CHARACTERIZATION OF F_6 LINES OF AUS RICE (*Oryza sativa*)

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CERTIFICATE

This is to certify that thesis entitled, **"CHARACTERIZATION OF F_6 LINES OF AUS RICE (*Oryza sativa*)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN GENETICS AND PLANT BREEDING**, embodies the result of a piece of bona fide research work carried out by **MD. HUMAUN KABIR LEZON**, Registration No. 15-06902 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:
Place: Dhaka, Bangladesh

____
(Prof. Dr. Md. Shahidur Rashid Bhuiyan)
Supervisor

DEDICATED

TO

MY BELOVED PARENTS

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The Author

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ABSTRACT

The present study entitled "Characterization of F_6 lines of Aus rice (*oryza sativa*)" was conducted at experimental farm, Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka during Aus 2017. This study was carried out to characterize advanced Aus lines based on morphological qualitative and quantitative traits. Boro rice requires large amount of underground water that is not feasible for future rice cultivation. So, present research was undertaken to fulfill the DUS test requirements of Aus rice advanced lines to cultivate with rain water where underground water can preserve. A total of eight lines of F_6 generation of Aus and Boro rice cross. The experiment was conducted in randomized complete block design with three replications. BRRIdhan43 and BRRIdhan55 were used as check variety in this experiment for comparison. Thirty seven qualitative and quantitative morphological traits were used to characterize Aus rice. The traits viz., leaf pubescence, shape of the ligule, attitude of the blade of flag leaf, days to heading, days to maturity, 1000-grain weight, grain length (without dehulling), sterile lemma length, decorticated grain length (after dehulling), decorticated grain shape, culm length, panicle length and no. of effective tiller per plant showed the most variation among the genotypes. Genotypes G2 (26 x 28 $S_1P_7P_2S_1$), G4 (26 x 28 $S_1P_7P_2$), G6 (21 x 36 $S_1P_4P_1S_1$) and G8 (26 x 28 $S_1P_7P_2$) had early time of heading and medium type of culm length. The genotypes G2, G4, G6 and G8 produced early maturity. Five genotypes viz. G2, G4, G6 and G8 were observed to produce more effective tiller per plant (>10). The information obtained would be produced very useful in identification and selection of suitable genotypes for use in future breeding programmes.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

SOME COMMONLY USED ABREVIATIONS

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

SOME COMMONLY USED ABREVIATIONS (Continued)

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

CHAPTER I
INTRODUCTION

The cultivated rice plant (*Oryza sativa* L.) belongs to the tribe Oryzeae under the sub-family Pooideae in the grass family Gramineae (Poaceae). It is distributed throughout the tropics and subtropics however it is grown more easily in the tropics (Acquaah, 2007). Two species of rice are considered important as food species for humans: *Oryza sativa* L., which is grown worldwide and indigenous to Asia; and *Oryza glaberrima*, the cultivated species of Africa. The two species can be distinguished in the field especially by differences in ligule shape and panicle branching. *Oryza sativa* have long (40-45 mm), pointed and thin ligules and many panicle branches, while *oryza glaberrima* has short (6 mm), oblong and thick ligules and lack secondary branching on the primary branches of the panicle (Sarla and Swamy, 2005).

Rice is the world's most important staple crop. It is the staple food for more than half of the world's population, most of them in the developing countries (Beverley *et al*., 1997). It is ranked second to maize among the most cultivated food crops in the world (Moukoumbi *et al*., 2011). Human consumption accounts for 85% of total production for rice, compared with 72% for wheat and 19% for maize (Maclean *et al*., 2002). According to Oteng and Sant'Anna (1999), during the past three decades, the rice crop has seen consistent increase in demand and its growing importance is evident in the strategic food security planning policies of many countries.

Almost in all major crop species, morphological and physiological descriptors are available to establish the uniqueness of a variety (Moukoumbi, *et al*., 2011). Hence, characterization and identification of rice cultivars are crucial for the genetic varietal improvement, release and seed production programmes.

Characterization of germplasm is of great importance for current and future agronomic and genetic improvement of the crop. Rice breeding strategy involves the assembling or generating variable germplasm and selection of superior genotypes from the germplasm for utilizing them as a promising variety or in hybridization programme to develop a superior variety.

Morphological characterization of germplasm accessions is fundamental in order to provide information for plant breeding programme. Morphological characterization gives the mark of identification which distinguishes one genotype from other. Techniques, such as plant characterization have been successfully used in recent years to help in identifying elite individuals. It is an indispensable tool for selecting varieties or lines based on agronomical, morphological, genetic or physiological characters (Ndour, 1998). Collection and characterization of this germplasm is not only important for utilizing the appropriate attribute based donors in breeding programmes, but is also essential in the present era for protecting the unique rice. However, the utilization of the genetic resources of the rice crop is mostly being used for higher yields and early maturity (Ogunbayo *et al*., 2005).

A variety will not be fully accepted only for its high yielding properties until it's combined with good acceptable grain qualities that meet farmers' needs and culinary preferences. Therefore, there is need to understand available genetic resources for better quality traits since inferior grain quality of the currently high yielding varieties in the domestic market is a dominant phenomenon (Somado *et al*., 2008).

Grain quality in rice is difficult to define with precision as preference for quality varies from country to country and within country from region to region and between ethnic groups. The concept of quality varies according to the preparations for which the varieties are used. Although, some of the quality characteristics desired by the grower, miller and consumer may be the same, yet each may place different emphasis on various quality characteristics. Consumers base their concept of quality on the grain appearance, size and shape of the grain, the behavior upon cooking, the taste, tenderness and flavor of cooked rice. Thus, grain size and shape, milling and cooking characters are important criteria of rice quality, that breeder considers in developing new varieties.

There are four distinct ecotypes of rice-Boro, Aus, Transplanted aman and Deep water aman in Bangladesh. Bangladesh has a good source of indigenous rice cultivars. About 4000 T. Aman, 2500 Boro and 1500 Aus landraces are present in BRRI rice germplasm gene bank. Only a few decades ago large numbers of farmers were growing local cultivars as their main crop. Those cultivars have good adaptation but are poor yielder. Actually cultivation of these landraces was gradually replaced by high yielding varieties during last twenty years. These landraces adapted in different parts of this country, some of which have very nice quality, fineness, aroma, taste and high protein contents (Dutta *et al*., 1998).

Indigenous crop landraces were characterized by phenotypic level by many countries. Such types of characterization have been done for keeping the crop identity and searching for new genes for further crop improvement. But information on local landraces particularly for Aus rice is very scanty. Precise information on the extent of characterization among population is crucial in any crop improvement program.

Aus rice cultivation area reduced day by day until the last decade of this century in Bangladesh. Total area under Aus rice cultivation was 1.45 million hectares with average yield 2.227 tons per hectare and total production was 2.328 million tons (BBS, 2015). It is a reinfed crop where we can use rain water for Aus cultivation.

Boro rice requires large amount of underground water that is not feasible for future rice cultivation as waterfall is going down day by day for irrigation purpose. So we should try to grow more Aus rice varieties in rainy season to reduce uplift out of underground water during Boro season. A program was initiated to develop Aus varieties through crossing between Aus and Boro varieties with the goal of increasing yield of Aus varieties without increasing maturity duration. The crossed materials have been selected through several years and F_6 lines were obtained during 2016, Aus season. Pure lines will be used in the study for characterization to fulfill the requirements of DUS test and to compare the characteristics among the different lines and with check varieties.

Ndour (1998) revealed that, techniques such as plant characterization have been successfully used in identifying elite individual genotypes. It is an indispensable tool for selecting varieties or lines based on agronomical, morphological, genetic or physiological characters. Therefore, in this study, the same technique (characterization) was used to identify the diversity that exists among the improved varieties and advanced lines. Thus characterization of these varieties will further contribute towards creating genetic database for breeding programmes strategies in the region.

The specific objectives of the study were to;

1. Characterization of rice genotypes based on morphology;
2. Characterization of rice genotypes based on quality;
3. Selection of suitable rice lines for future study.

CHAPTER II

REVIEW OF LITERATURE

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

Characterization is a critical step to be carried out to identify accessions to find genetic relationships among genotypes. A flourishing plant breeding programme heavily relies upon existence of variability in the base population for various traits, and information on genetic control of concerned character is useful for effective execution of any breeding programme. Systematic study and characterization of high quality germplasm is not only important for utilizing the appropriate attribute based donors, but also essential in the present era for protecting the unique rice. In this regard, knowledge of different genetic parameters is important and essential. Thus, literature on rice relevant to this investigation has been reviewed and summarized as follows:

2.1 Characterization based on morphology
2.2 Characterization based on quality

2.1 Characterization based on morphology

Germplasm provides the base material for crop improvement. A need for germplasm collection, evaluation and cataloguing is of utmost importance to have a dynamic crop improvement programme. The morphological characterization of

plant is the basic criteria in order to provide fundamental information. The literature available on those aspects is reviewed in the following paragraphs.
Evaluation of germplasm accessions in any genetic material collections is essential to ensure the principles of conservation and utilization of germplasm hence characterization of morphological traits of rice is important (Riley *et al.*, 1995). According to Thimmanna *et al.* (2000) the characters such as leaf length and width, pubescence of leaf, leaf angle, ligule shape and colour, panicle type, secondary branching, exertion, awning, seed length and width and 1000 grain weight can be used in differentiating the parental lines of rice cultivar.

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

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

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

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

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

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

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

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

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

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

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

2.2 Characterization based on quality

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

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

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

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

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

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

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

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

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

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

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

CHAPTER III

MATERIALS AND METHODS

The present investigation "Characterization of F_6 lines of Aus rice (*Oryza sativa*)" was carried out during the Aus season 2017. The techniques followed and materials used during the course of investigation are presented below:

3.1 Experimental Site

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

3.2 Climate and Soil

The experimental site was situated in the sub-tropical zone. The soil of the experimental site lies in Agro-ecological region of "Madhupur Tract" (AEZ No. 28). It`s top soil is clay loam in texture and olive gray with common fine to medium distinct dark yellowish brown mottles. The pH is 4.47 to 5.63 and organic carbon content is 0.82%. The record of air temperature, humidity and rainfall during the period of experiment were noted from mini weather center of Sher-e-Bangla Agricultural University (Appendix III).

3.3 Genotypes

The healthy seeds of eight advanced lines collected from the Dept. of Genetics and Plant Breeding, Sher-e-Bnalga Agricultural University, Dhaka which were used as experimental materials. Two check varieties BRRI dhan 43 and BRRI dhan 55 were used in this experiment. The materials used in that experiment is shown in Table 1.

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 genotypes were randomly assigned in total 30 plots. The experimental field size was 26 m x 29 m = 754 m^2 where 1m boarder was maintained surrounding the field and every block. The unit plot size was 6 m x 2 m. The 30 genotypes were distributed to each plot within each block randomly.

