CHARACTERIZATION AND VARIABILITY STUDY AMONG 10 F9 AUS LINES

TAPOSI RABEYA

INSTITUTE OF SEED TECHNOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
SHER-E-BANGLA NAGAR, DHAKA -1207, BANGLADESH

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TAPOSI RABEYA
REGISTRATION NO. 13-05660

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Approved By:

Dr. Md. Shahidur Rashid Bhuiyan
Professor
Department of Genetics & Plant Breeding
Sher-e-Bangla Agricultural University
Supervisor

Prof. Dr. Md. Sarowar Hossain
Professor
Department of Genetics & Plant Breeding
Sher-e-Bangla Agricultural University
Co-Supervisor

Dr. Md. Ismail Hossain
Examination Committee
Department of Horticulture
Sher-e-Bangla Agricultural University

Dr. Md. Shahidur Rashid Bhuiyan
Professor
Department of Genetics and Plant Breeding
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207,
Bangladesh.
Mobile: +8801552467945

CERTIFICATE

This is to certify that thesis entitled, "**CHARACTERIZATION AND VARIABILITY STUDY AMONG 10 AUS LINES**" 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 **SEED TECHNOLOGY**, embodies the result of a piece of bona fide research work carried out by **TAPOSI RABEYA**, **Registration No. 13-05660** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2020
Dhaka, Bangladesh

Prof. Dr. Md. Shahidur Rashid Bhuiyan
Supervisor

DEDICATED TO

MY

BELOVED PARENTS

&

TEACHERS

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ABSTRACT

The present research work was conducted at the farm, Sher-e-Bangla Agricultural University (SAU), Dhaka during March, 2018- August, 2018 to characterization and variability study among 10 F9 Aus lines. Ten rice genotypes viz. L1= BRRI dhan29× BRRI dhan36, $S_2P_2P_4S_6$, L2= BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_6$, L3= BRRI dhan28×BRRI dhan29, $S_2P_4P_3S_3$, L4= BRRI dhan28×BRRI dhan29, $S_2P_4P_3S_2$, L5= BRRI dhan29×BRRI dhan36, $S_5P_2P_4S_5$, L6=BRRI dhan26×BRRI dhan28, $S_1P_9P_4S_1$, L7= BR 21×BRRI dhan29, $S_2P_1S_1$, L8= BR 21×BRRI dhan29, $S_6P_1P_1S_2$, L9=BR 21×BRRI dhan29, $S_6P_1P_1S_1$, L10= BR 24×BRRI dhan36, $S_8P_1P_1S_1$were used for this present study. The experiments were designed in a randomized complete block design (RCBD) with three replications. All data were analyzed by one-way analysis of variance (ANOVA) using MSTATC. Differences were found in the genotypes studied characteristics viz. penultimate leaf pubescence, penultimate leaf: shape of the ligule, flag leaf: attitude of the blade, time of heading (50% of plants with heads), time of maturity, grain length, decorticated grain length and polished grain: size of white core or chalkiness (% of kernel area) and rest of the characters found no variation. Seven lines (L3, L4, L5, L6, L7, L8, L10) showed long grain length and rest three lines (L1, L2, L9) showed very long category of grain length. Medium type of decorticated grain length were found in six lines (L3, L4, L6, L7, L8, L10) and rest four lines (L1, L2, L5, L9) found long type of grain length after dehulling. Six lines (L3, L4, L6, L7, L8, L10) were represented small and four lines (L1, L2, L5, L9) were showed medium size of white core of polished grain. The maximum number of ineffective tillers per plant (15.80) was recorded from L2 and the minimum number of ineffective tillers per plant (0.37) was recorded from L7. The highest panicle length (24.90 cm) was recorded from L7 and the lowest panicle length (22.17 cm) was recorded from L2. The highest number of filled spikelets per panicle (119.90) was recorded from L7 while the highest number of unfilled spikelets per panicle was recorded in L2 (88.93). The highest grain yield (3.83and 5.25 t ha^{-1}) was recorded from L7 and the lowest grain yield (1.19 and 3.23 t ha^{-1}) was observed in L2. The highest harvest index (43.10 %) was recorded from L7. Line L7 (BR 21× BRRI dhan29, $S_2P_1S_1$)was better cultivar in terms of quality, yield and yield contributing characters.

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List of Abbreviations of Technical Symbols and Terms

Full Word	**Abbreviation/ Symbol**
Agricultural	Agril.
Agriculture	Agric.
Analysis of Variance	ANOVA
And	&
And Others	*et al.*
Bangladesh Rice Research Institute	BRRI
Centimeter	cm
Coefficient of Variation	CV
Days After Transplanting	DAT
Degree Centigrade	°C
Gram	g
Journal	*J.*
Least Significant Difference	LSD
Litre	L
Metric Ton	MT
Millimeter	mm
Namely	viz.
Percentage	%
Randomized Complete Block Design	RCBD
Sher-E-Bangla Agricultural University	SAU
That is	i.e.
Ton	T

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) 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 glaberrirra* (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 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 produced in 1995 to meet the demands (Virmani *et al.*, 1997).

Rice is the staple food in Bangladesh, grown in a wide range of environment. Rice is the second largest produced cereal in the world in 161.1 million hectares area with annual production of about 758.9 million metric tons (Statista, 2018). Rice is the staple food for over one third of the world's population (Poehlman and Sleper, 1995) and more than 90% to 95% of rice is produced and consumed in Asia (Virmani, 1996). It provides 75% of the calories and 55% of the proteins in the average daily diet of the people (Bhuiyan *et al.*, 2002). The total rice production in Bangladesh is 36.2 MT among in Aus season rice cultivated area is 11.45 lac hectares and total production is 29 lac ton with average yield 2.55 t ha^{-1} (BBS, 2019).

In Bangladesh, the production of Aus rice is relatively low due to some biotic and abiotic factors. In Aus season highest amount of rainfall is observed than (Appendix III) any other seasons but we cannot use natural water since the production of Aus rice is significantly lower than Aman and Boro seasons. Else this, Aus rice face the maximum attack from pests and diseases. For this reason, we need to develop some advance lines so that it can show some sort of tolerancy or resistancy against pest and diseases. The advance lines (Table 1) are developed through crossing between some cultivars of Aus and Boro rice so that the lines can get short duration traits from Aus cultivars and high yielding traits from Boro cultivars.

Rice is consumed mainly in the form of a whole cooked milled grain. Therefore, the global rice demand is the amount of milled rice required. To obtain milled rice for consumption, removing the hull and bran layer of the whole rice grain is necessary. The majority of consumers prefer well milled rice with little or no bran remaining on the endosperm (Roy *et al.*, 2011). However, the germ and bran contain high level of minerals, proteins, and vitamins, so, milled rice which contains less food nutrients compared to that of brown rice (unpolished rice or whole grain) (Roy *et al.*, 2008).

Grain appearance including size, shape, and color is the first thing that consumers can be seen. This characteristic influences to consumer preference which varies greatly from region to region (Calingacion *et al.*, 2014). For instance, consumers in China, a large country prefer either short and bold grain, or grain that is long in size but with the grain shape ranging from medium to slender depending on the province (Calingacion *et al.*, 2014). The whiteness or translucency of milled rice is also an attractive to the rice consumer. The texture attribute of *hardness* was significantly different among bran colors, and 64% of the variance was explained by kernel density and bran thickness (Bett-Garber *et al.*, 2013). However, the relationship between the bran layer characteristics and cooking and eating properties of unpolished rice is not clearly understood. Even though the milled rice is the main form of rice consumption, rice flour is also a major ingredient in rice products such as rice noodles, rice paper, rice cakes, baked rice product, fermented rice products, rice milk and rice bran oil (Juliano, 1993). The quality of rice relates to consumer preference while the quality of rice flour is associated with rice characteristics of components, for example rice starch fine structures (Champagne, 2004, Prasert and Suwannaporn, 2009, Vandeputte *et al.*, 2003).

Over 90% people depend on rice for their daily diets. Rice sector contributes one-half of agricultural GDP and one-sixth of the national income in Bangladesh. The population of Bangladesh is still growing by two million every year and may increase by another 30 million over the next 20 years. But the average yield of rice is poor (3.13 tha^{-1}) in Bangladesh (BBS, 2019). However, rice production area is decreasing day by day due to high population pressure. Now modern high yielding varieties in Aus season are essential to increase the total rice production of Bangladesh. The high yielding varieties of Aus rice are developed through crossing between Aus rice and boro rice with the modern intension to increase the yield of Aus rice having genes from boro rice without much affecting the days to maturity. The present study is undertaken to characterize the variability and the quality characters of 10 F9 lines which is the prerequisite to release rice variety to fulfill the following objectives.

Objectives of the study

- To study the variability among the 10 advanced Aus lines.
- To select quality rich Aus lines.
- To select the short duration and higher yielding Aus rice lines for release.

CHAPTER II
REVIEW OF LITERATURE

Maclean *et al.* (2002) stated that 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 it is important 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.

According to Riley *et al.* (1995) characterization is a critical step to be carried out to identify accessions to find genetic relationships among genotypes. A flourishing plant breeding program 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 program. 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.

According to Thimmanna *et al.* (2000) the characters such as leaf length and Width, pubescence of leaf, leaf angle, ligule shape and color, 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 l participates in regulating leaf morphology through coordinating the regulation of constitutively wilted l/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 OsBZRl, 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 adecline 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 to75% 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 color, stigma color, lemma and palea color, lemma and palea pubescence etc. The specific genotypes B: 1340, B: 2039, B: 2495, B: 2816, B: 16930, B: Z354, 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 alteratives 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 emobilization 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

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 1000g 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 spikelets per panicle.

