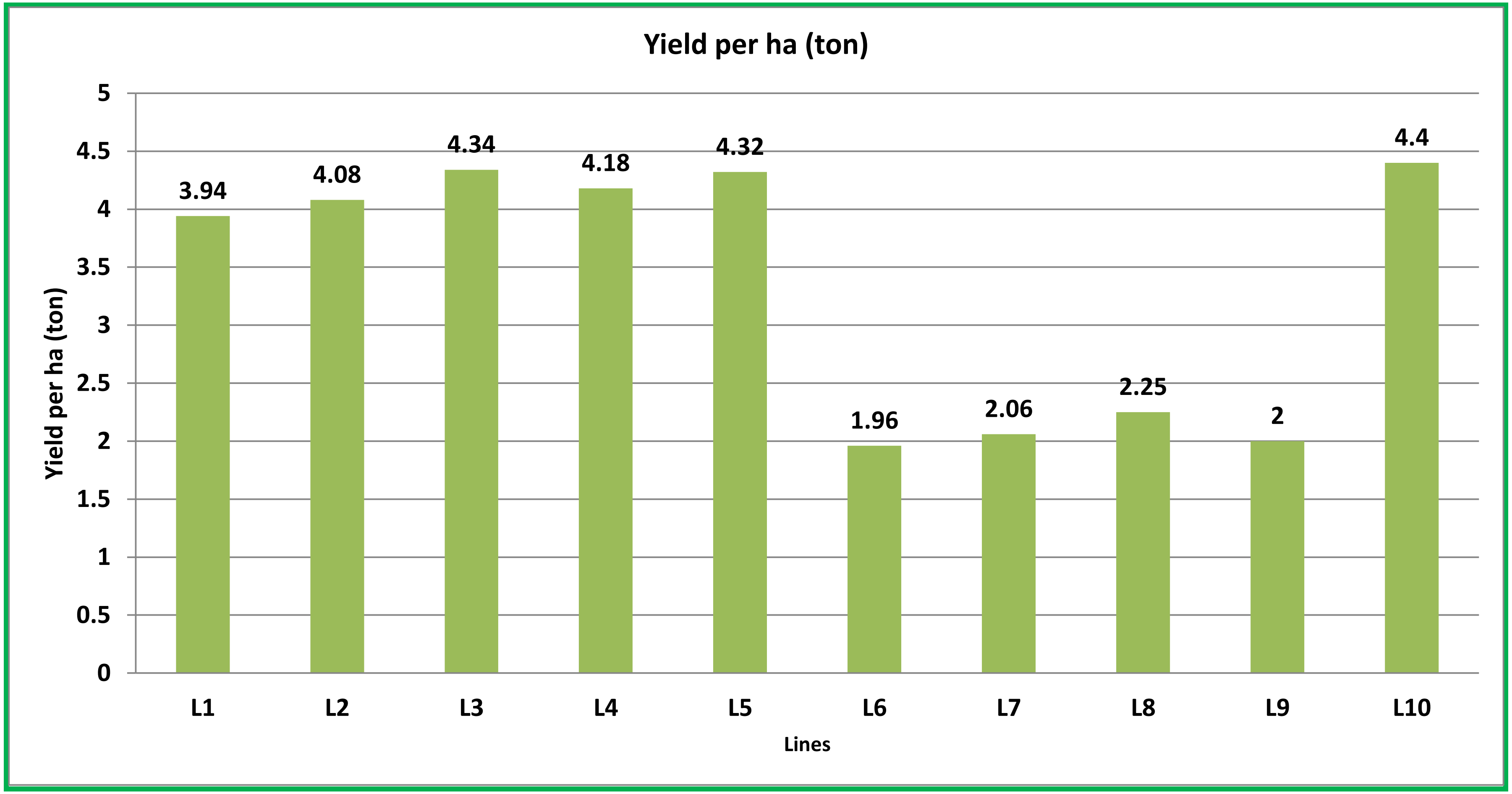


Figure 19. Variation in mean performance of 10 lines of yield per ha of rice

Yield/plant

The most important trait yield/plant was ranged from 8.6 g to 24.77 g. The average value of yield/plant was estimated 16.39 g. The highest yield/plant was observed by the line L10 which was statistically similar with L3 (20.47 g) and L5 (20.40 g) while line L9 showed the lowest yield/plant. A graphical demonstration of 10 lines was shown for mean yield/plant in Figure 18.

Yield/ha

Regarding the yield/ha, it was ranged from 1.96 ton to 4.40 ton with mean of 3.25 ton. Maximum yield/ha was obtained in both lines L10 which was statistically similar with L3 (4.34) and L5 (4.32) while line L6 showed the lowest value of this trait. The yield of L10 were high may be due to high effective tiller (12.10), high secondary branches/panicle (26.03), high panicle length (24.80 cm) and yield/plant (24.77 g). A graphical representation of variation was shown on mean performance of 11 genotypes for yield/ha of rice in Figure 19.