Table 1. Genotypes used for the experiment

Sl No.	Genotypes	Source
G1	24 x 36 $S_8P_1P_1S_2$ F_6	Department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University
G2	26 x 28 $S_1P_7P_2S_1$ F_6	
G3	26 x 29 $S_6P_3P_2$ F_6	
G4	26 x 28 $S_1P_7P_2$ F_6	
G5	24 x 36 $S_8P_1P_1$ F_6	
G6	21 x 36 $S_1P_4P_1S_1$ F_6	
G7	24 x 36 S_8P_1 F_6	
G8	26 x 28 $S_1P_7P_2$ F_6	
G9	BRRI dhan 43 (Check 1)	BRRI
G10	BRRI dhan 55 (Check 2)	

3.5 Raising of Seedling

Seeds of all collected rice genotypes were soaked in water for 24 hours on 5 April 2017. Then seeds were rapped with cloth and kept in drum with straw for 48 hours for seed germination evenly. Germinated seeds were sown on 11 April 2017 in the seed bed separately and proper tags were maintained.

3.6 Preparation of Main Field

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

3.7 Application of Fertilizers

Total Urea was applied in three installments, at 15 days after transplanting (DAT), 30 DAT and 45 DAT recommended by BRRI. The recommended doses of fertilizer such as cow dung, Urea, TSP and MoP @ 6 t, 135 Kg, 55 Kg, 85 Kg per ha, respectively were applied in the experimental field. 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, at 15 days after transplanting (DAT), 30 DAT and 45 DAT recommended by BRRI.

3.8 Transplanting of Seedling

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

3.9 Intercultural Operation and After Care

Necessary gap filling was done within seven days of transplanting. The crop was kept weed free throughout the growth period. Hand weeding was done at 25 and 40 days after transplanting. Flood irrigation was given to the field when necessary.

3.10 Plant Protection Measure

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

Plate 1. Seed soaking (left) and seed germination (right)

Plate 2. Seedling in seedbed

Plate 3. Transplanting of Aus rice genotypes

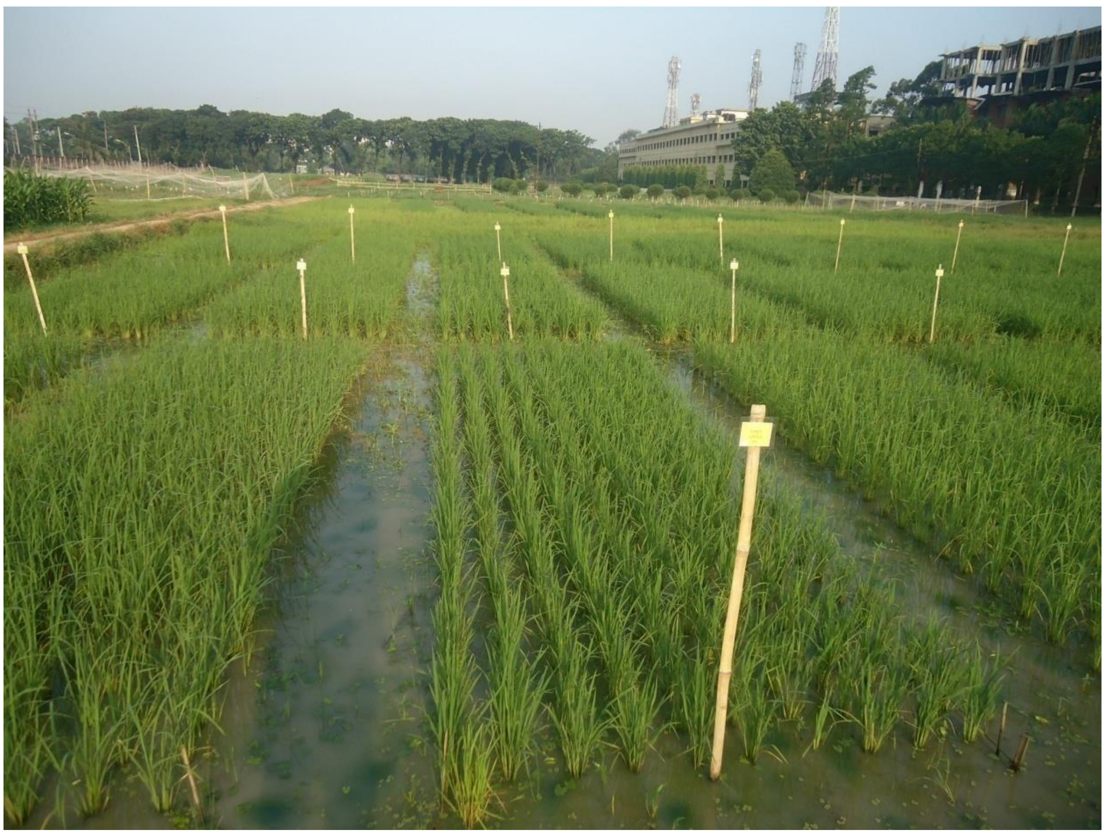


Plate 4. Pictorial view of experimental layout

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. The plants were selected from middle to avoid border effect and portion of the plot. The quantitative data mean was estimated. Fourteen qualitative and three quantitative traits based on DUS and IRRI guidelines presented in Appendix 1. The observations for characterization were recorded under field condition as follows.

3.11.1 Morphological 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 were done. 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 qualitative traits were taken on each of the ten Aus rice genotypes. This was done particularly to find out the expression of the morphological qualitative traits of the genotypes irrespective of constant environment. Photograph showing morphology of rice plant at vegetative stage in Figure 1.

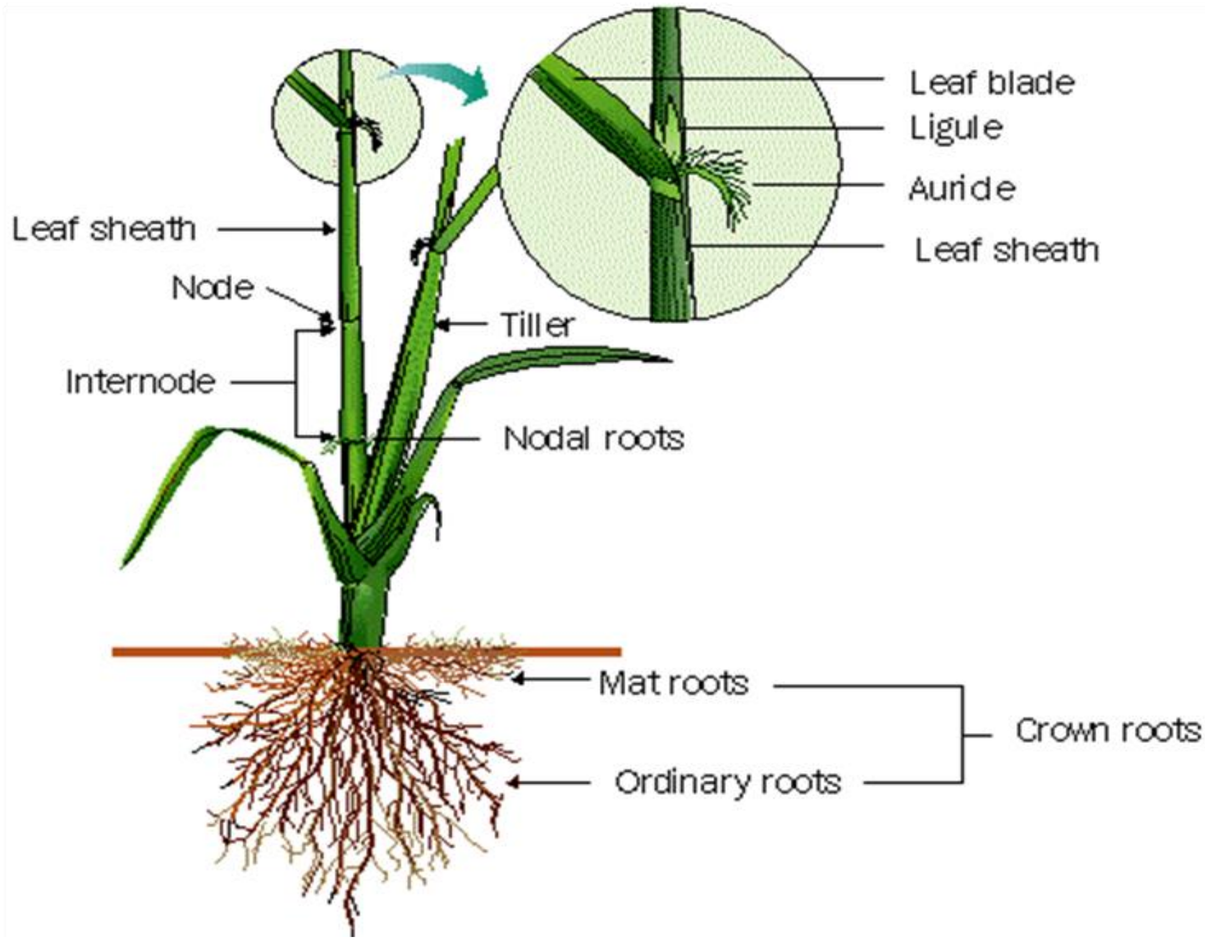


Figure 1. Morphology of a rice plant (vegetative stage)

3.11.1.1 Leaf sheath anthocyanin color

The presence or absence of anthocyanin colouration on leaf sheath was recorded at early root stage by visual assessment in a group of plant.

3.11.1.2 Leaf color

Data was collected at more tillering stage on leaf color and the Aus rice genotypes were classified into seven groups with codes according to guided descriptors presented in Appendix.

3.11.1.3 Penultimate leaf pubescence

The leaf blade pubescence was recorded at late vegetative stage by visual assessment of individual plants.

3.11.1.4 Penultimate leaf anthocynin coloration of auricles & collar

The anthocyanin colouration of auricle i.e. absent and present in auricles was recorded at late vegetative stage with visual assessment by observation of individual plant.

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.

3.11.1.6 Penultimate leaf: Shape of the ligule

Shape of the penultimate leaf ligule was observed and the genotypes were categorized according to descriptor (Appendix 1) which is also shown hypothetically in figure 1.

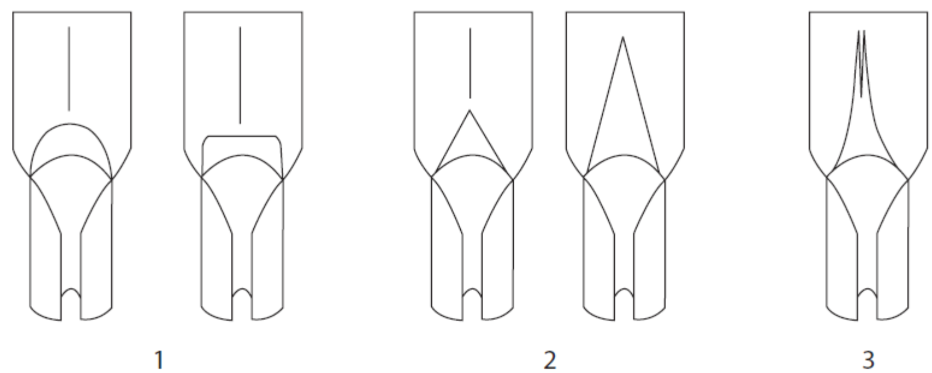


Figure 2. Ligule Shape (1-truncate, 2-acute and 3- Split or two cleft)

3.11.1.7 Flag leaf: attitude of the blade

The flag leaf attitude was recorded at beginning of anthesis through visual assessment and categorized in to erect, semi-erect, horizontal and descending types by observation of group of plants.