2.2 Variability and comparison

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 hada delay in their maturity. Early flowering indicates short life cycle and is considered a positive character for rice improvement.

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.

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.

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 28g. 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 angala, 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.

Numzzaman *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 27.50cm 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 MH2005 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 was observed between number of panicle/plant and panicle length.

2.2.4 Filled grain per panicle

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.

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: adaptability, 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 23.8g. In different trials, ADTRH1 showed 26.9g 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.

2.2.7 Grain yield

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 Badshahbhog 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 program 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 color and leaf sheath color, node base color, awning, distribution of awns, stigma color, anthocyanin coloration 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 color, awning and auricle color. 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 color (87.25 %), green leaf blade color (89.70%), pubescent leaf (48.03 %), well panicle exertion (57.10 %), white stigma color(65.93 %), straw apiculus color (78.18 %), compact panicle type (55.63 %), awnless (88.48 %), white seed coat (82.84 %), straw hull color (70.34 %),intermediate thresh ability (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 gemplasm accessions and characterized for fourteen quantitative and fifteen qualitative traits. The accessionsPKSLGR-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 agromorphological and quality traits and all 64 rice germplasm were found to be distinction 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 program.

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 color, color of ligule, shape of ligule, auricles, anthocyanin coloration of auricles and anthocyanin coloration 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.

Lapitan et al. (2007) stated that as such development of cultivars with good grain qualities is an important objective to emphasize in rice improvement programs. Grain appearance and culinary grain quality (milling, cooking and eating qualities) are the major criteria considered in evaluation of grain quality in a breeding program.

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 of rice. 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 from19.7 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 to3.12, 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.

According to Traore *et al.* (2011) 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.

Hai-mei *et al.* (2011) stated that 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.

IRRI (2009a) reported that 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 (2009b) reported that 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.

Mutters (2003) The accurate measurement of the amounts and classes of broken grains is very important to consumers and breeders.

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 IRS.

Parikh *et al.* (2012) evaluated 36 rice genotypes, 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 variability study among 10 F9 Aus lines" was carried out during the Aus season 2018. 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 March 2018 to August 2018. 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 6.1 and organic carbon content is 0.82%. The experiment area was above flood level and having available irrigation and drainage system and has been presented in Appendix III. 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 III.

3.3 Experimental materials

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

Table 1. List of the F9 lines used in the experiment with their source

Sl. No.	Line	Pedigree	Source
1	L1	BRRI dhan29× BRRI dhan36, $S_2P_2P_4S_6$	GEPB
2	L2	BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_6$	GEPB
3	L3	BRRI dhan28× BRRI dhan29, $S_2P_4P_3S_3$	GEPB
4	L4	BRRI dhan28× BRRI dhan29, $S_2P_4P_3S_2$	GEPB
5	L5	BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_5$	GEPB
6	L6	BRRI dhan26× BRRI dhan28, $S_1P_9P_4S_1$	GEPB
7	L7	BR 21× BRRI dhan29, $S_2P_1S_1$	GEPB
8	L8	BR 21× BRRI dhan29, $S_6P_1P_1S_2$	GEPB
9	L9	BR 21× BRRI dhan29, $S_6P_1P_1S_1$	GEPB
10	L10	BR 24× BRRI dhan36, $S_8P_1P_1S_1$	GEPB

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. Each replication size was 15m × 12m where 50cm boarder was maintained surrounding the field in every block. The unit plot size was 5m x 4m. 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. Soaked seeds were picked out from water and wrapped with straw and gunny bag to increase the temperature for facilitating germination. Seeds were sprouted properly after 72 hours.

3.6 Seedbed preparation and seedling raising

The seed bed was prepared by puddling the wetland with repeated ploughing followed by laddering. Germinated seeds were sown in the seedbed separately and proper tags were maintained (plate 1). Beds were protected from birds and other pest.

Plate 1: Photograph showing seedbed preparation

3.7 Preparation of main field

The land was prepared thoroughly by 3-4 ploughing followed by laddering to attain a good puddle (Plate 2). Weeds and stubbles were removed and the land was finally prepared by the addition of basal dose of fertilizers recommended by BRRI.

Plate 2: Photograph showing preparation of main field

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. The total urea and remaining MoP were applied in three installments (Plate 3), at l5 days after transplanting (DAT), 30 DAT and 45 DAT recommended by BRRI (2014).

Table 2. The doses of fertilizer applied in a hectare of land

SL NO	Fertilizers	Dose (Kg/ha)
1	Urea	261.45
2	TSP	97.11
3	MP	119.52
4	Gypsum	112.05
5	Zinc Sulphate	11.205

The second, third and fourth splits of urea were applied at 15, 30 and 45 days after transplanting (DAT), respectively (BRRI, 2011).

Plate 3: Photograph showing application of fertilizer

3.9 Transplanting of seedling

Healthy seedlings of 25 days old were transplanted on 4th April 2018 in separate strip of experimental field (Plate 4). Water level was maintained properly after transplanting. The distance between row to row was 25 cm and plant to plant was 15 cm.

Plate 4: Photograph showing transplanting of seedling

3.10 Intercultural operation

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

3.10.1 Gap filling

1st gap filling was done within ten days of transplanting on 14th April 2018.

3.10.2 Irrigation and drainage

Flood irrigation was given to maintain a constant level of standing water up to 6 cm in the early stages to enhance tillering, proper growth and development of the seedlings and l0-12 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 (Plate 5). Hand weeding was done at 25 and 40 days after transplanting.

Plate 5: Photograph showing weeding operation

3.10.4 Tagging

The tagging was placed in every plot on 10th May 2018.

3.10.5 Plant protection

Proper control measures were taken against rice stem borer during tillering and heading stage of rice (Plate 6). Diazinon SOEC was applied for controlling stem borer. Furadan 5G @ l kg per bigha was applied at active tillering stage and panicle initiation stage of rice for controlling rice yellow stem borer. Cupravit 80 WP @ 2.5 g per liter water was applied against bacterial leaf blight of rice.

Plate 6: Photograph showing application of insecticide

3.10.6 Harvesting, threshing and cleaning

The rice was harvested manually according to their maturity. Harvested crop from each crop was 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

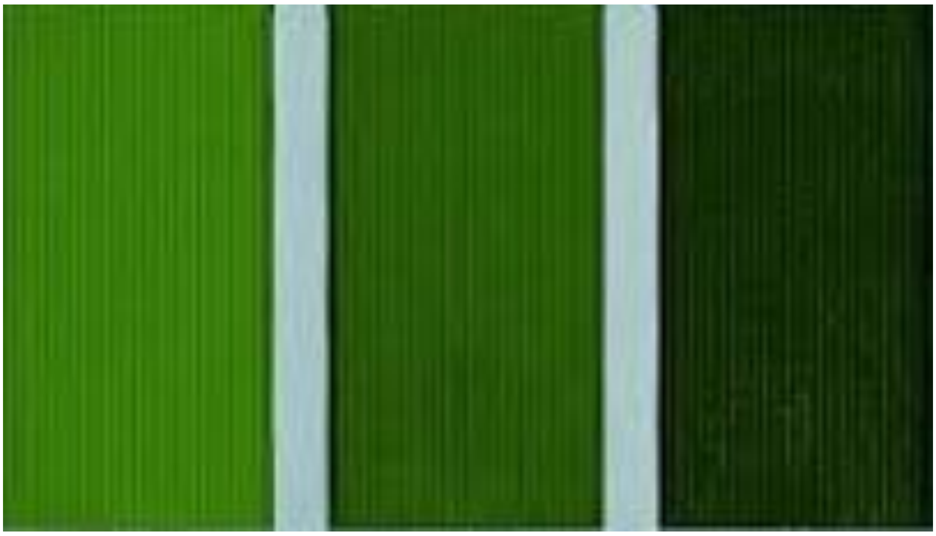
The experimental plots were visited frequently and required data were collected as per schedule. An appropriate data record book was used for keeping records of data related to identification of the genotypes. According to Rice descriptors data collection and recording was used. The photographs of specific 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-l 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 Plate 7 is 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.



Pale green Pale green Dark green

Plate 7: Photograph showing 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 anthocyanin coloration of auricles & collar

The anthocyanin coloration 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).

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 anthocyanin 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

Sl No.	Characteristics	Descriptors with Codes
7	Flag leaf: attitude of the blade	Erect (<300)-1, Intermediate or semi-erect (300 -450) -3, Horizontal (460 -900)-5, reflexed or descending (>900)-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 I2-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 orfew (<5%)-1, Low (5-20%)-3, Medium (21-40%)-5, High (41-60%)-7, Very high (>61%)-9

Sl No.	Characteristics	Descriptors with Codes
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
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

Sl No.	Characteristics	Descriptors with Codes
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 2 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 plate 8.

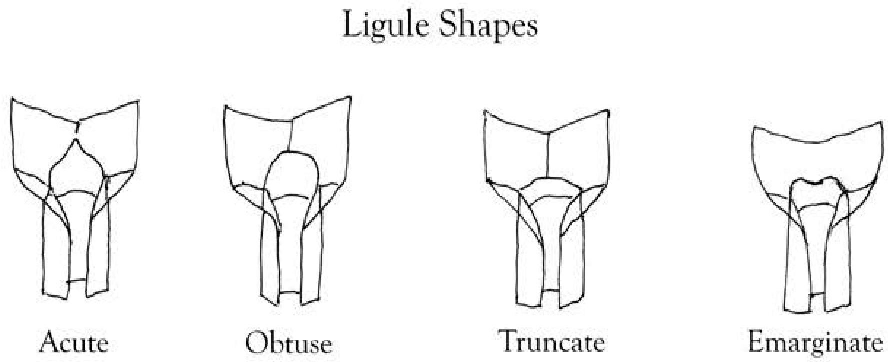


Plate 8. Diagram ligule Shape

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). Plate 9 is showing the flag leaf attitude.