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from April to August 2017 to study the characterization and comparison of ten Aus rice lines. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. To establish distinctiveness among rice lines qualitative characters have been used. Qualitative traits are considered as morphological markers in the identification of genotypes of rice because they are less influenced by environment.

Ten rice lines were evaluated for thirty one qualitative and five quantitative traits of morphological characters to identify the genotypes as per DUS testing guidelines of rice. Aus rice lines also evaluated for yield and yield traits by variation and comparison study .All the lines scored exactly same for the characters viz. leaf sheath: anthocyanin color, leaf color, anthocynin coloration of auricles & collar, presence of leaf ligule, male sterility, microscopic observation of pollen, anthocyanin coloration of lemma and palea, anthocyanin coloration of lemma of area below apex, anthocyanin coloration of lemma of apex, stigma color, stigma exertion, culm diameter, anthocyanin coloration of stem nodes, anthocyanin coloration of stem internodes, panicle curvature of main axis, panicle exertion, pubescence of lemma & palea, color of the tip of lemma, awn in the spikelet, attitude of branches of panicle, Sterile lemma length, leaf senescence, decorticated grain (bran) color and grain aroma. Such result revealed that there was no variation for these traits among the test lines. Differences were found in the genotypes studied for rest of the aforesaid characteristics.

A wide range of variation was observed in all the genotypes for 12 qualitative and the quantitative character. Variation was observed in the traits like leaf pubescence, shape of the ligule, attitude of the blade of flag leaf, days to heading, days to maturity, 1000-grain weight, grain length (without dehulling), sterile lemma length, decorticated grain length (after dehulling), decorticated grain shape, culm length, panicle length and no. of effective tiller per plant.

Six lines (L1, L2, L3, L4, L5, L10) showed early time of heading. All ten lines showed well exerted panicle hence they are good for grain yield improvement. Six lines (L1, L2, L3, L4, L5, and L10) were early maturing type. Six lines (L1, L2, L3, L4, L5, and L8) showed long grain length and three lines (L1, L3, L5) showed high category of 1000-grain weight. Five lines (L4, L6, L7, L8, and L10) showed long type of grain length after dehulling with more than 7.5 mm of grain length.

Six lines (L1, L2, L3, L4, L5, and L10) were represented medium type of culm length. Two lines (L6, L7) were represented long type of culm length. Two lines (L7, L9) were observed long panicle and between 26-30 cm long. Five lines (L2, L3, L4, L6, and L10) were observed more effective tiller per plant (more than 10).

In the competitive study the analysis of variance indicated that the significant variation was observed among the different lines. Highest plant height was observed in line L9 while lowest in line L2. Line L10 showed highest significant number of total tiller per plant while line L1 represented the lowest value of this trait. The most significant number of effective tiller per plant was exhibited by line L10 while line L1 showed the lowest number for this trait. The line L8 represented the longest panicle while the shortest panicle length by line L5. The highest and lowest number of secondary branches/panicle was exhibited by the lines L8 and L2, respectively. Highest total no. of spikelets/panicle was observed by the line L8 while L5 showed the lowest no. of spikelets/panicle. The maximum number of filled grains of main tiller was observed in genotype L8 and minimum in line L4. The maximum value of thousand seed weight was observed in line L3 and minimum value in line L9. The highest yield/plant was observed by the line L10 while line L9 showed the lowest yield/plant.

The present study was done with an objective of characterizing the rice lines in qualitative and quantitative basis for studying eligibility of the Aus season. Out of 31 morphological traits observed, shape of the ligule, attitude of the blade of flag leaf, days to heading, days to maturity, 1000-grain weight, grain length (without dehulling), sterile lemma length, decorticated grain length (after dehulling), decorticated grain shape, culm length, panicle length and no. of effective tiller per plant showed most variation among the lines, from where we can select some lines. In this characterization and comparative studies L10, L5, L3 and L4 lines showed promising performance to study further if they are eligible to release as Aus variety.