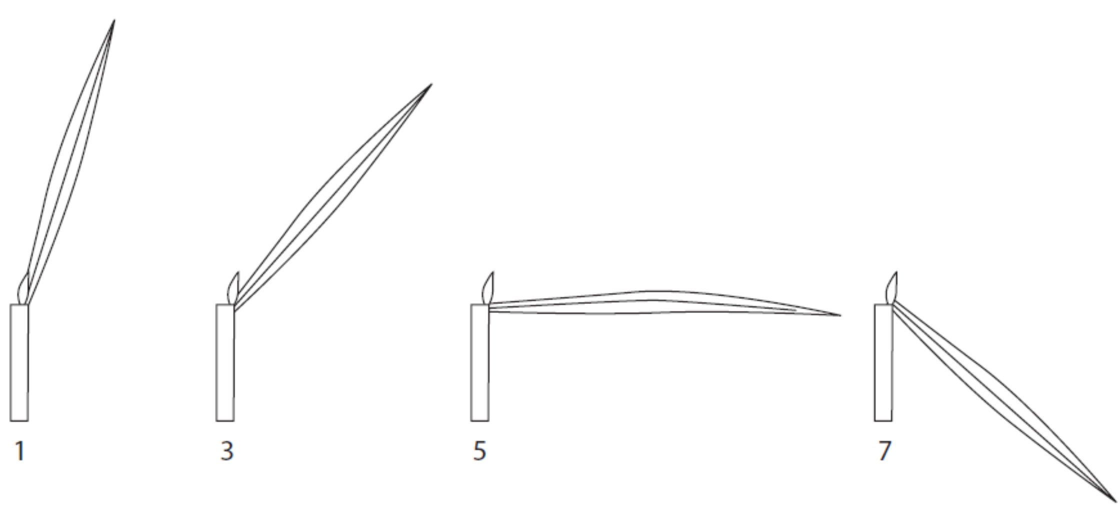


Figure 3. Flag Leaf Attitude (1-errect, 3-semi erect, 5- horizontal and 7- descending)

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

Days to heading was observed at beginning of anthesis through visual assessment and categorized according to described in Appendix 1 by observation of group of plants.

3.11.1.9 Male sterility

Presence or absence of male sterility was observed visually.

3.11.10 Microscopic observation of pollen with I_2-KI solution

Microscopic observation of pollen was observed at anthesis using I_2-KI solution and categorized according to described in Appendix 1 by observation of group of plants.

3.11.1.11 Lemma and Palea: anthocyanin coloration

The anthocyanin colouration of lemma and palea was recorded by visual observation and grouped into absent or very weak, weak, medium, strong and very strong.

3.11.1.12 Lemma: anthocyanin coloration of area below apex

The anthocyanin colouration below apex of lemma was recorded at half way of anthesis by visual observation and grouped into absent, weak, medium and very strong.

3.11.1.13 Lemma: anthocyanin coloration of apex

The anthocyanin colouration on apex of lemma was recorded at half way of anthesis by visual observation and grouped into absent, very weak, weak, strong and very strong.

3.11.1.14 Color of stigma

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

3.11.1.15 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.

3.11.1.16 Stem: culm diameter

Culm diameter of the rice plant was recorded during flowering or late reproductive stage.

3.11.1.17 Stem: Anthocyanin coloration of nodes

The presence or absence of anthocyanin colouration of nodes was recorded at milk filling stage through visual assessment of individual plants nodes.

3.11.1.18 Stem: Anthocyanin coloration of internodes

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

3.11.1.19 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.

3.11.1.20 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.

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. Erect (compact panicle)-1, Semi-erect (semi-compact panicle)-3, Spreading (open panicle)-5, Horizontal-7, Drooping-9.

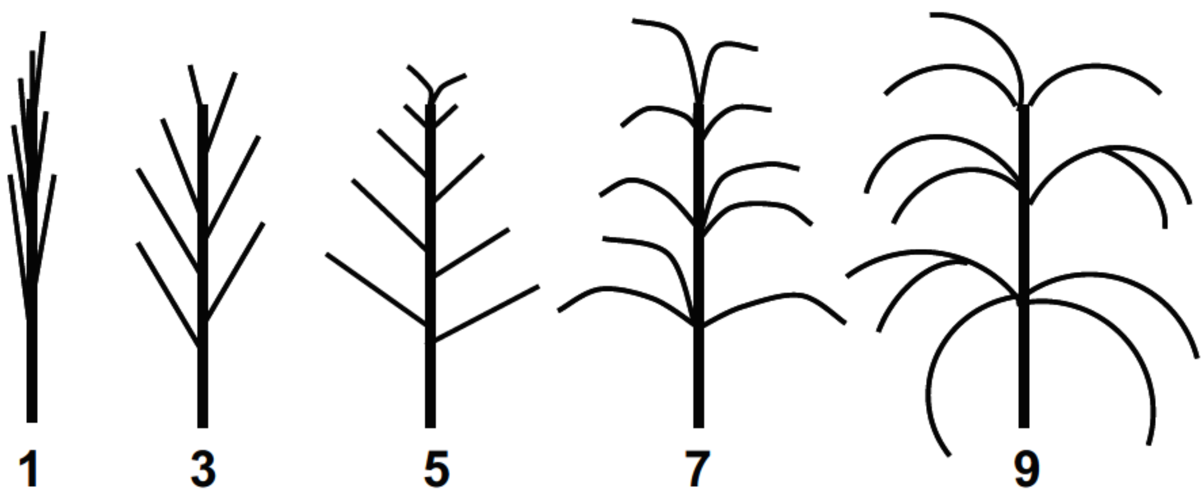


Figure 4. Attitude of panicle branches

3.11.1.22 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.

3.11.1.23 Spikelet: color of the tip of lemma

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

3.11.1.24 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.

3.11.1.25 Time of maturity

Number of days to 80% maturity of plant and recorded as according to descriptor described in Appendix 1.

3.11.1.26 1000-grain weight (g)

Thousand well-developed, whole grains dried to 13% moisture content of each of the entry were taken randomly and weighed in gram on a precision balance.

3.11.1.27 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.

3.11.1.28 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.

3.11.1.29 Decorticated grain length (after dehulling)

Grain length was measured with digital calipers and calculated in mm. Ten grains from every genotypes were measured and the mean value was recorded. The genotypes were classified as per the guided descriptors and grouped into short, medium, long and very long grain.

Figure 5. Measurement of grain length (without dehulling) by digital calipers

3.11.1.30 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.

3.11.1.31 Decorticated grain shape

After dehusking (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.

3.11.1.32 Decorticated grain (bran): color

The colour of seed coat was recorded after hulling and characterized into white, light brown, variegated brown, dark brown, light red, red, variegated purple, purple and dark purple.

3.11.1.33 Polished grain: size of white core or chalkiness (% of kernel area)

The size of randomly selected ten grain was measured in terms of absent, small, medium and large.

3.11.1.34 Decorticated grain: aroma

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

3.11.2 Quantitative characters

3.11.2.1 Stem length (Culm length)

The length of stem was measured in centimeter and categorized in to very short, short, medium and long and very long.

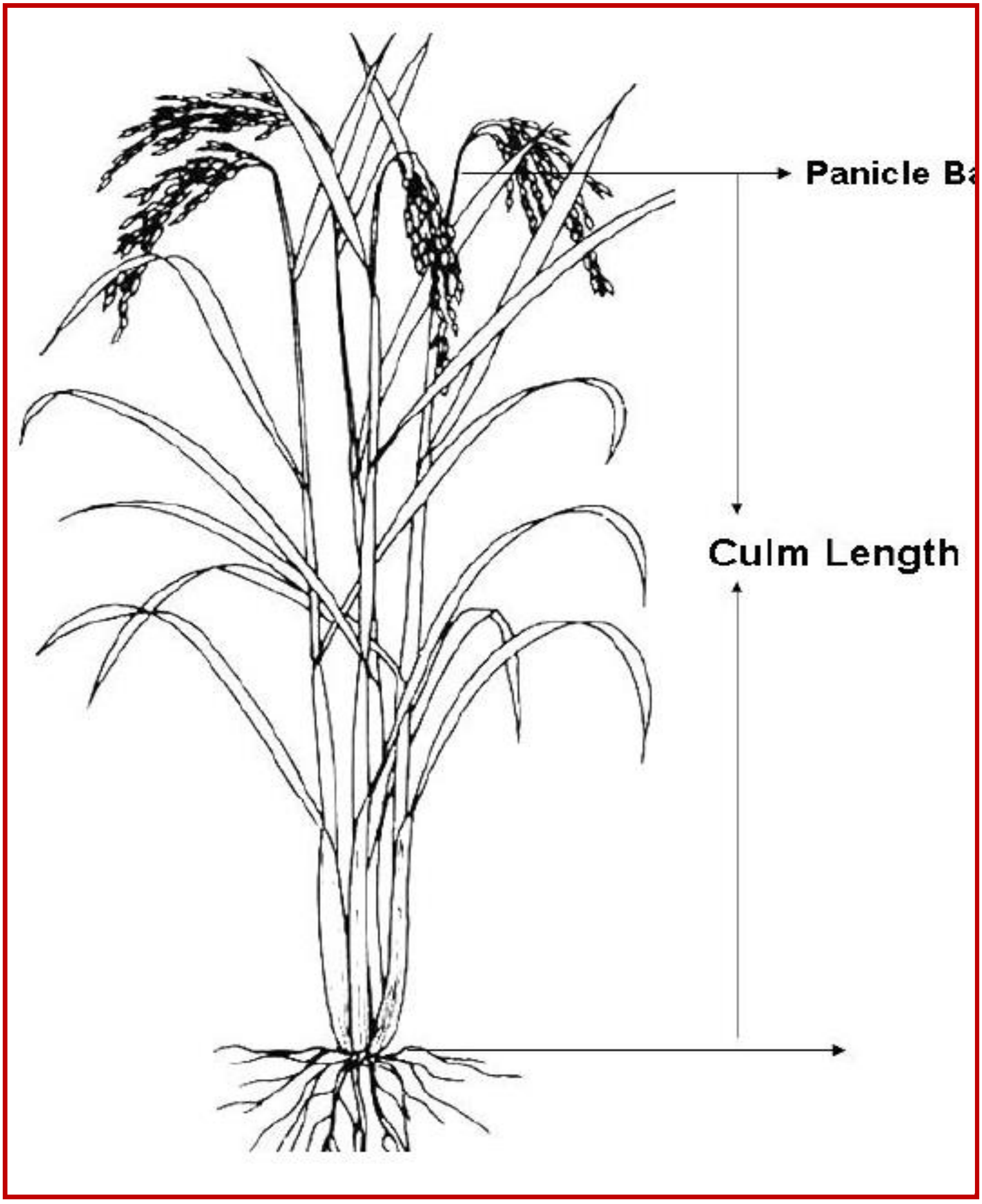


Figure 6. Culm Length

3.11.2.2 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.