Erect (<30°)-1,

Intermediate or Semi-erect (300-45°)-3,

Horizontal (460-90°)-5 and

Reflexed or descending (>900)-7.

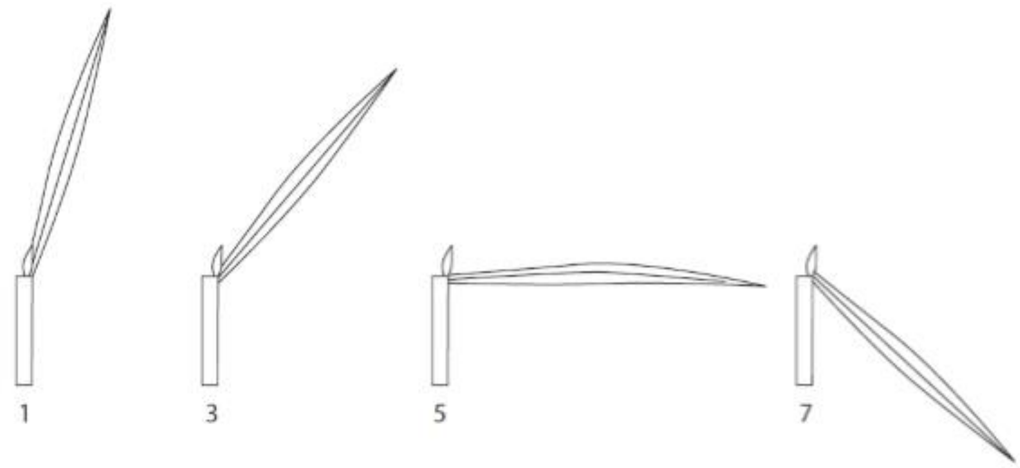


Plate 9. Diagram flag leaf attitude (1-erect, 3-semi erect, 5- horizontal and 7-descending)

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)-l

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-Kl solution

Microscopic observation of pollen was observed at anthesis period of rice using Ig-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-l, 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-l, Weak-3, Medium-5, Strong-7 and Very strong-9.

3.11.1.13 (a) Color of stigma

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

3.11.1.13 (b) 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 (>6l%)-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 (5.1-6.0mm)-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 coloration 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-l and Present-9.

3.11.1.16 Stem: anthocyanin coloration of internodes

The presence or absence of anthocyanin coloration 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 color 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. Plate 10 is represented the rice grain with awn.

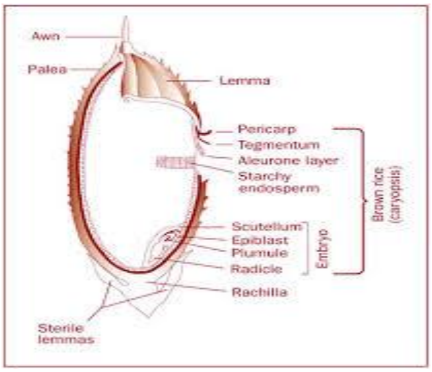


Plate 10: Diagram rice grain showing different parts

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. Plate 11 is showing the attitude of different panicle branching.

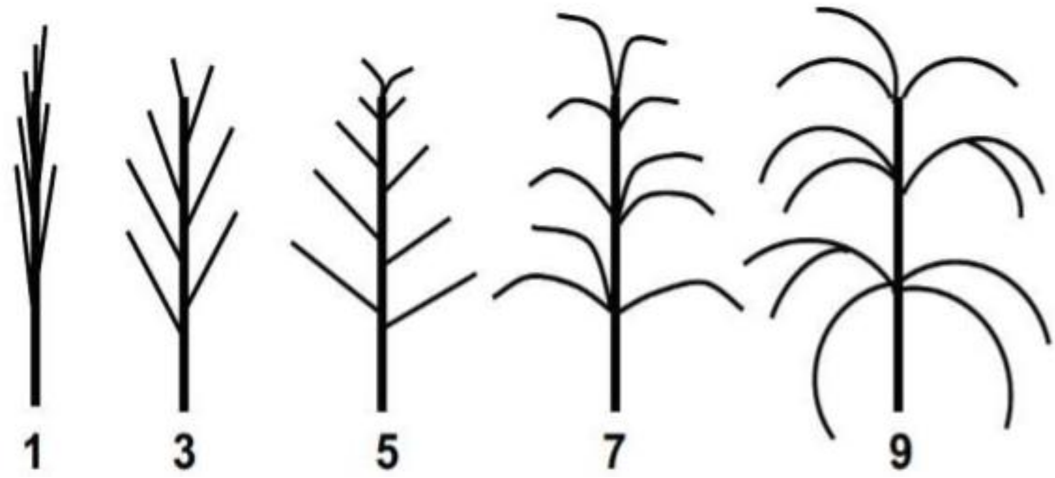


Plate 11. Diagram attitude of panicle branches

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). Plate 12 is represented panicle exertion of rice lines.

Enclosed-1,

Partly exerted-3, Just exerted-5,

Moderately exerted-7 and Well exerted -9.

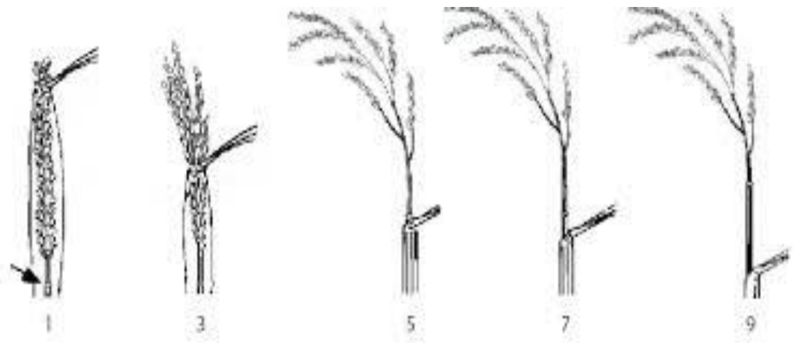


Plate 12: Diagram panicle exertion

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 groups:

Very early (<l00 days)-l

Early (101-115 days)-3

Medium (116-135 days)-5

Late (136-150 days)-7 and 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 plate 13, the sterile lemma and palea is shown.

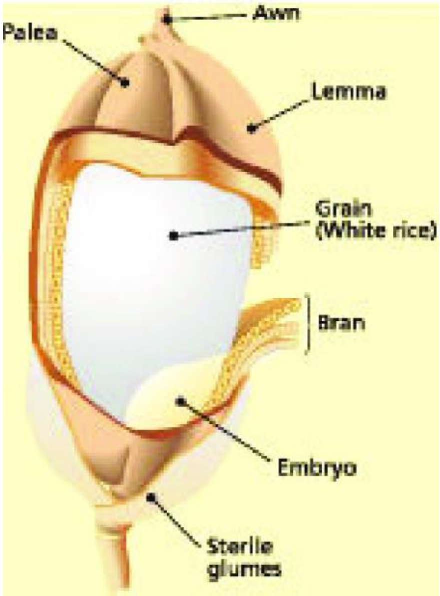


Plate 13: Diagram lemma and palea of rice grain

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 genotype 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). Plate 14 is showing the procedure measuring grain shape.

Round (L: W<l.5)-l

Bold (L: W=l.5-2.0)-3

Medium (L: W=2.l-2.5)-5

Medium slender (L: W=2.6-3.0)-7 and Slender (L: W>3.0)-9.

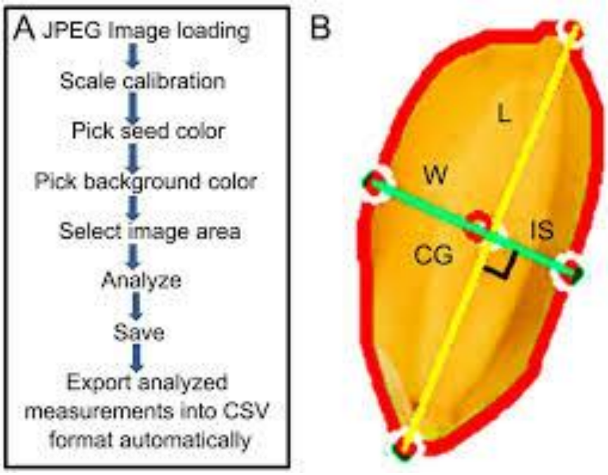


Plate 14: Diagram grain shape measuring procedure

3.11.1.29 Decorticated grain (bran): color

The color 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- l, Light brown-2, Variegated brown-3, Dark brown-4, Red-5, Variegated purple-6 and Purple-7. Plate 15 is showing bran color of rice.

Plate 15: Photograph showing 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 (<l0%)-3,

Medium (1 1-20%)-5 and Large (1 l-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 (Jermings *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-l, 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) and plate 16 is showing the morphology of a rice plant.