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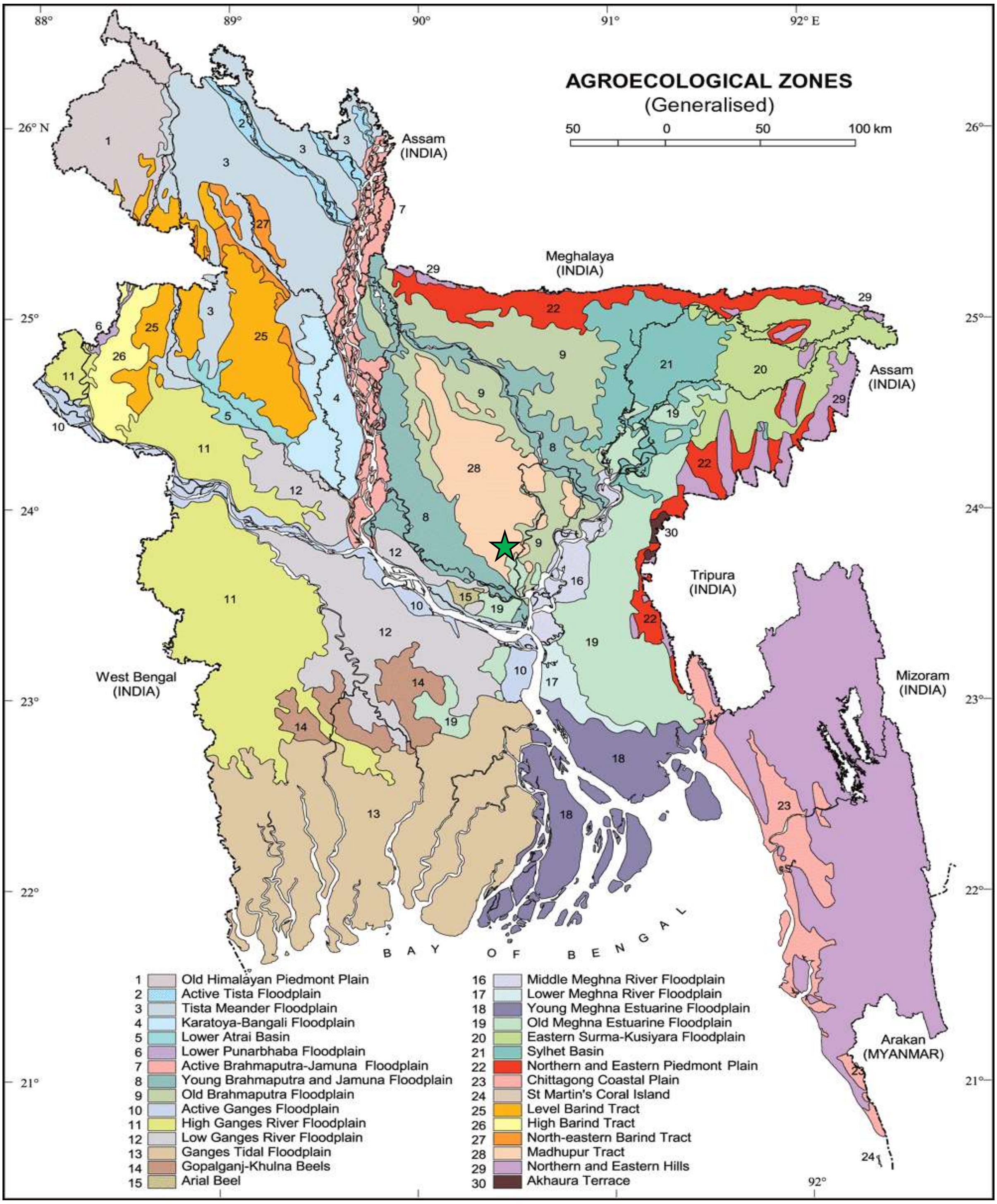
APPENDICES

Appendix I. Map showing the experimental site under the study



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

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Research Farm, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Deep Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical composition of the soil

Soil separates	**%**	**Methods employed**
Sand	26	Hydrometer method (Day, 1915)
Silt	45	Do
Clay	29	Do
Texture class	Silty loam	Do

C. Chemical composition of the soil

Sl. No	**Soil characteristics**	**Analytical data**	**Methods employed**
1	Organic carbon (%)	0.45	Walkley and Black, 1947
2	Total N (%)	0.03	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 (ppm)	20.54	Olsen and Dean, 1965
7	Exchangeable K (me/100 g soil)	0.10	Pratt, 1965
8	Available S (ppm)	16.00	Hunter, 1984
9	pH (1:2.5 soil to water)	5.6	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Source: Soil Resource and Development Institute (SRDI), Farmgate, Dhaka

Appendix III. Monthly average temperature, relative humidity and total rainfall and sunshine of the experimental site during the period from November, 2016 to February, 2017.

Month	**Air temperature (ºc)**		**Relative humidity (%)**	**Rainfall (mm) (total)**	**Sunshine (hr)**
	Maximum	**Minimum**			
November, 2015		18.0	77	227	**5.8**
December, 2016	32.4	16.3	69	0	**7.9**
January, 2017	29.1	13.0	79	0	**3.9**
February, 2017	**28.1**	**11.1**	**72**	**1**	**5.7**

Source: Bangladesh Meteorological Department (Climate & Weather Division), Agargoan, Dhaka – 1212