3.11.2.3 No. of effective tiller/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.

3.11.3 Statistical Application

The qualitative and quantitative data in relation to morphological traits are just presented in tabular form according to description. The data were arranged as per IBPGR-IRRI formulation with the help of Microsoft-XL program.

CHAPTER IV

RESULTS AND DISCUSSIONS

The present study was conducted with a view to characterizing of F_6 Aus lines as per the guided descriptors developed by IBPGR-IRRI. Thirty four qualitative and three quantitative characters were observed. The results of the present study have been presented and discussed in this chapter under the following heading.

- Qualitative Characteristics
- Quantitative Characteristics

4.1 Qualitative Characteristics

4.1.1 Leaf sheath: anthocyanin color

On the basis of leaf sheath anthocyanin coloration the test genotypes were categorized as Absent-1 and Present-9 according to descriptors. No significant differentiation was observed in the tested genotypes for this trait. All genotypes were present leaf sheath anthocyanin color.

4.1.2 Leaf color

No character has received as much attention, with so little justification as the pigmentation patterns of different plant parts. Pigmentation 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 test genotypes were categorized as Pale green-1, Green-2, Dark green-3, Purple-tip-4, Purple margins-5, Purple bloch-6, Purple-7. But only one type of color was found in this investigation i.e. Green. All genotypes showed green color. However, it will not be reliable for identification of cultivars, because the intensity of green color of many cultivars gets bleached when the plant are left in the field to dry in sun or as a result of influence of fertilizers and environmental conditions (Kooistra, 1964).

Table 2. List of qualitative traits (1 to 9) and their stages of observation for DUS test of Aus Rice

Sl No.	Trait	Description	Scale	Time/stage of observation
1	Leaf sheath anthocyanin color	Absent Present	1 9	15-17
2	Leaf color	Pale green Green Dark green Purple tip Purple margin Purple blotch Purple	1 2 3 4 5 6 7	25-40
3	Penultimate leaf pubescence	Absent or very weak Weak or only on the margins Medium hairs on the lower portion of the leaf Strong hairs on the leaf blade Very strong	1 3 5 7 9	40
4	Penultimate leaf anthocynin coloration of auricles & collar	Absent Present	1 9	40
5	Penultimate leaf: ligule	Absent Present	1 9	40-45
6	Penultimate leaf: Shape of the ligule	Truncate Acute Split or two cleft	1 2 3	40-45
7	Flag leaf: attitude of the blade	Erect (<30) Intermediate or semi-erect (30-45) Horizontal (46-90) Reflexed or descending (>90)	1 3 5 7	60-65
8	Time of heading (50% of plants with heads)	Very early (<70 days) Early (70-85 days) Medium (86-105 days) Late (106-120 days) Very late (>120 days)	1 3 5 7 9	55
9	Male sterility	Absent CMS TGMS PGMS P(T)GMS	1 3 5 7 9	55-59

4.1.3 Penultimate leaf pubescence

The leaves of most rice varieties are pubescent but those of a few are weak. On the basis of penultimate leaf pubescence, Aus rice genotypes 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 genotypes tested and found two types of leaf pubescence (Table 3). Only one genotype (G5) represent weak or only on the margin type pubescence and nine genotypes (G1, G2, G3, G4, G6, G7, G8, G9, G10) shown Medium hairs on the lower portion of the leaf type pubescence (Figure 7).

4.1.4 Penultimate leaf: anthocynin coloration of auricles and collar

On the basis of anthocyanin coloration of auricles & collar the test genotypes were categorized as Absent-1 and Present-9 according to descriptors. No significant differentiation was observed in the tested genotypes for this trait. All genotypes were absent of anthocyanin coloration of auricles and collar.

4.1.5 Penultimate leaf: ligule

On the basis leaf ligule the test genotypes were categorized as Absent-1 and Present-9 according to descriptors. No significant differentiation was observed in the tested genotypes for this trait. All genotypes had leaf ligule.

Table 3. Scaling of penultimate leaf pubescence of Aus rice genotypes

Sl No.	Pedigree	Penultimate leaf pubescence
G1	24 x 36 $S_8P_1P_1S_2$	5
G2	26 x 28 $S_1P_7P_2S_1$	5
G3	26 x 29 $S_6P_3P_2$	5
G4	26 x 28 $S_1P_7P_2$	5
G5	24 x 36 $S_8P_1P_1$	3
G6	21 x 36 $S_1P_4P_1S_1$	5
G7	24 x 36 S_8P_1	5
G8	26 x 28 $S_1P_7P_2$	5
G9	BRRI dhan 43	5
G10	BRRI dhan 55	5

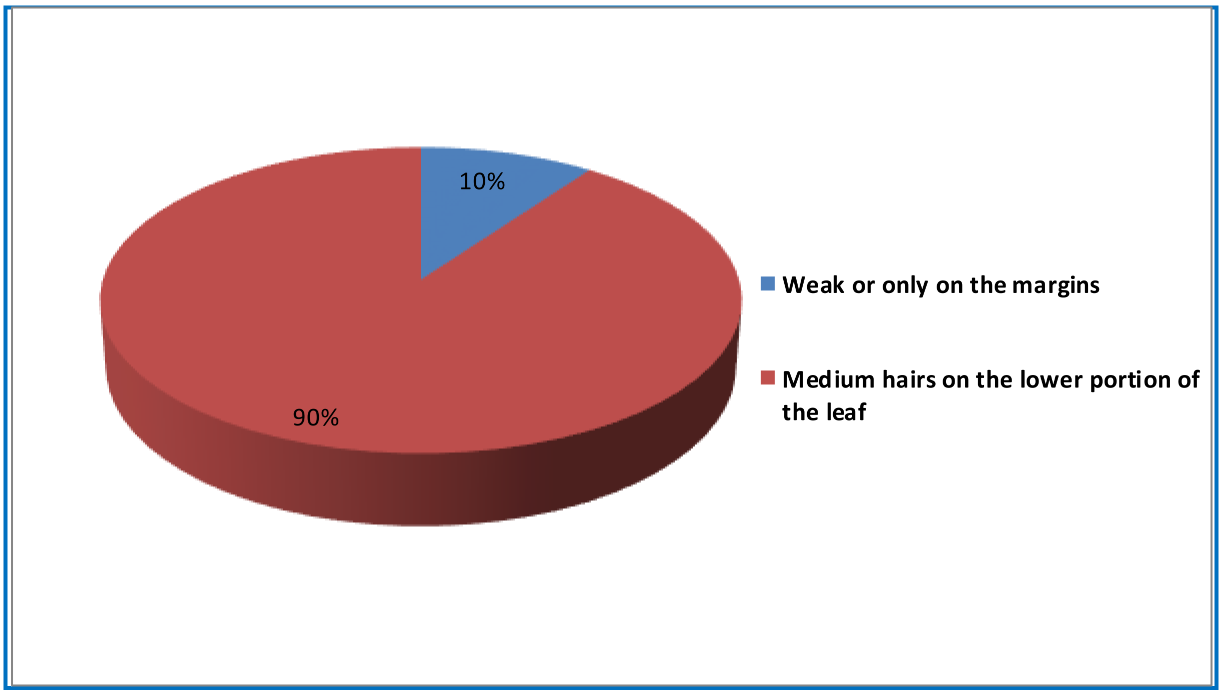


Figure 7. Penultimate leaf pubescence as observed in Aus rice genotypes

4.1.6 Penultimate leaf: Shape of the ligule

On the basis of ligule shape, Aus rice genotypes were classified as Truncate-1, Acute-2 and Split or two-cleft-3 type. Three genotypes were acute type and seven genotypes were 2-cleft type shape of ligule (Table 4 and Figure 8). According to IRRI most of the cultivated rice have 2-cleft type ligule shape and wild type genotypes show others type. From the figure we can see the 2-ceft type ligule where Figure 9 is a hypothetical view and Figure 10 shows real view taken from my experimental field.

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, 2009c). Ligule shape can serve as a unique character in identifying genotypes and hence could be of importance in every rice breeding programme.

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 genotypes were categorized in four groups like Erect (<30)-1, Intermediate or semi-erect (30-45)-3, Horizontal (46-90)-5 and Reflexed or descending (>90)-7 type (Table 5). Here six genotypes (G2, G3, G6, G8, G9 and G10) showed erect type flag leaf and rest four genotypes (G1, G4, G5, G7) showed intermediate or semi erect type flag leaf (Figure 11 and Plate 5).

Table 4. Scaling of shape of the ligule of penultimate leaf of Aus rice genotypes

Sl No.	Pedigree	Penultimate leaf: Shape of the ligule
G1	24 x 36 $S_8P_1P_1S_2$	3
G2	26 x 28 $S_1P_7P_2S_1$	2
G3	26 x 29 $S_6P_3P_2$	3
G4	26 x 28 $S_1P_7P_2$	3
G5	24 x 36 $S_8P_1P_1$	3
G6	21 x 36 $S_1P_4P_1S_1$	2
G7	24 x 36 S_8P_1	3
G8	26 x 28 $S_1P_7P_2$	3
G9	BRRI dhan 43	3
G10	BRRI dhan 55	2

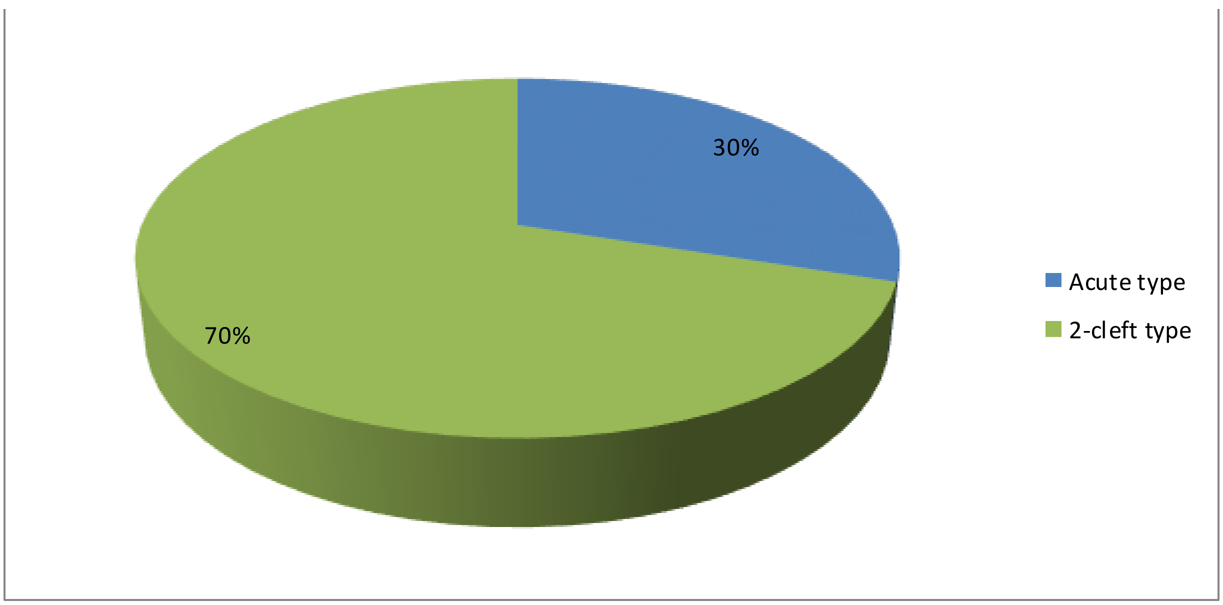


Figure 8. Shape of the ligule of penultimate leaf as observed in Aus rice genotypes