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

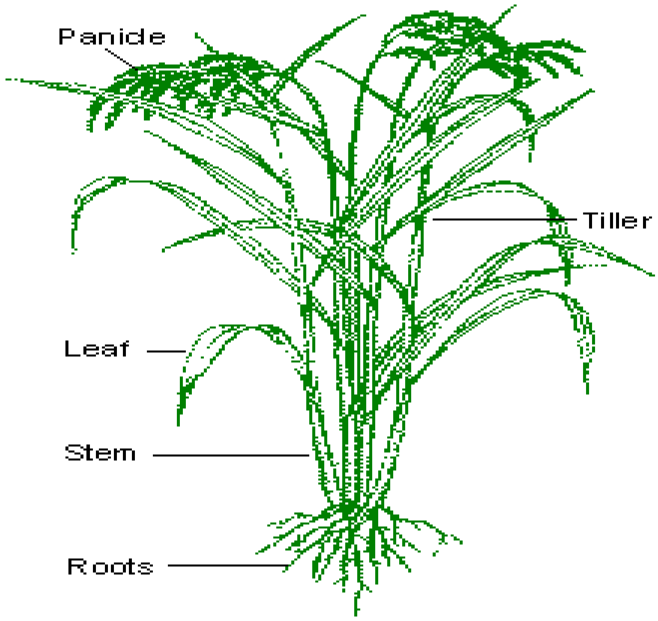


Plate 16: Diagram morphology of a rice plant

Table 4. Stem length parameter

SI. NO.	Characteristics	Descriptors with Codes
1	Stem length (culm length)	Very short-< 40 cm, Short-41-60cm, Medium-61-80 cm, Long-81-110cm and Very long-> 110cm
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 (21-25cm)-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

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 Number of tillers per plant

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

3.11.2.4 Number of effective tillers 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.

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 Number of spikelets per panicle

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

3.11.2.7 Number of filled grain of main tiller

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

3.11.2.8 Number 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.

3.11.2.9 1000 grain 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.

3.11.2.10 Grain yield (t ha^{-1})

Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central $1m^2$ area and five sample plants were added to the respective unit plot yield to record the final grain yield $plot^{-1}$ and finally converted to t ha^{-1} in both locations.

3.11.2.11 Straw yield (t ha^{-1})

Straw obtained from each unit plot including the straw of central $1m^2$ and five sample plants of respective unit plots was dried in the sun and weighed from both locations to record the straw yield $plot^{-1}$ and finally converted to t ha^{-1}.

3.11.2.12 Harvest index (%)

Straw of the 1 m^2 harvested area of both locations were dried in sunlight to a constant weight and dry weight was taken. It indicates the ratio of economic yield (grain yield) to biological yield (grain yield + straw yield) and was calculated by the following formula (Gardner *et al.*, 1985):

$$\text{Harvest index (\%)} = \left[\frac{\text{Grain yield (t ha}^{-1})}{\text{Biological yield (t ha}^{-1})} \times 100\right]$$

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 analysis like analysis of variance (ANOVA), mean, range (LSD) were calculated by using MSTATC software program.

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 17**.**

		
L8	L9	L7

Plate 17: Photograph showing leaf sheath anthocyanin color

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 dark 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 plants 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 18.

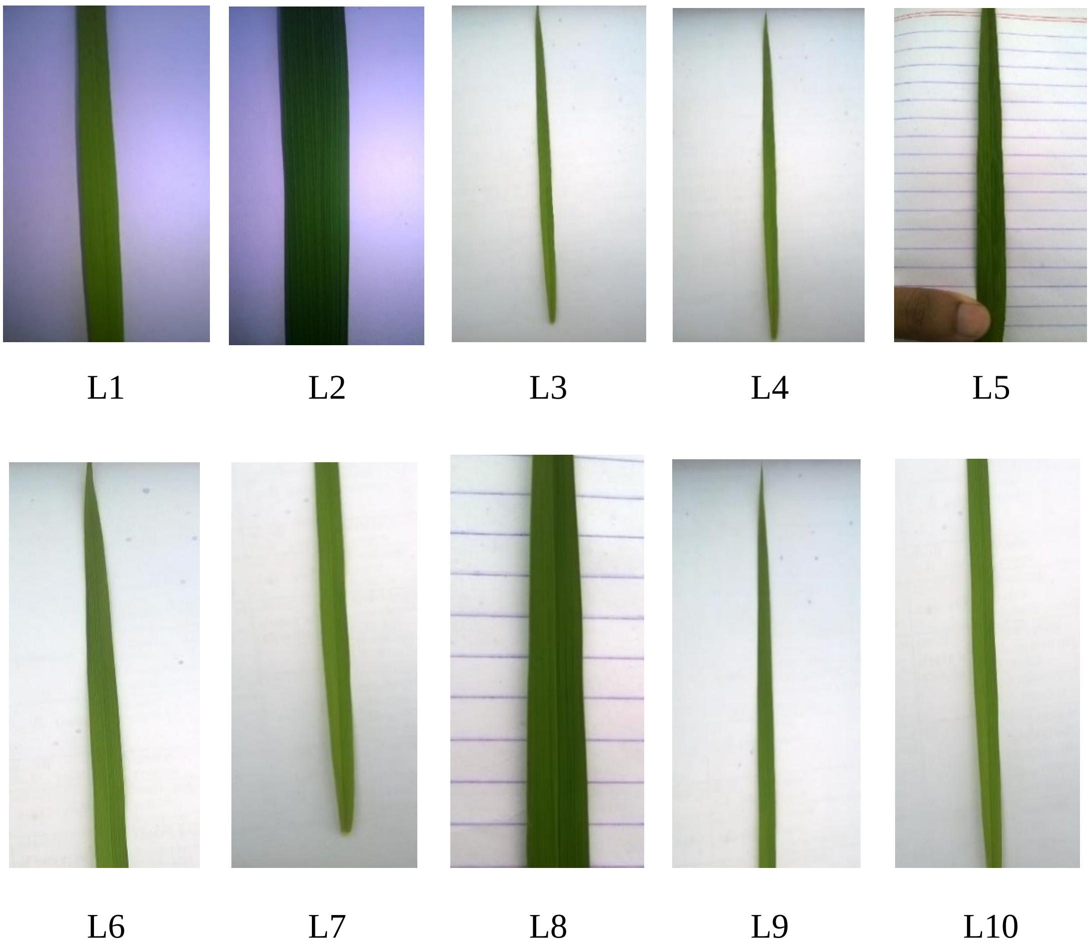


Plate 18. Photograph showing leaf color (code 3) of 10 line

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 in 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 (L1, L2, L5 and L9) represent weak or only on the margin type pubescence and rest six lines (L3, L4, L6, L7, L8 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 1.

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**	L1, L2, L5, L9
Medium hairs on the lower portion of the leaf	**5**	L3, L4, L6, L7, L8, L10
Strong hairs on the leaf blade	**7**	**Nil**
Very strong	**9**	**Nil**

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 19.

L4 L7 L8

Plate 19: Photograph showing anthocyanin coloration of auricles and color of penultimate leaf

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.

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, L5 and L6) were truncate type, one line(L9) acute and rest five lines (L3, L4, L7, L8, L10) were split or 2-cleft type shape of ligule (Table 6). A pictorial view of shape of 2-cleft ligule of penultimate leaf is presented in Plate 20. 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 program.

Table 6. Categorization and grouping based on shape of the ligule

Types	Code	Lines
Truncate	**1**	L1, L2, L5, L6
Acute	**2**	L9
Split or two-cleft	**3**	L3, L4, L7, L8, L10

Plate 20: Photograph showing 2-cleft ligule of penultimate leaf of L10

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 (<300)-1, intermediate or semi-erect (300-450)-3, horizontal (460-900)-5 and reflexed or descending (>900)-7 type. Here four lines (L4, L7, L8, L10) showed erect type flag leaf and rest six lines (L1, L2, L3, L5, L6, L9) showed intermediate or semi erect type flag leaf (Table 7). Pictorial view of attitude of the blade of flag leaf is presented in Plate 21. 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.

L7 L1

Plate 21: Photograph showing attitude of the blade

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

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

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 (106-120days)-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 (L3, L4, L6, L7, L8 and L9) showed very early time of heading and rest four lines (L1, L2, L5, L10) showed early time of heading (Table 8). Flowering duration is an important character that is frequently considered before release of a variety for commercial cultivation (Shahidullah *et al.*, 2009).

Table 8. Categorization and grouping based on time of heading

Types	**Code**	**Lines**
Very early (<70 days)	**1**	L3, L4, L6, L7, L8, L9
Early (70-85 days)	**3**	L1, L2, L5, L10
Medium (86-105 days)	**5**	**Nil**
Late (106-120 days)	**7**	**Nil**
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 combinedly 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, strong-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 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 Green-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 22**.**

Plate 22: Photograph showing 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 (>7.0mm). 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. Absence of anthocyanin coloration of nodes was observed among all lines. A pictorial view of anthocyanin coloration of nodes is present in Plate 23.

Plate 23: Photograph showing 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 24. 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.

Plate 24: Photograph showing 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 awn less 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 program for the purpose of increasing rice production. Pictorial view of attitude of branches of panicle is presented in Plate 25.

Plate 25: Photograph showing attitude of branches of panicle

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).

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 (L3, L4, L6, L7, L8, L10) were found very early maturing type and rest of the three lines (L1, L2, L5) were found as early maturating type and only L9 line was found medium maturing type (Table 9). 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 26 represented 80% maturity stage of rice lines.

Palate 26: Photograph showing 80% maturity stage

Table 9. Categorization and grouping based on time of maturity

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

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 seven lines (L3, L4, L5, L6, L7, L8, L10) showed long grain length and rest three lines (L1, L2, L9) showed very long category of grain length. Table 10 and plate 27 are showing the grain length variation.

Table 10. Categorization and grouping based on grain length

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 mm)	**7**	L3, L4, L5, L6, L7, L8, L10
Very long (>9.0 mm)	**9**	L1, L2, L9

Plate 27: Photograph showing grain length

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 (>3.0mm)-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 (>7.5mm)-7. In this experiment there were found two types of decorticated grain length. Six lines (L3, L4, L6, L7, L8, L10) were represented medium type of decorticated grain length. Rest four lines (L1, L2, L5, L9) showed long type of grain length after dehulling (Table 11). Long grain length (after dehulling) was represented in Plate 28.

Table 11. Categorization and grouping based on decorticated grain length (after dehulling)

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

Plate 28: Photograph showing decorticated grain

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. All lines 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 program 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 29.

Plate 29: Photograph showing decorticated grain (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 (>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 (L3, L4, L6, L7, L8, L10) were represented small and four lines (L1, L2, L5, L9) were showed medium size of white core of polished grain (Table 12).

Table 12. Categorization and grouping based on size of white core or chalkiness of polished grain

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

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 Plant height (cm)

Plant height of 10 advance lines varied significantly (Appendix IV). The highest plant height (123.57 cm) was recorded in L9 (BR 21× BRRI dhan29, $S_6P_1P_1S_1$) which was taller than other nine lines and L6 showed the lowest plant height which is statistically similar with L1, L2, L3, L5, L6, L7, L8 and L10 (Table 13). Plant height of L9 was different from other nine lines. It has been seen that plant height has a significant positive relationship with days to maturity. As the days to maturity (145 days) of L9 line is highest its height (123.57 cm) is also highest.

Table 13: Performance of growth and yield contributing characters of 10 F9 Aus rice

Line	Plant height (cm)	Days to 50% flowering	Days to Maturity	No. of tiller plant^{-1}	No. of effective tiller plant^{-1}	No. of ineffective tiller plant^{-1}
L1	102.73b	93.67a	134.00b	13.89c	12.80c	1.09ab
L2	102.93b	93.67a	134.00b	12.57c	11.27c	1.30a
L3	102.40b	89.00cd	112.67d	14.23c	13.53c	0.70cd
L4	96.80b	82.00e	110.00de	17.77b	17.17b	0.60de
L5	102.83b	93.33ab	130.00b	12.94c	12.07c	0.88bc
L6	98.67b	90.33b-d	121.33c	13.97c	12.83c	1.13a
L7	102.73b	84.00e	107.00e	21.17a	20.80a	0.37e
L8	100.97b	88.33e	102.33de	19.40ab	19.00ab	0.40e
L9	123.57a	85.00e	145.00a	12.80c	12.07c	0.73cd
L10	101.07b	92.00a-c	109.00de	18.13b	17.60b	0.53de
LSD $_{(0.05)}$	6.26	3.29	4.89	2.46	2.38	0.24
CV (%)	3.53	2.78	2.87	9.15	9.31	18.49

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

L1= BRRI dhan29× BRRI dhan36, $S_2P_2P_4S_6$, L2= BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_6$, L3= BRRI dhan28× BRRI dhan29, $S_2P_4P_3S_3$, L4= BRRI dhan28× BRRI dhan29, $S_2P_4P_3S_2$, L5= BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_5$, L6=BRRI dhan26× BRRI dhan28, $S_1P_9P_4S_1$ L7= BR 21× BRRI dhan29, $S_2P_1S_1$, L8= BR 21× BRRI dhan29, $S_6P_1P_1S_2$, L9=BR 21× BRRI dhan29, $S_6P_1P_1S_1$, L10= BR 24× BRRI dhan36, $S_8P_1P_1S_1$.

4.2.2 Days to 50% flowering

Days to 50% flowering of 10 different lines of rice varied significantly (Appendix IV). The maximum days to 50% flowering (93.67 days) was recorded from L1 (BRRI dhan29× BRRI dhan36, $S_2P_2P_4S_6$) and L2 (BRRI dhan29× BRRI dhan36, S2P2P4S6) which is statistically similar with L5 and L10 line whereas the minimum days (82.00 days) was recorded from L4 (BRRI dhan28×

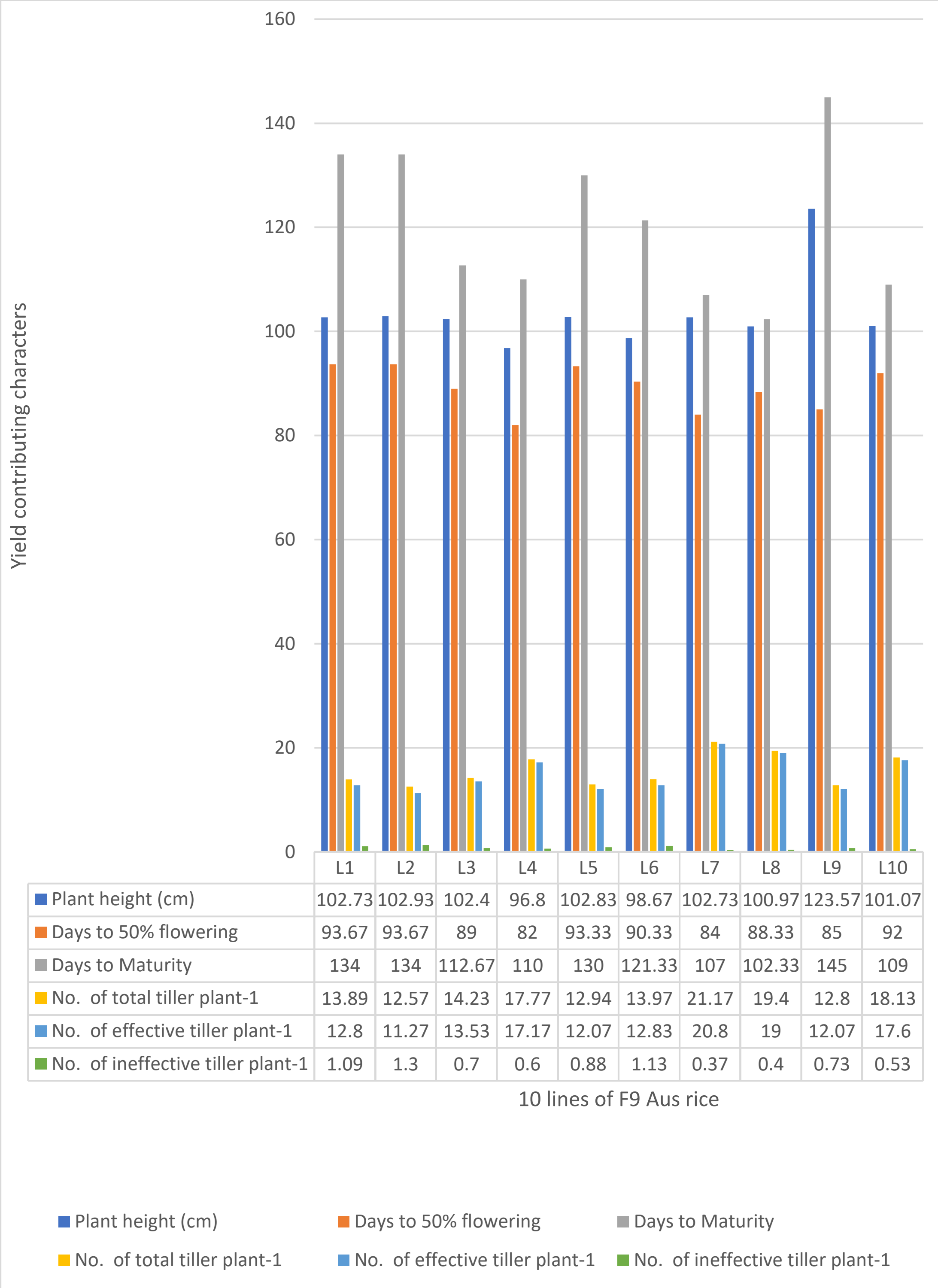
BRRI dhan29), which was statistically similar with the line L7 and L9 (Table 13). Days to 50% flowering has no significant co-relation with other growth and yield contributing characters.

		
L7	**L8**	**L10**

Plate 30: Photograph showing variation in flowering among different lines

4.2.3 Days to maturity

Days to maturity of 10 F9 different lines of Aus rice varied significantly (Appendix IV). The maximum days to maturity (145.00) was found in line L9 (BR 21× BRRI dhan29, $S_6P_1P_1S_1$) followed by L1 and L2. The line L8 (BR 21× BRRI dhan29) had the shortest maturity period 102 days which was statistically similar with line L7 and Line L10. The L7(BR 21× BRRI dhan29, $S_2P_1S_1$) line also showed minimum 50% flowering (Table 13). These short duration lines can a good source for future trial. Variations in duration of crop could be utilized directly under varied agro-ecological situation as well as breeding program. Days to maturity has a reverse significant relationship with plant height. If plants with higher height tends to take more days to mature.