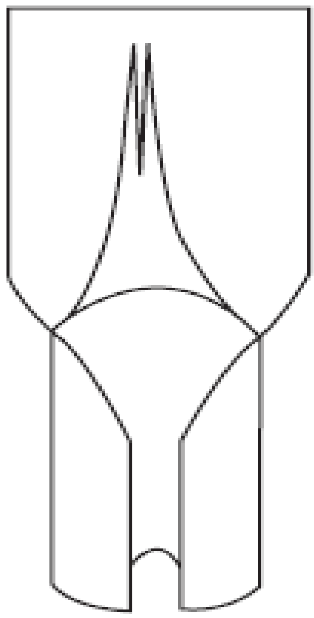


Figure 9. Hypothetical view of 2-cleft type

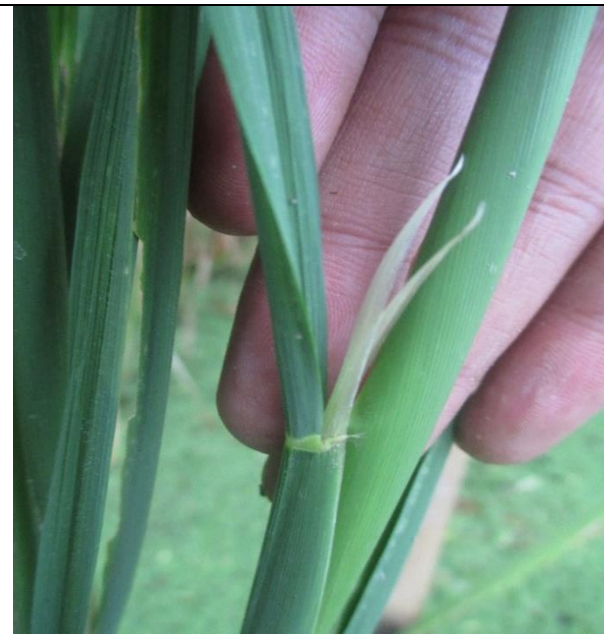
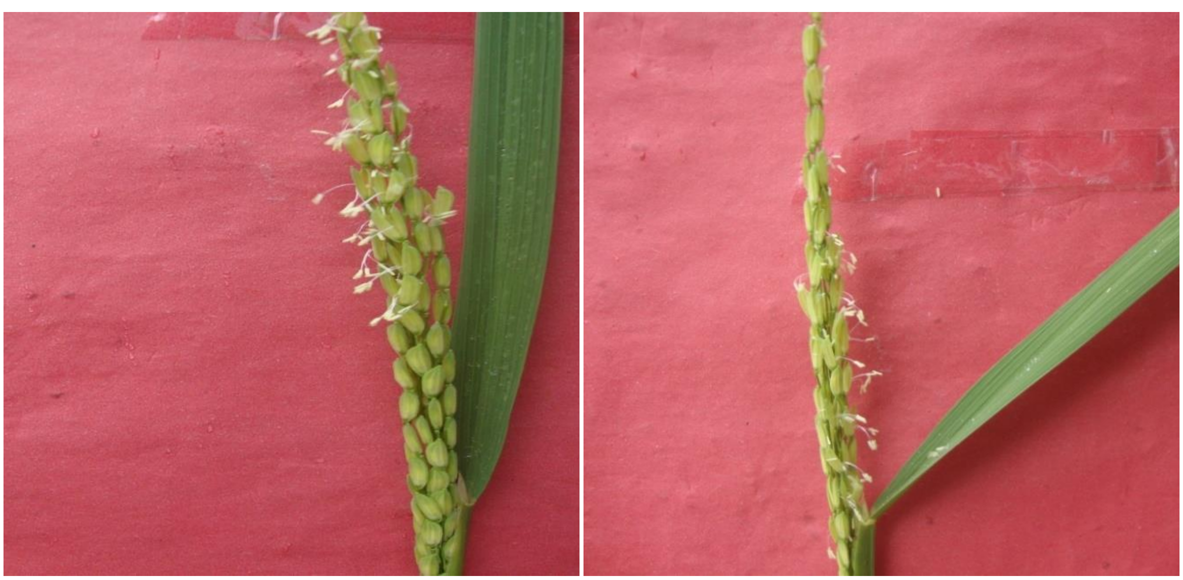


Figure 10. Real view of 2-cleft type ligule



Erect type **Semi-erect type**

Plate 5. Attitude of the blade of flag leaf

Table 5. Scaling of attitude of the blade of flag leaf of Aus rice genotypes

Sl No.	Pedigree	Flag leaf: attitude of the blade
G1	24 x 36 $S_8P_1P_1S_2$	3
G2	26 x 28 $S_1P_7P_2S_1$	1
G3	26 x 29 $S_6P_3P_2$	1
G4	26 x 28 $S_1P_7P_2$	3
G5	24 x 36 $S_8P_1P_1$	3
G6	21 x 36 $S_1P_4P_1S_1$	1
G7	24 x 36 S_8P_1	3
G8	26 x 28 $S_1P_7P_2$	1
G9	BRRI dhan 43	1
G10	BRRI dhan 55	1

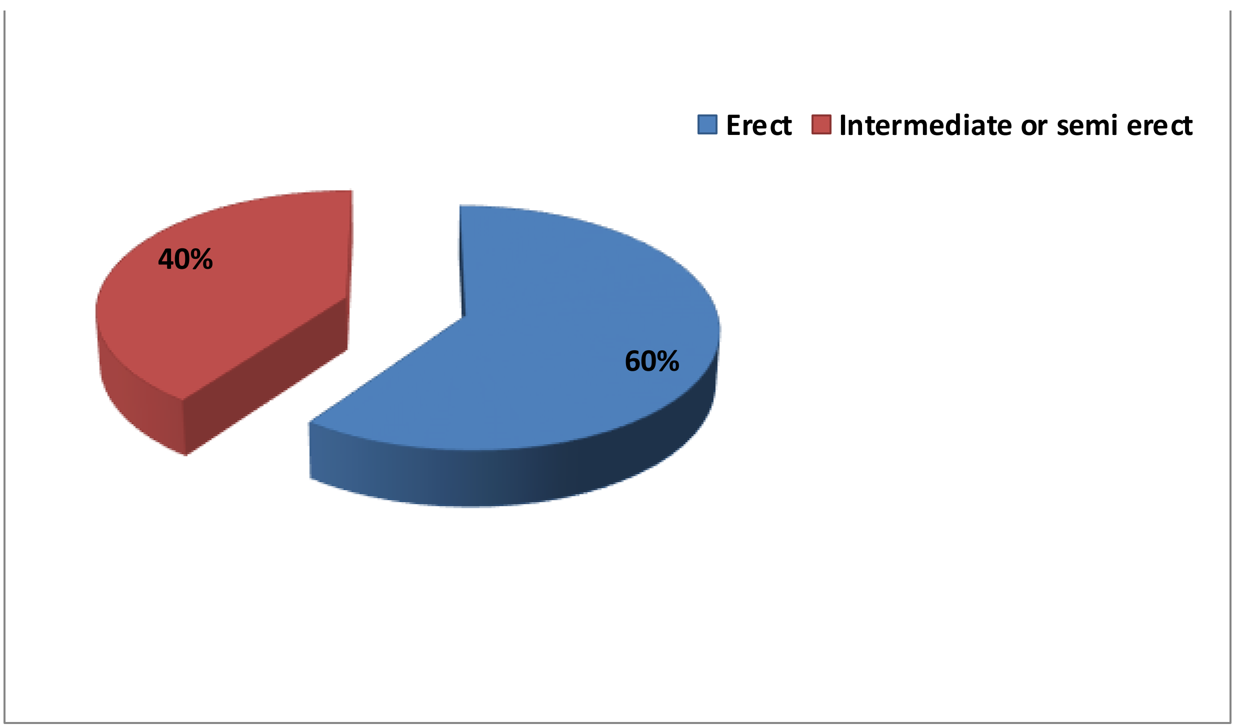


Figure 11. Attitude of the blade of flag leaf as observed in Aus rice genotypes

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

Based on time of heading the test genotypes were categorized in five groups like Very early (<70 days)-1, Early (70-85 days)-3, Medium (86-105 days)-5, Late (106-120 days)-7 and Very late (>120 days)-9 (Table 6). Two categories of time of heading were observed in this experiment. So variation was observed in these studied genotypes. This type of variation might be due to genetic makeup of genotypes and genotypic environmental interactions. Six genotypes (G2, G4, G6, G8, G9, G10) showed early time of heading and rest four genotypes (G1, G3, G5, G7) showed late time of heading (Plate 6 and Figure 12). Flowering duration is an important character that is frequently considered before release of a variety for commercial cultivation (Shahidullah *et al.*, 2009).

4.1.9 Male sterility

Based on male sterility the test genotypes were categorized in five groups like Absent-1, CMS-3, TGMS-5, PGMS-7 and P(T)GMS-9. There was no significant difference of the genotypes for this trait. Here all eight genotypes showed absent for male sterility trait.

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 genotypes 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 genotypes for this trait. All genotypes were shown fully fertile pollen.

Plate 6. Time of heading (50% of plants with heads).