	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
Plant height (cm)	102.73	102.93	102.4	96.8	102.83	98.67	102.73	100.97	123.57	101.07
Days to 50% flowering	93.67	93.67	89	82	93.33	90.33	84	88.33	85	92
Days to Maturity	134	134	112.67	110	130	121.33	107	102.33	145	109
No. of total tiller plant-1	13.89	12.57	14.23	17.77	12.94	13.97	21.17	19.4	12.8	18.13
No. of effective tiller plant-1	12.8	11.27	13.53	17.17	12.07	12.83	20.8	19	12.07	17.6
No. of ineffective tiller plant-1	1.09	1.3	0.7	0.6	0.88	1.13	0.37	0.4	0.73	0.53

Figure 1. Performance of growth and yield contributing characters of 10 F9 Aus rice

L7

L8

L10

Plate 31: Photograph showing variation in days to maturity in different lines

4.2.4 Number of tillers per plant

Number of tillers per plant of different F9 lines of rice varied significantly (Appendix IV). The maximum number of tillers per plant (21.17) was recorded L7 (BR 21× BRRI dhan29, $S_2P_1S_1$,), which was similar to L8 (19.40). The minimum number (12.57) was recorded from L2 (BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_6$) which was statistically with L5 and L9 (Table 9). Similar trend is also observed in case of effective tillers per plant. Number of effective tillers per plant showed positive relation with grain yield. It has been seen that L7 (20.08), which produces highest number of tillers per plant also showed maximum yield (3.83 t ha^{-1}) (Table 13).

4.2.5 Number of effective tillers per plant

Number of effective tillers per plant of different F9 line of Aus rice varied significantly (Appendix IV). The highest number of effective tillers per plant (20.80) was recorded L7 (BR 21× BRRI dhan29, $S_2P_1S_1$,), which was similar to L8 (19.00). Lowest number of effective tiller (11.27) was recorded from L2 (BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_6$) which was statistically with L1, L3, L5, L6 and L9 (Table 13). Similar trend is also observed in case of tillers per plant. Earlier many workers reported that higher numbers of productive tillers are responsible for higher yield (Pandey *et al.*, 1995; Reddy and Ramachandraiah, l995*;* Padmavathi *et al.*,1996; Rao *et al.*, 1996). According to new plant type concept of Khush (1999) reduced tillering habit (6-10 tillers/plant) would give higher yield than the modem varieties having 20-25 tillers. He observed that only 14-15 of these tillers produce panicles which are small and rest remaining unproductive. Reduced tillering facilitates synchronous flowering and maturity and more uniform panicle size. Genotypes with lower tiller number are also reported Lo produce a larger proportion of heavier grains (Padmaja Rao, 1987).

4.2.6 Number of ineffective tillers per plant

Number of ineffective tillers per plant of different F9 lines of rice varied significantly (Appendix IV). The highest number of ineffective per plant (1.30) was recorded L2 (BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_6$), which was similar to L6 (1.13). The lowest number of ineffective tillers per plant (0.37) was recorded from L7 which was statistically with L8 and L10 (Table 13).

L7	L8	L10

Plate 32: Photograph showing variation in number of tillers per plant in different lines

4.2.7 Panicle length (cm)

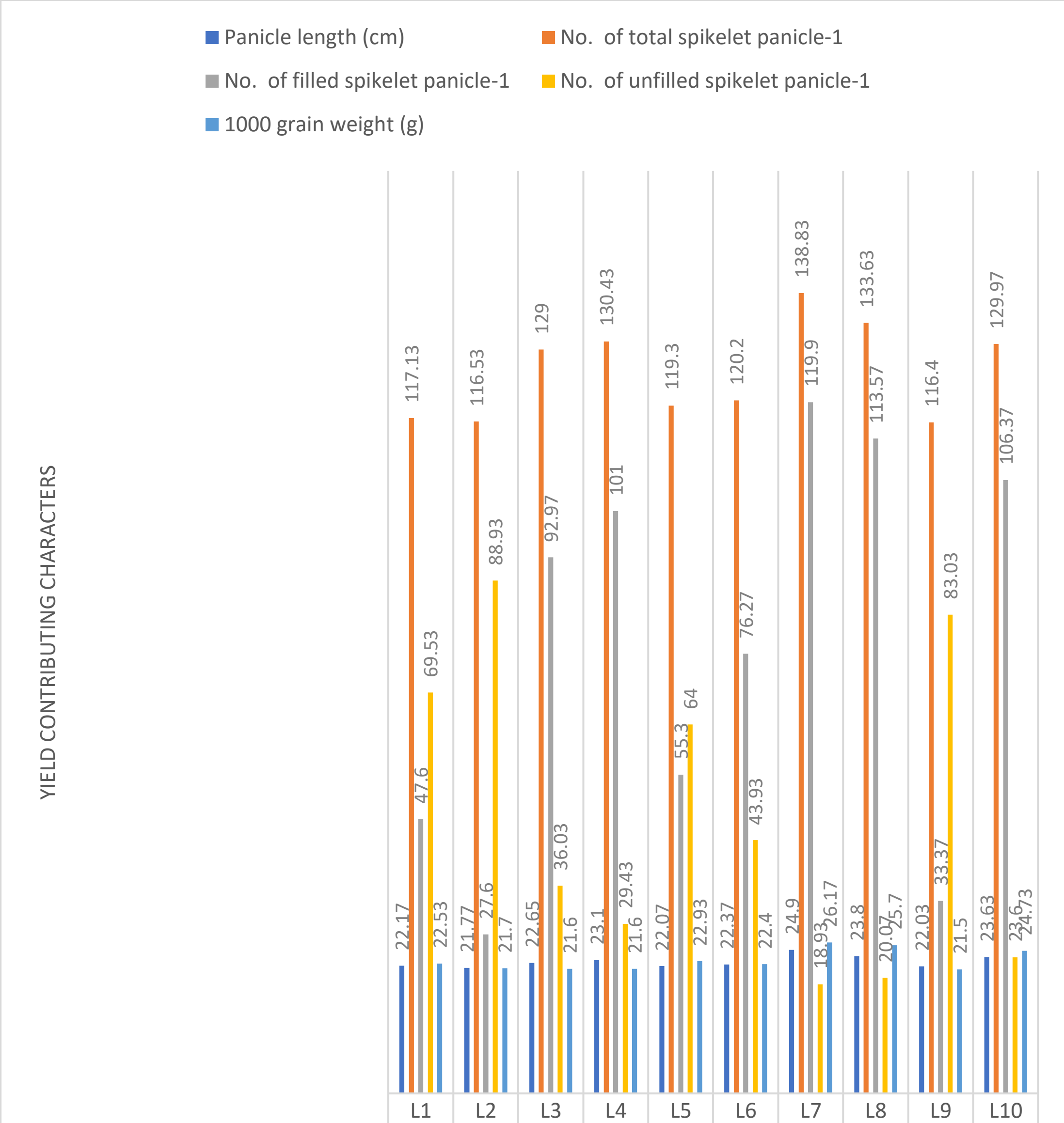
Panicle length was significantly varied on different F9 lines of Aus rice (Appendix V). The highest panicle length (24.90 cm) was recorded from L7 (BR 21× BRRI dhan29, $S_2P_1S_1$) and the lowest panicle length (21.17 cm) was recorded from L2 (BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_6$) which was statistically similar with L1, L5 and L9 (Table 10). The rest of lines showed different panicle length. It has been observed that L7 with produces largest panicle in length (24.90 cm) also showed maximum yield (3.83 t ha^{-1}) (Table 14).

Table 14. Performance of yield contributing characters of 10 F9 Aus rice

Line	Panicle length (cm)	No. of spikelet panicle^{-1}	No. of filled spikelet panicle^{-1}	No. of unfilled spikelet panicle^{-1}	1000 grain weight (g)
L1	22.17de	117.13d	47.60f	69.53b	22.53b
L2	21.77e	116.53d	27.60g	88.93a	21.70b
L3	22.65cd	129.00bc	92.97d	36.03d	21.60b
L4	23.10bc	130.43ab	101.00c	29.43e	21.60b
L5	22.07de	119.30d	55.30f	64.00b	22.93b
L6	22.37c-e	120.20cd	76.27e	43.93c	22.40b
L7	24.90a	138.83a	119.90a	18.93f	26.17a
L8	23.80b	133.63ab	113.57ab	20.07f	25.70a
L9	22.03de	116.40d	33.37g	83.03a	21.50b
L10	23.63b	129.97ab	106.37a	23.60ef	24.73a
$LSD_{(0.05)}$	0.79	9.44	7.86	5.99	1.51
CV (%)	2.04	4.40	5.92	7.32	3.83

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

L1= BRRI dhan29× BRRI dhan36, $S_2P_2P_4S_6$, L2= BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_6$, L3= BRRI dhan28× BRRI dhan29, $S_2P_4P_3S_3$, L4= BRRI dhan28× BRRI dhan29, $S_2P_4P_3S_2$, L5= BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_5$, L6=BRRI dhan26× BRRI dhan28, $S_1P_9P_4S_1$ L7= BR 21× BRRI dhan29, $S_2P_1S_1$, L8= BR 21× BRRI dhan29, $S_6P_1P_1S_2$, L9=BR 21× BRRI dhan29, $S_6P_1P_1S_1$, L10= BR 24× BRRI dhan36, $S_8P_1P_1S_1$.



	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
Panicle length (cm)	22.17	21.77	22.65	23.1	22.07	22.37	24.9	23.8	22.03	23.63
No. of total spikelet panicle-1	117.13	116.53	129	130.43	119.3	120.2	138.83	133.63	116.4	129.97
No. of filled spikelet panicle-1	47.6	27.6	92.97	101	55.3	76.27	119.9	113.57	33.37	106.37
No. of unfilled spikelet panicle-1	69.53	88.93	36.03	29.43	64	43.93	18.93	20.07	83.03	23.6
1000 grain weight (g)	22.53	21.7	21.6	21.6	22.93	22.4	26.17	25.7	21.5	24.73

10 F9 LINES OF AUS RICE

Figure 2. Performance of yield contributing characters of 10 F9 Aus rice

4.2.8 Number of spikelets per panicle

Number of spikelets per panicle of different F9 lines of Aus rice varied significantly (Appendix V). The highest number of spikelets per panicle (138.83) was recorded from L7 (BR 21× BRRI dhan29, $S_2P_1S_1$) while the lowest number (116.40) recorded from L9 (BR 21× BRRI dhan29, $S_6P_1P_1S_1$) which was statistically similar with L1, L2, L5 and L6 (Table 14). Positive association between grain number per panicle and grain yield has been reported by number of workers (Chauhan *et al.*, 1986; Janagle *el al.*, 1987; Kalaimani and Kadambavanaundaram, 1988).