Table 6. Scaling of time of heading of Aus rice genotypes

Sl No.	Pedigree	Time of heading (50% of plants with heads)
G1	24 x 36 $S_8P_1P_1S_2$	7
G2	26 x 28 $S_1P_7P_2S_1$	3
G3	26 x 29 $S_6P_3P_2$	7
G4	26 x 28 $S_1P_7P_2$	3
G5	24 x 36 $S_8P_1P_1$	7
G6	21 x 36 $S_1P_4P_1S_1$	3
G7	24 x 36 S_8P_1	7
G8	26 x 28 $S_1P_7P_2$	3
G9	BRRI dhan 43	3
G10	BRRI dhan 55	3

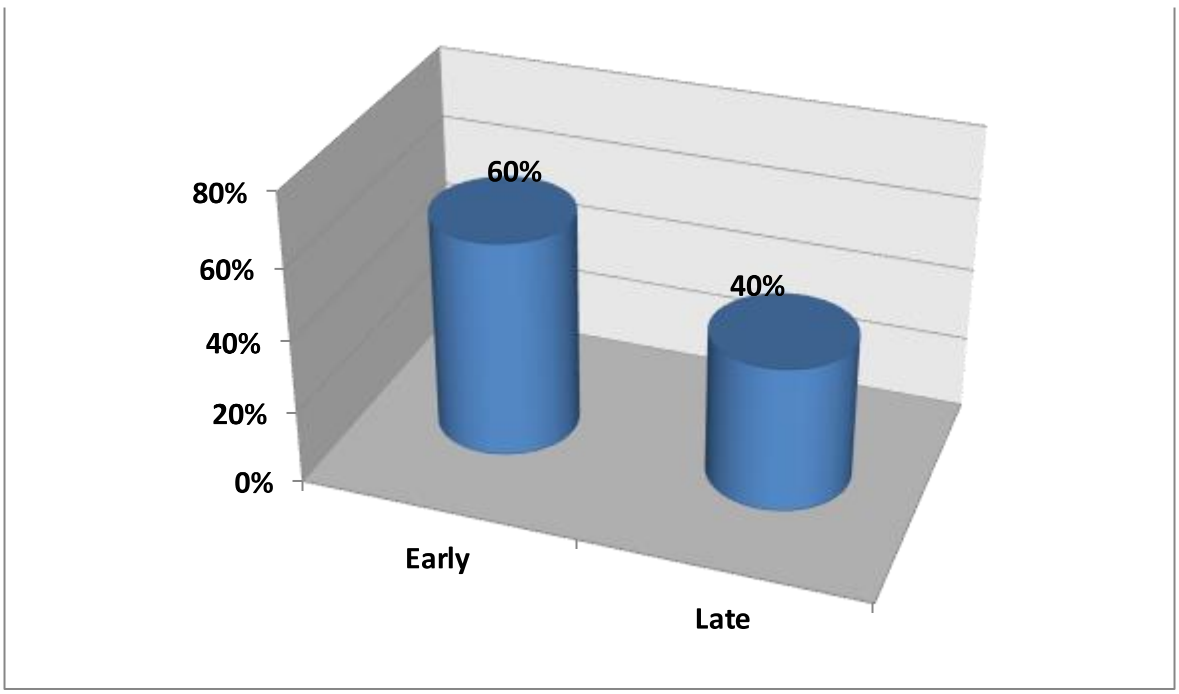


Figure 12. Time of heading as observed in Aus rice genotypes

4.1.11 Lemma and Palea: anthocyanin coloration

On the basis of lemma and palea anthocyanin coloration the test genotypes were categorized as Absent or very weak-1, Weak-3, Medium-5, Strong-7 and Very strong-9 according to descriptors. Lemma and palea combindly indicates the seed coat anthocyanin color actually. In this case all the genotypes were absent of anthocyanin coloration.

4.1.12 Lemma: anthocyanin coloration of area below apex

On the basis of lemma anthocyanin coloration of area blow apex the test genotypes were categorized as Absent or very weak-1, Weak-3, Medium-5, Strong-7 and Very strong-9 according to descriptors. No significant differentiation was observed in the tested genotypes for this trait. In this case all the genotypes were absent of anthocyanin coloration of lemma of area below apex.

4.1.13 Lemma: anthocyanin coloration of apex

On the basis of lemma anthocyanin coloration of apex the test genotypes were categorized as Absent or very weak-1, Weak-3, Medium-5, Strong-7 and Very strong-9 according to descriptors. No significant differentiation was observed in the tested genotypes for this trait. All the genotypes were absent of anthocyanin coloration of lemma of apex.

Table 7. List of qualitative traits (10-17) and their stages of observation for DUS test of Aus Rice

Sl No.	Trait	Description	Scale	Time/stage of observation
10	Microscopic observation of pollen with I_2-KI solution	Completely sterile with TA pollen Completely sterile with 80% TA pollen Completely sterile with 50% TA pollen Sterile (91-99%) Partial sterile (31-70%) Partial fertile (31-70%) Fertile (21-30%) Fully fertile (0-20%)	1 2 3 4 5 6 7 8	55-59
11	Lemma and Palea: anthocyanin coloration	Absent or very weak Weak Medium Strong Very strong	1 3 5 7 9	75-85
12	Lemma: anthocyanin coloration of area below apex	Absent or very weak Weak Medium Strong Very strong	1 3 5 7 9	75-85
13	Lemma: anthocyanin coloration of apex	Absent or very weak Weak Medium Strong Very strong	1 3 5 7 9	75-85
14	Color of stigma	White Light Green Yellow Light purple Purple	1 2 3 4 5	65
15	Stigma exertion	No or few (<5%) Low (5-20%) Medium (21-40%) High (41-60%) Very high (>61%)	1 3 5 7 9	68-69
16	Stem: culm diameter (from five mother tillers in the lowest internode)	Small (<5.0 mm) Medium (5.1-6.0 mm) Large (6.1-7.0 mm) Very large (>7.0 mm)	1 3 5 7	65
17	Stem: Anthocyanin coloration of nodes	Absent Present	1 9	70

4.1.14 Color of stigma

Based on color of stigma the test genotypes were categorized in five groups like White-1, Light Green-2, Yellow-3, Light purple-4 and Purple-5. No significant differentiation was observed in the tested genotypes for this trait. All the genotypes were shown white color of stigma.

4.1.15 Stigma exertion

Based on stigma exertion the test genotypes were categorized in five groups like No or few (<5%)-1, Low (5-20%)-3, Medium (21-40%)-5, High (41-60%)-7and Very high (>61%)-9. No significant differentiation was observed in the tested genotypes for this trait. All genotypes were shown no or few stigma exertion.

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

Based on culm diameter the test genotypes were categorized in four groups like Small (<5.0 mm)-1, Medium (5.1-6.0 mm)-3, Large (6.1-7.0 mm)-5 and Very large (>7.0 mm). No significant differentiation was observed in the tested genotypes for this trait. All eight genotypes were shown small culm diameter category.

4.17 Stem: Anthocyanin coloration of nodes

On the basis of anthocyanin coloration of nodes the test genotypes were categorized as Absent or very weak-1, Weak-3, Medium-5, Strong-7 and Very strong-9 according to descriptors. No significant differentiation was observed in the tested genotypes for this trait. All eight genotypes were absent of anthocyanin coloration of nodes.

4.18 Stem: Anthocyanin coloration of internodes

On the basis of anthocyanin coloration of internodes the test genotypes were categorized as Absent or very weak-1, Weak-3, Medium-5, Strong-7 and Very strong-9 according to descriptors. No significant differentiation was observed in the tested genotypes for this trait. All eight genotypes were absent of anthocyanin coloration of internodes.

4.19 Panicle: curvature of main axis

Based on panicle curvature of main axis the test genotypes were categorized in four groups like Absent or very weak-1, Weak-3, Medium-5 and Strong-7. There is no significant differentiation observed in the tested genotypes for this trait. All the genotypes were absent of panicle curvature of main axis.

4.1.20 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 the genotypes 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).

Table 8. List of qualitative traits (18-26) and their stages of observation for DUS test of Aus Rice

Sl No.	Trait	Description	Scale	Time/stage of observation
18	Stem: Anthocyanin coloration of internodes	Absent or very weak Weak Medium Strong Very strong	1 3 5 7 9	70
19	Panicle: curvature of main axis	Absent or very weak Weak Medium Strong	1 3 5 7	70
20	Panicle: exertion	Enclosed Partly enclosed Just exerted Moderately exerted Well exerted	1 3 5 7 9	90
21	Panicle: attitude of branches	Erect Semi erect Spreading Horizontal Drooping	1 3 5 7 9	90
22	Spikelet: pubescence of lemma & palea	Absent or very weak Weak Medium Strong	1 3 5 7	60-80
23	Spikelet: color of the tip of lemma	White Yellowish Brownish Red Purple Black	1 2 3 4 5 6	65-90
24	Spikelet: awn in the spikelet	Absent Present	1 9	90
25	Time of maturity	Very early (<100 days) Early (101-115 days) Medium (116-135 days) Late (136-150 days) Very late (>150 days)	1 3 5 7 9	92
26	1000-grain weight (g)	Very low (<15 g) Low (16-19 g) Medium (20-23 g) High (24-27 g) Very high (>27 g)	1 3 5 7 9	92

4.1.21 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 genotypes showed spreading type panicle (Plate 7). Erect and semi erect panicles were not found among the genotypes studied. Crop breeders usually selectively breed for an erect panicle type; spreading panicle type is actively selected against, for reasons of maximizing crop grain production and harvest. Hence the genotypes with compact panicle types can be used in breeding programmes for the purpose of increasing rice production.

4.1.22 Spikelet: pubescence of lemma and palea

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

4.1.23 Spikelet: color of the tip of lemma

On the basis of color of the tip of lemma, Aus rice genotypes were classified as White-1, Yellowish-2, Brownish-3, Red-4, Purple-5 and Black-6. There was no variation among the genotypes tested and found only one type of color. All genotypes represent brownish color of the tip of lemma.

Plate 7. Photograph showing of attitude of branches of panicle of ten Aus rice genotypes

4.1.24 Spikelet: awn in the spikelet

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

4.1.25 Time of maturity

Based on time of maturity the test genotypes 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. Two types of genotypes were recorded according to maturity. Six genotypes (G2, G4, G6, G8, G9, G10) were early maturing type and rest four genotypes (G1, G3, G5, G7) were late maturity. 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.

Table 9. Scaling of time of maturity of Aus rice genotypes

Sl No.	Pedigree	Time of maturity
G1	24 x 36 $S_8P_1P_1S_2$	7
G2	26 x 28 $S_1P_7P_2S_1$	3
G3	26 x 29 $S_6P_3P_2$	7
G4	26 x 28 $S_1P_7P_2$	3
G5	24 x 36 $S_8P_1P_1$	7
G6	21 x 36 $S_1P_4P_1S_1$	3
G7	24 x 36 S_8P_1	7
G8	26 x 28 $S_1P_7P_2$	3
G9	BRRI dhan 43	3
G10	BRRI dhan 55	3