4.2.9 Number of filled spikelet per panicle

The highest number filled spikelet per panicle (119.90) was recorded in L7 (BR 21× BRRI dhan29, $S_2P_1S_1$) which was which was statistically similar with L8 and L10. The lowest number filled spikelet (27.60) per panicle was recorded in L2 (BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_6$) which was statistically similar with L9 (BR 21× BRRI dhan29, $S_6P_1P_1S_1$) (Table 14). Rest of the population showed different number of filled grains per panicle.

4.2.10 Number of unfilled spikelets per panicle

The highest number unfilled spikelet per panicle was recorded in L2 (88.93) which was statistically similar with L9. The lowest number of unfilled spikelets per panicle was recorded in L7 (18.93) which was statistically similar with L8. Rest of populations showed different number of unfilled grains per panicle (Table 14).

4.2.11 Thousand seed weight (gm)

The highest 1000-seed weight (26.17) was recorded from L7 (BR 21× BRRI dhan29, $S_2P_1S_1$) which was statistically similar with L8 and L10. The lowest 1000-seed weight (21.50) was recorded from L9 which was statistically similar with L2, L3 and L4 (Table 14).

4.2.12 Grain yield (ton ha^{-1})

Grain yield of different F9 lines of Aus rice varied significantly (Appendix VI). The highest grain yield (3.83 t ha^{-1}) was recorded from L2 (BRRI dhan29× BRRI dhan36) whereas the lowest grain yield (1.19 t ha^{-1}) recorded from L9 (BR 21× BRRI dhan29, $S_6P_1P_1S_1$). Rest of population showed different yield per plant (Table 15). Recorded data shows significant relation with grain yield and some yield contributing factors, viz. number of tillers per plant, number of effective tillers per plant, panicle length, number of spikelets per panicle and number of filled spikelets per panicle. With the higher values of the characters grain yield increases. Among all other lines L7 showed significantly higher values of these characters and maximize its grain yield from other lines. Sadeghi (2011) observed positive significant association of grain yield with grains per panicle, days to maturity and number of productive tillers. Hairmansis *et al.* (2010) recorded a positive and significant association of grain yield with filled grains per panicle, spikelet per panicle and spikelet fertility.

Table 15. Performance of yield characters of 10 F9 Aus rice

Line	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest Index (%)
L1	1.71h	3.50d	32.77de
L2	1.19j	3.23e	26.81f
L3	2.64e	5.00ab	34.56d
L4	3.02d	5.22a	36.65c
L5	2.18g	4.75c	31.43e
L6	2.45f	4.81bc	33.73d
L7	3.83a	5.05ab	43.10a
L8	3.47b	5.25a	39.77b
L9	1.39i	3.44de	28.68f
L10	3.25c	5.15a	38.68b
$LSD_{(0.05)}$	0.17	0.25	1.93
CV (%)	4.57	3.79	2.35

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.

L1= BRRI dhan29× BRRI dhan36, $S_2P_2P_4S_6$, L2= BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_6$, L3= BRRI dhan28× BRRI dhan29, $S_2P_4P_3S_3$, L4= BRRI dhan28× BRRI dhan29, $S_2P_4P_3S_2$, L5= BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_5$, L6=BRRI dhan26× BRRI dhan28, $S_1P_9P_4S_1$ L7= BR 21× BRRI dhan29, $S_2P_1S_1$, L8= BR 21× BRRI dhan29, $S_6P_1P_1S_2$, L9=BR 21× BRRI dhan29, $S_6P_1P_1S_1$, L10= BR 24× BRRI dhan36, $S_8P_1P_1S_1$.

4.2.13 Straw yield (t ha^{-1})

The straw yield of different F9 lines of Aus rice varied significantly (Appendix VI). The highest straw yield (5.25 t ha^{-1}) was recorded from L8 (BR 21× BRRI dhan29, $S_6P_1P_1S_2$) which was statistically significant with L4 and L10. The lowest straw yield (3.23 t ha^{-1}) was recorded from L2 (BRRI dhan29× BRRI dhan36). Rest of population showed different yield per plant (Table 15).

4.2.14 Harvest index (%)

Harvest index of different F9 lines of Aus rice varied significantly (Appendix VI). The highest harvest index (43.10 %) was recorded from L7 (BR 21× BRRI dhan29, $S_2P_1S_1$) whereas the lowest harvest index (26.81 %) recorded from L2 (BRRI dhan29× BRRI dhan36). Rest of population showed different yield per plant (Table 15).

4.2.15 Correlation and regression study between grain yield and harvest index

Correlation and Regression between grain yield and harvest index was studied. The regression line suggested that, there is a positive relationship between grain yield and harvest index. It means, harvest index increases with the increase of grain yield. The regression equation was **$y = 5.4875x + 20.828$** where x denotes grain yield and Y denotes harvest index. The value of correlation co-efficient **R^2** was **0.9488**, which was statistically significant (Figure 3).

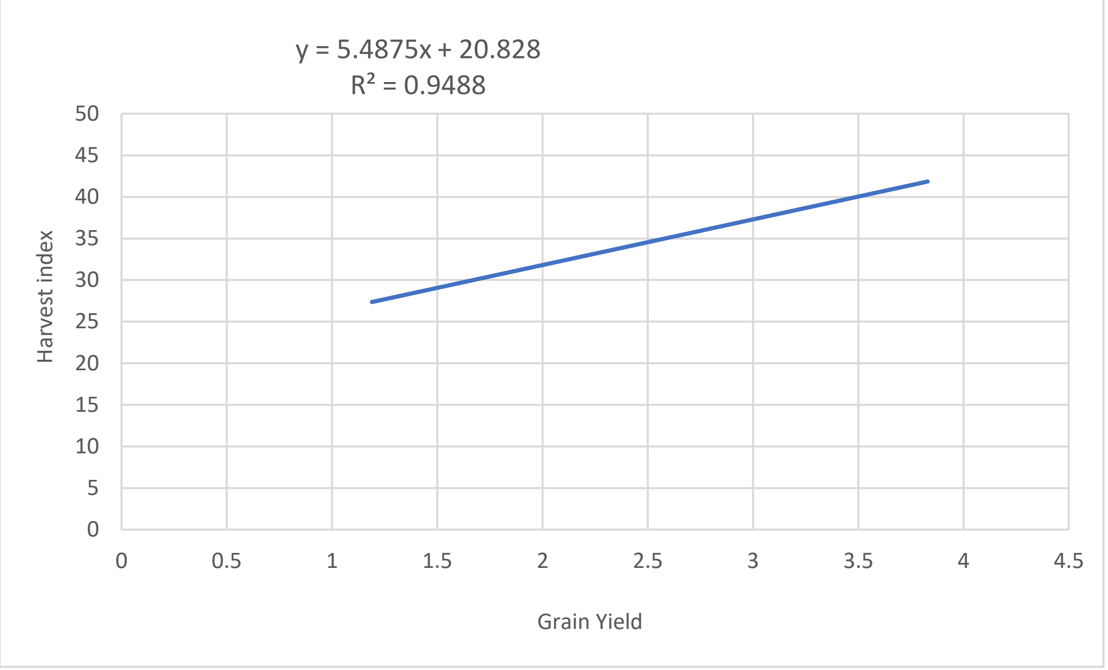


Figure 3. Correlation and regression study between grain yield and harvest index

CHAPTER V

SUMMARY AND CONCLUSION

The present research work was conducted at the farm, Sher-e-Bangla Agricultural University (SAU), Dhaka during March, 2018- August, 2018 to characterization and variability study among 10 F9 Aus lines. Ten rice advance lines viz. L1= BRRI dhan29× BRRI dhan36, $S_2P_2P_4S_6$, L2= BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_6$, L3= BRRI dhan28× BRRI dhan29, $S_2P_4P_3S_3$, L4= BRRI dhan28× BRRI dhan29, $S_2P_4P_3S_2$, L5= BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_5$, L6=BRRI dhan26× BRRI dhan28, $S_1P_9P_4S_1$, L7= BR 21× BRRI dhan29, $S_2P_1S_1$, L8= BR 21× BRRI dhan29, $S_6P_1P_1S_2$, L9=BR 21× BRRI dhan29, $S_6P_1P_1S_1$, L10= BR 24× BRRI dhan36, $S_8P_1P_1S_1$ were used for this present study. The experiments were designed in a randomized complete block design (RCBD) with three replications. All data were analyzed by one-way analysis of variance (ANOVA) using MSTAT-C.