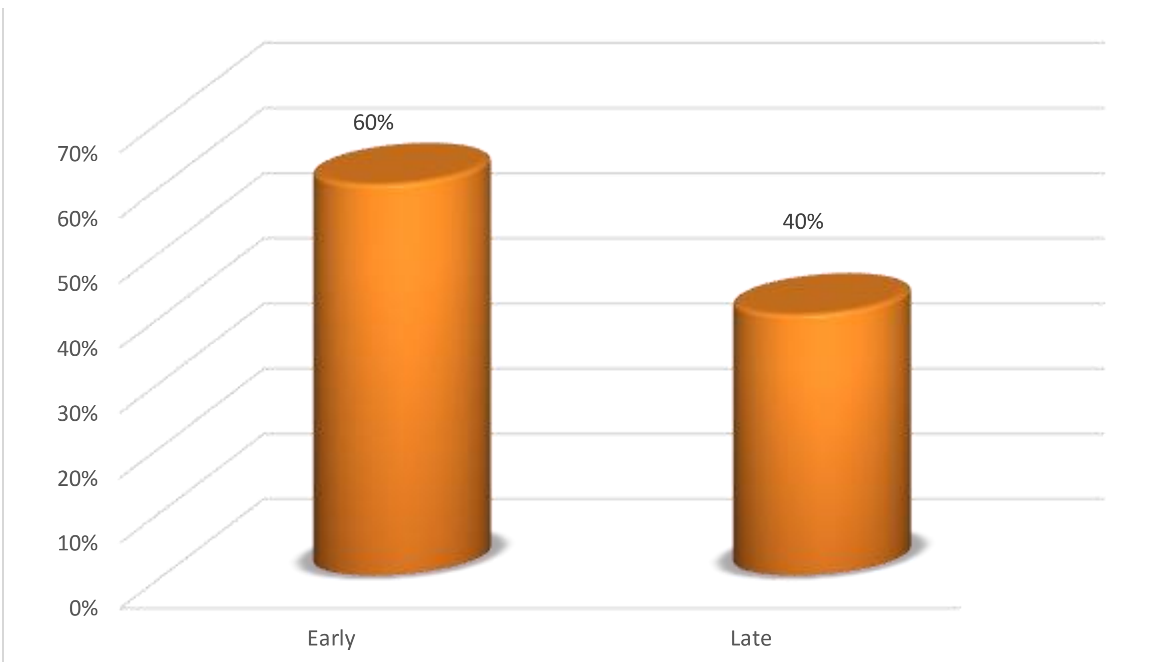


Figure 13. Time of maturity as observed in Aus rice genotypes

4.1.26 1000-grain weight (g)

Based on 1000 seed weight the test genotypes were categorized in five groups like Very low (<15 g)-1, Low (16-19 g)-3, Medium (20-23 g)-5, High (24-27 g)-7 and Very high (>27 g)-9. Three types of category were found for 1000-seed weight (Table 10). Here five genotypes (G2, G4, G5, G7 and G8) showed medium weight of 1000-seeds, three genotypes (G1, G3 and G6) showed high weight and rest two genotypes (G9 and G10) showed very high category weight of 1000-seeds (Figure 14). IRRI (2009b) reported that longer grains are lighter in weight than medium or bold grains.

4.1.27 Grain: length (without dehulling) (mm)

Based on grain length the test genotypes 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 five genotypes (G2, G3, G4, G6, G9) showed long grain length (Table 11 and Figure 15) and rest five genotypes (G1, G5, G7, G8, G10) showed very long category of grain length (Plate 8).

Table 10. Scaling of 1000-seed weight of Aus rice genotypes

Sl No.	Pedigree	1000 seed weight (g)
G1	24 x 36 $S_8P_1P_1S_2$	7
G2	26 x 28 $S_1P_7P_2S_1$	5
G3	26 x 29 $S_6P_3P_2$	7
G4	26 x 28 $S_1P_7P_2$	5
G5	24 x 36 $S_8P_1P_1$	5
G6	21 x 36 $S_1P_4P_1S_1$	7
G7	24 x 36 S_8P_1	5
G8	26 x 28 $S_1P_7P_2$	5
G9	BRRI dhan 43	9
G10	BRRI dhan 55	9

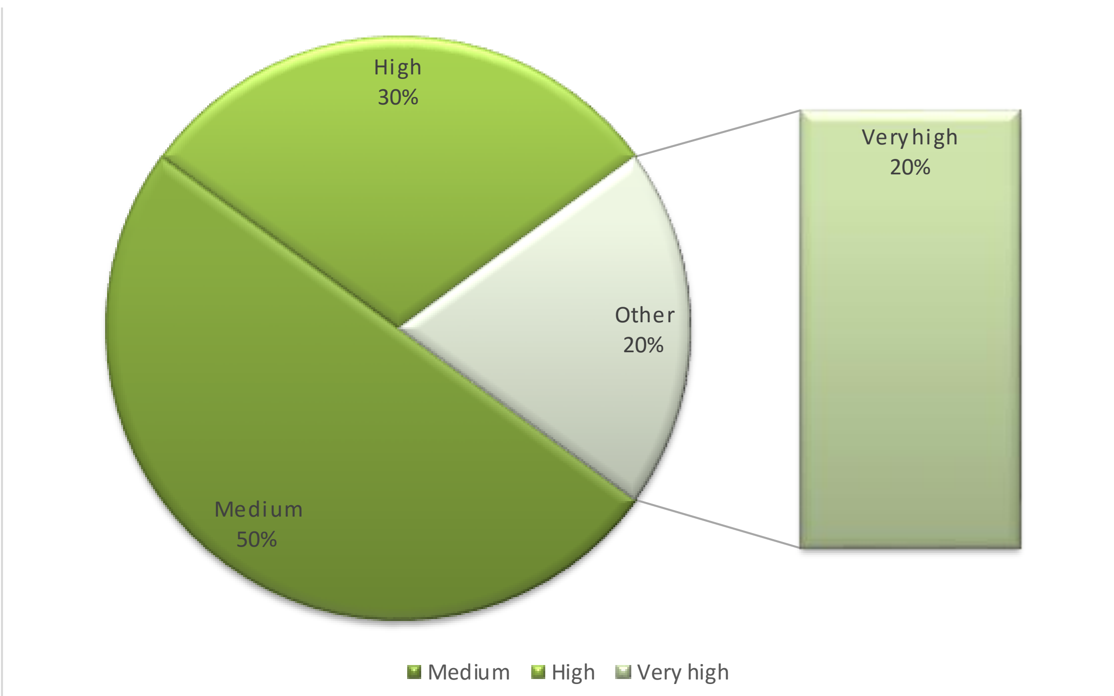
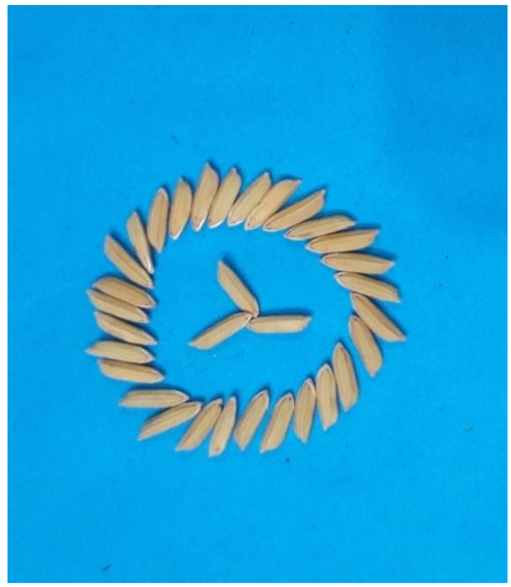


Figure 14. 1000-seed weight as observed in Aus rice genotypes

Long type



Very long type

Plate 8. Grain length without dehulling

Table 11. Category of grain length without dehulling of Aus rice genotypes

Sl No.	Pedigree	Grain: length (without dehulling)
1	24 x 36 $S_8P_1P_1S_2$	9
2	26 x 28 $S_1P_7P_2S_1$	7
3	26 x 29 $S_6P_3P_2$	7
4	26 x 28 $S_1P_7P_2$	7
5	24 x 36 $S_8P_1P_1$	9
6	21 x 36 $S_1P_4P_1S_1$	7
7	24 x 36 S_8P_1	9
8	26 x 28 $S_1P_7P_2$	9
9	BRRI dhan 43	7
10	BRRI dhan 55	9

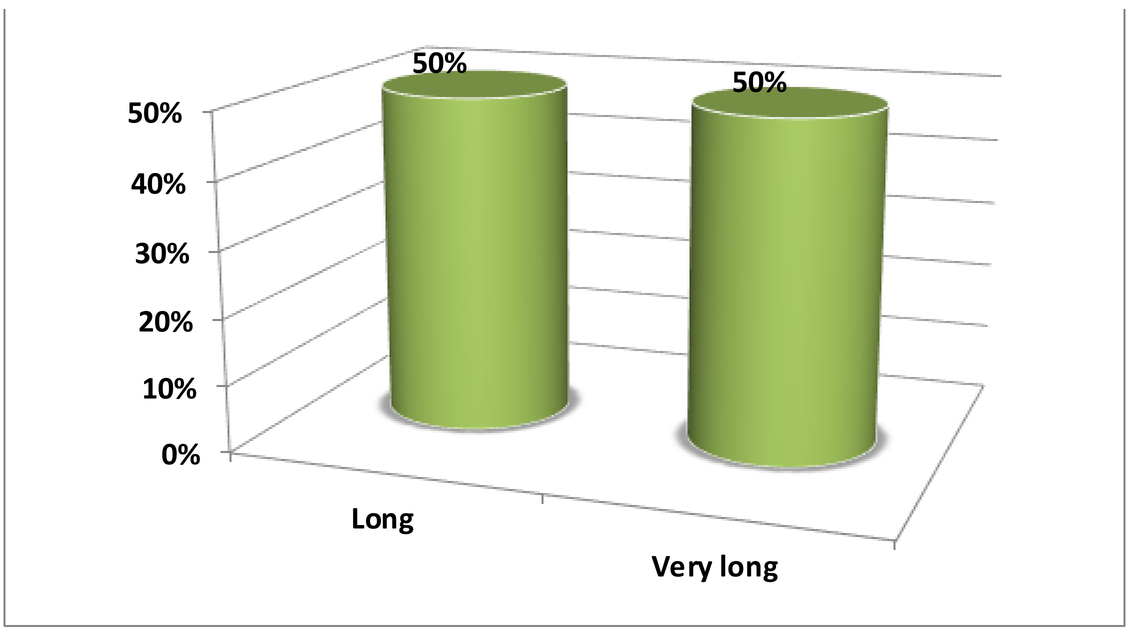


Figure 15. Grain length as observed in Aus rice genotypes

Table 12. List of qualitative traits (27-34) and their stages of observation for DUS test of Aus Rice

Sl No.	Trait	Description	Scale	Time/stage of observation
27	Grain: length (without dehulling) (mm)	Very short (<6.0 mm) Short (6.1-7.0 mm) Medium (7.1-8.0 mm) Long (8.1-9.0 mm) Very long (>9.0 mm)	1 3 5 7 9	92
28	Sterile lemma length: measure at post harvest stage	Short (<1.5 mm) Medium (1.5-2.5 mm) Long (2.6-3 mm) Very long (>3.0 mm)	1 3 5 7	92
29	Decorticated grain length (after dehulling)	Short (<5.5 mm) Medium (5.6-6.5 mm) Long (6.6-7.5 mm) Very long (>7.5 mm)	1 3 5 7	92
30	Leaf senescence	Late and slow Intermediate Early and fast	1 5 9	92
31	Decorticated grain shape	Round (L: W <1.5) Bold (1.5-2.0) Medium (2.1-2.5) Medium slender (2.6-3.0) Slender (>3.0)	1 3 5 7 9	92
32	Decorticated grain (bran): color	White Light brown Variegated brown Dark brown Red Variegated purple Purple	1 2 3 4 5 6 7	92
33	Polished grain: size of white core or chalkiness (% of kernel area)	Absent or very small Small (<10%) Medium (11-20%) Large (>20%)	1 3 5 7	92
34	Decorticated grain: aroma	Absent Lightly present Strongly present	1 5 9	92