All the lines scored exactly same for the characters viz. anthocyanin color of leaf sheath, leaf color, anthocyanin coloration of auricles & collar, penultimate leaf ligule, male sterility, microscopic observation of pollen with I2-kI solution, lemma and palea: anthocyanin coloration, lemma: anthocyanin coloration of area below apex, lemma: anthocyanin coloration of apex, color of stigma, stigma exertion, stem: culm diameter (from five mother tillers in the lowest internode) anthocyanin coloration of nodes of stem, anthocyanin coloration of internodes of stem, curvature of main axis of panicle, pubescence of lemma & palea of spikelet, color of the tip of lemma of spikelet, awn in the spikelet, panicle: attitude of branches of panicle, exertion of panicle, sterile lemma length, leaf senescence, decorticated grain shape, decorticated grain (bran) color, decorticated grain aroma which 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 viz. penultimate leaf pubescence, penultimate leaf: shape of the ligule, flag leaf: attitude of the blade, time of heading (50% of plants with heads), time of maturity, grain: length (without dehulling), decorticated grain length (after dehulling) and polished grain: size of white core or chalkiness (% of kernel area).Four lines (L1, L2, L5 and L9) represent weak or only on the margin type pubescence and rest six lines (L3, L4, L6, L7, L8 and L10) shown medium hairs on the lower portion of the leaf type pubescence. Four lines (L1, L2, L5 and L6) were truncate type, one line(L9) acute and rest five lines (L3, L4, L7, L8, L10) were split or 2-cleft type shape of ligule. Here four lines (L4, L7, L8, L10) showed erect type flag leaf and rest six lines (L1, L2, L3, L5, L6, L9) showed intermediate or semi erect type flag leaf. Result found that six lines (L3, L4, L6, L7, L8 and L9) showed very early time of heading and rest four lines (L1, L2, L5, L10) showed early time of heading. In maturity type, six lines (L3, L4, L6, L7, L8, L10) were found very early maturing type and rest of the three lines (L1, L2, L5) were found as early maturating type and only L9 line was found medium maturing type. Here seven lines (L3, L4, L5, L6, L7, L8, L10) showed long grain length and rest three lines (L1, L2, L9) showed very long category of grain length. Medium type of decorticated grain length were found in six lines (L3, L4, L6, L7, L8, L10) and rest four lines (L1, L2, L5, L9) found long type of grain length after dehulling. Six lines (L3, L4, L6, L7, L8, L10) were represented small and four lines (L1, L2, L5, L9) were showed medium size of white core of polished grain.

The highest plant height (133.57 cm) was recorded in L9 (BR 21× BRRI dhan29, $S_6P_1P_1S_1$) and L4 showed the lowest. The maximum number of total and effective tillers per plant (16.17 and 15.80) was recorded L7 and the minimum number (8.57 and 7.27) was recorded from L2. The highest number of ineffective tillers per plant (1.30) was recorded L2 and the lowest number of ineffective tillers per plant (0.37) was recorded from L7.

The highest panicle length (24.90 cm) was recorded from L7 and the lowest panicle length (19.77 cm) was recorded from L2. The highest number of total and filled spikelets per panicle (138.83 and 119.90) was recorded from L7 while the lowest number (116.40 and 27.60) recorded from L9 and L2, respectively.

The highest number unfilled spikelet per panicle was recorded in L2 (88.93) and the lowest number of unfilled spikelets per panicle was recorded in L7 (18.93). The highest 1000-seed weight (26.17) was recorded from L7 and the lowest 1000-seed weight (21.50) was recorded from L9. The highest grain yield (3.83and 5.25 t ha^{-1}) was recorded from L7 and the lowest grain yield (1.19 and 3.23 t ha^{-1}) was observed in L2. The highest harvest index (43.10 %) was recorded from L7 whereas the lowest harvest index (26.81 %) recorded from L9. From the above discussion the following conclusion could be made

i. Line L7 (BR 21× BRRI dhan29, $S_2P_1S_1$) was better line in terms of qualitative characters.

ii. Line L7 (BR 21× BRRI dhan29, $S_2P_1S_1$) was found better line in terms of yield and yield contributing characters.

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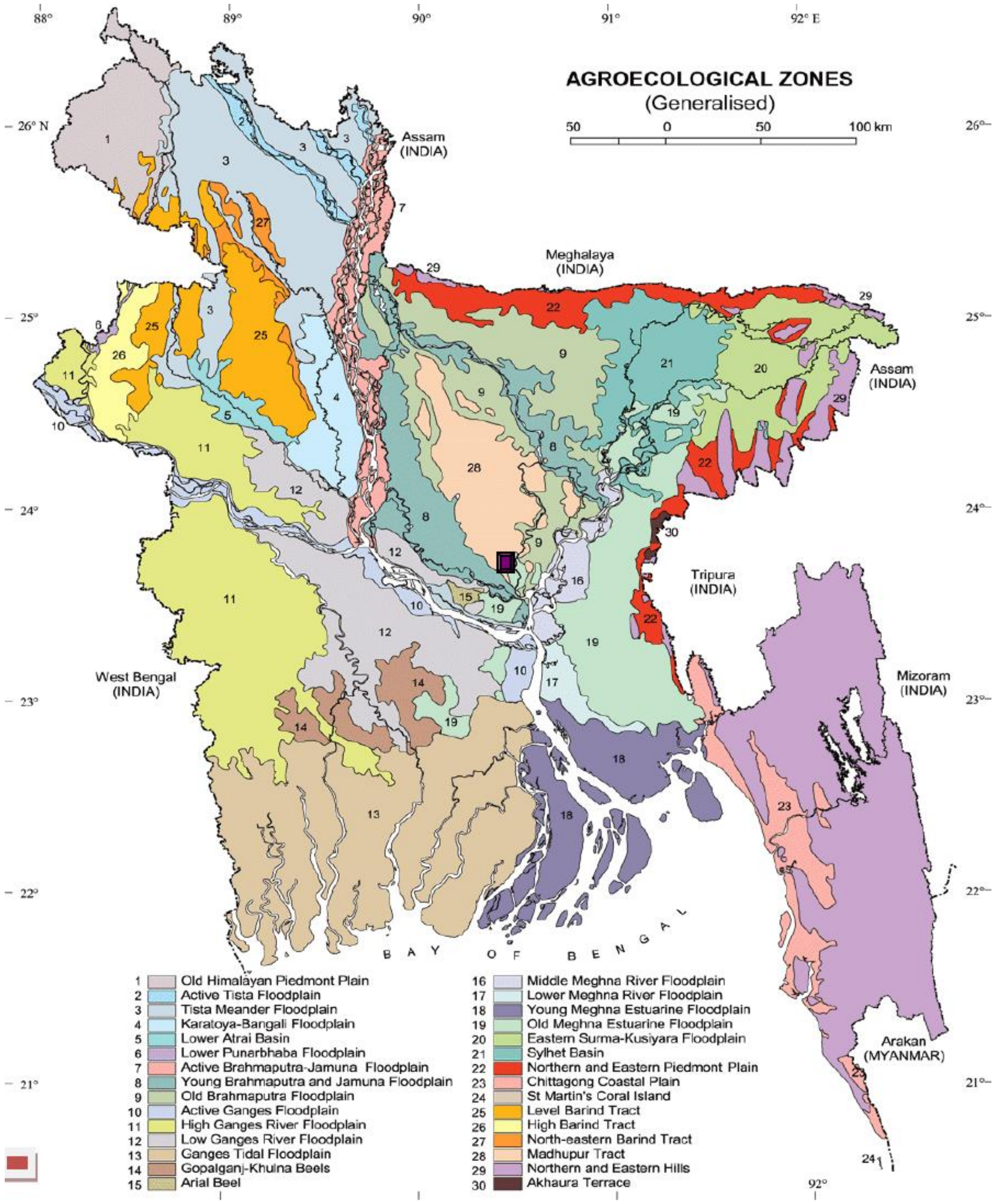
APPENDICES

Appendix I. Map showing the experimental site under the study



The experimental site under 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	Agronomy Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical composition of the soil

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

C. Chemical Composition of soil

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

Appendix III. Monthly average Temperature, Relative Humidity and Total Rainfall and sunshine of the experimental site during the period from March, 2018 to August, 2018

Month	Air temperature (°c)		Relative humidity (%)	Rainfall (mm) (total)
	Minimum	Maximum		
March	20.4	28.1	38	65.8
April	23.6	33.7	42	156.3
May	24.5	32.9	59	339.4
June	26.1	32.1	72	340.4
July	26.2	31.4	72	373.1
August	26.3	31.6	74	316.5

Source: Weather station, SAU

Appendix IV: Analysis of variance (ANOVA) of growth and yield contributing characters of 10 F9 Aus rice

Source of variance	Degree of freedom (d.f)	Plant height (cm)	No. of total tiller plant^{-1}	No. of effective tiller plant^{-1}	No. of ineffective tiller plant^{-1}
		20.748	2.55	2.24	0.014
Treatment	9	162.13**	29.34**	34.61**	0.305**
Error	18	13.315	2.06	1.92	0.020
Total	29				

Appendix V: Analysis of variance (ANOVA) of yield contributing characters of 10 F9 Aus rice

Source of variance	Degree of freedom (d.f)	Mean Square				
		Panicle length (cm)	No. of total spikelet panicle^{-1}	No. of filled spikelet panicle^{-1}	No. of unfilled spikelet panicle^{-1}	1000 grain weight (g)
Replication	2	0.151	16.49	10.94	23.29	0.257
Treatment	9	2.991**	199.64**	3516.45**	2115.63**	9.563**
Error	18	0.216	30.29	21.01	12.22	0.780
Total	29					

Appendix VI: Analysis of variance (ANOVA) of yield characters of 10 F9 Aus rice

Source of variance	Degree of freedom (d.f)	Mean Square		
		Grain yield (t ha-1)	Straw yield (t ha-1)	Harvest Index (%)
Replication	2	0.002	0.004	0.025
Treatment	9	13.304**	22.429**	213.84**
Error	18	0.047	0.595	0.907
Total	29			