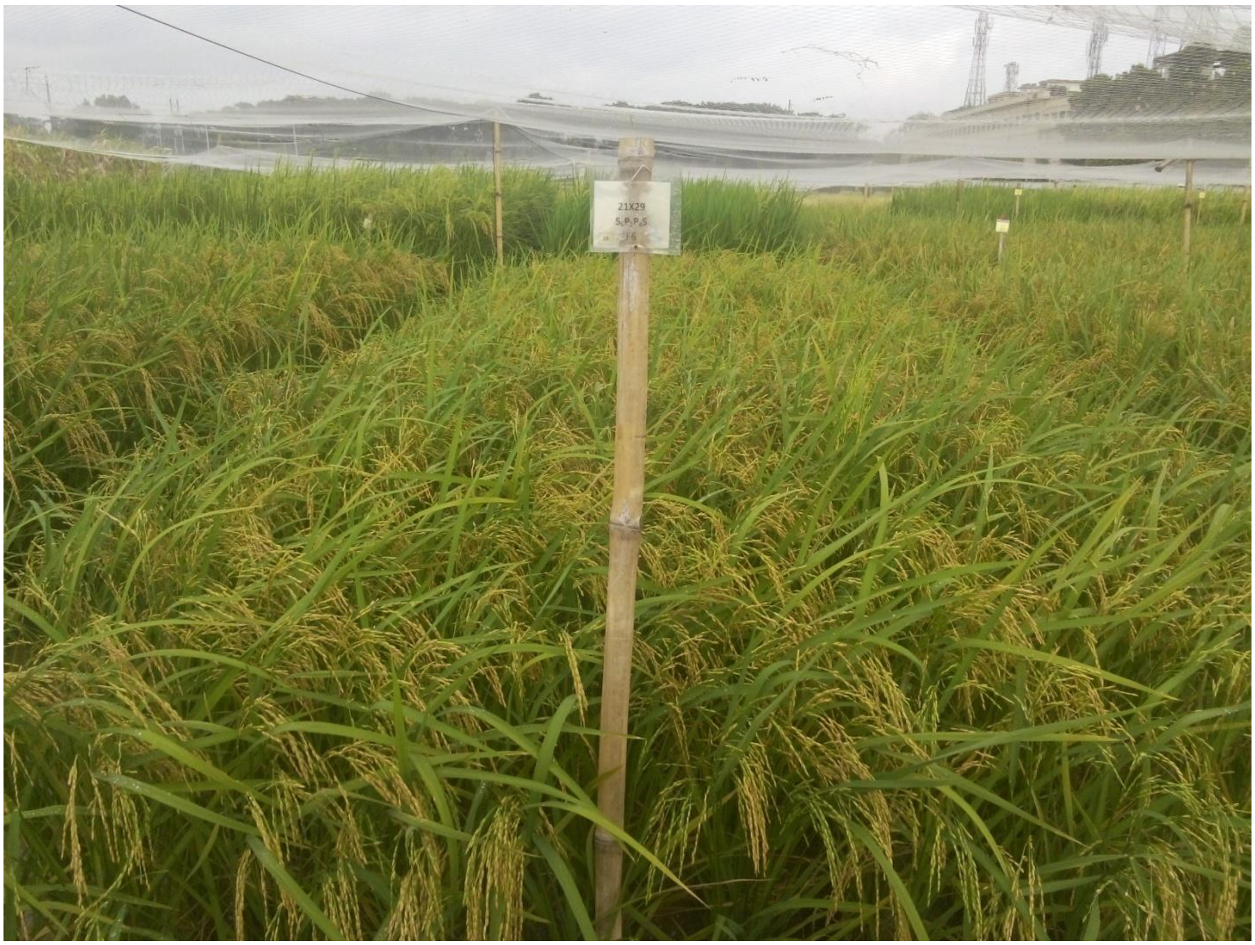


Plate 9. Rice plot showing 80% of grain maturity

4.1.28 Sterile lemma length: measure at post harvest stage

Based on sterile lemma length the test genotypes were categorized in four groups like Short (<1.5 mm)-1, Medium (1.5-2.5 mm)-3, Long (2.6-3 mm)-5 and Very long (>3.0 mm)-7. Two category of sterile lemma length were found in present study. A rice grain with sterile lemma was shown in Plate 10. Here five genotypes (G1, G2, G4, G5, G6) showed medium type of sterile lemma length and rest five genotypes (G3, G7, G8, G9, G10) showed long category of sterile lemma length (Table 13).

4.1.29 Decorticated grain length (after dehulling)

Decorticated grain length of the test genotypes were categorized in four groups like Short (<5.5 mm)-1, Medium (5.6-6.5 mm)-3, Long (6.6-7.5 mm)-5 and Very long (>7.5 mm)-7. In this experiment there are found three types of decorticated grain length. Five genotypes (G3, G4, G5, G6 and G7) were represented medium type of decorticated grain length and their grain length was between 5.6 mm to 6.5 mm. Four genotypes (G1, G2, G8. G9) showed long type of grain length. Only one genotype (G10) was performed very long type grain length with more than 7.5 mm of grain length (Table 14 and Figure 17).

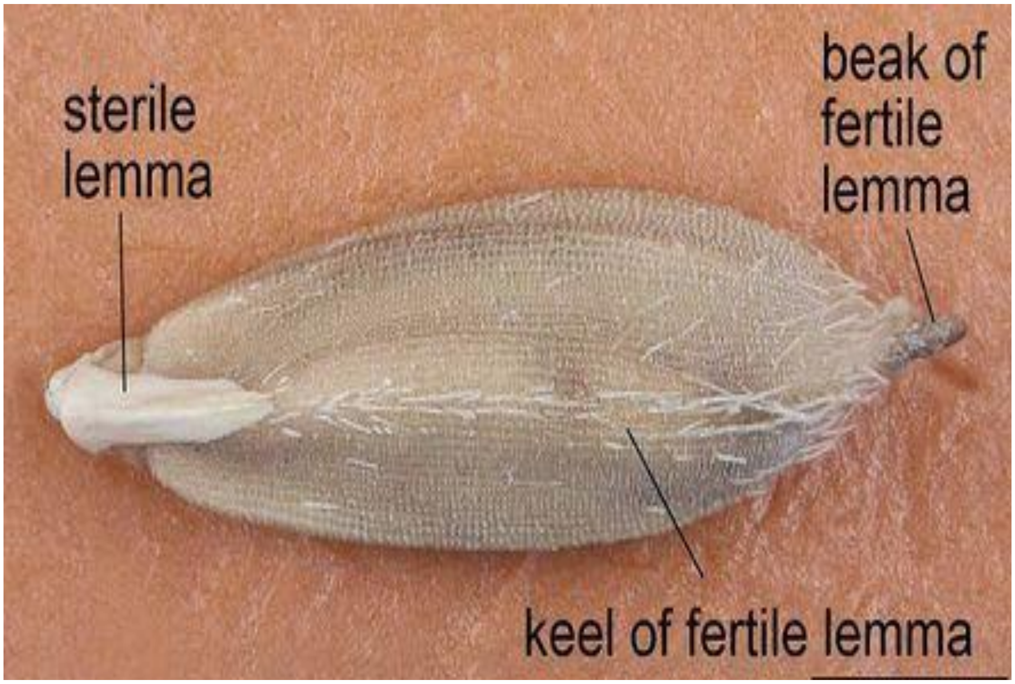


Plate 10. Rice grain with sterile lemma

Table 13. Category of sterile lemma length of Aus rice genotypes

Sl No.	Pedigree	Sterile lemma length: measure at post harvest stage
1	24 x 36 $S_8P_1P_1S_2$	3
2	26 x 28 $S_1P_7P_2S_1$	3
3	26 x 29 $S_6P_3P_2$	5
4	26 x 28 $S_1P_7P_2$	3
5	24 x 36 $S_8P_1P_1$	3
6	21 x 36 $S_1P_4P_1S_1$	3
7	24 x 36 S_8P_1	5
8	26 x 28 $S_1P_7P_2$	5
9	BRRIDhan43	5
10	BRRIDhan55	5

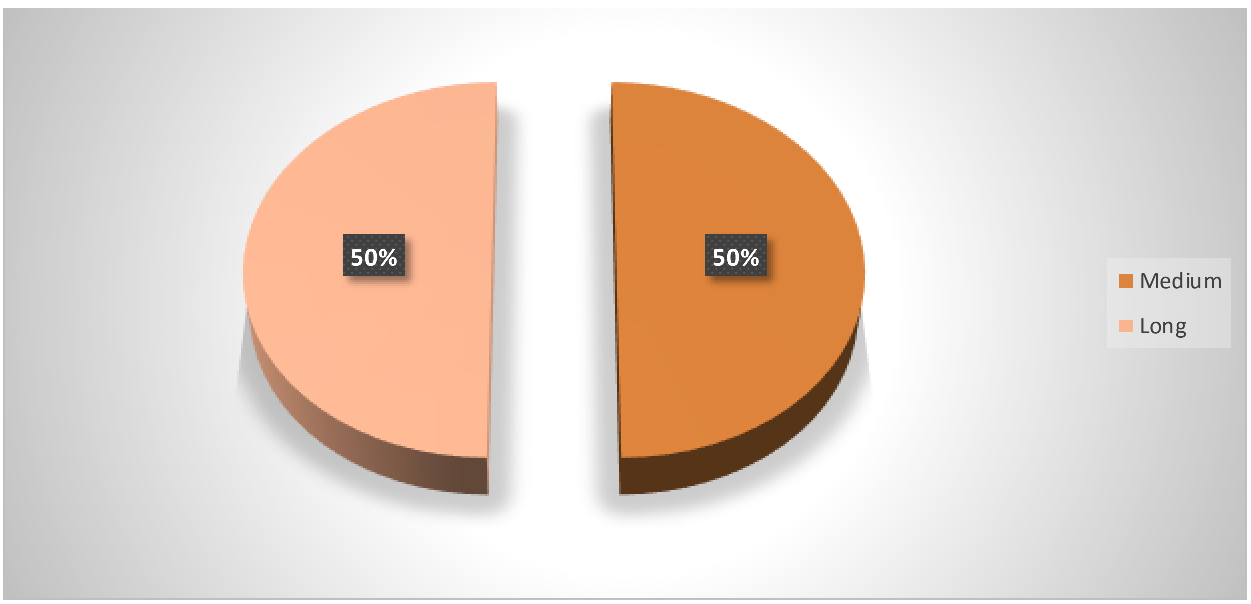


Figure 16. Sterile lemma length as observed in Aus rice genotypes

Table 14. Category of decorticated grain length after dehulling of Aus rice genotypes

Sl No.	Pedigree	Decorticated grain length (after dehulling)
G1	24 x 36 $S_8P_1P_1S_2$	5
G2	26 x 28 $S_1P_7P_2S_1$	5
G3	26 x 29 $S_6P_3P_2$	3
G4	26 x 28 $S_1P_7P_2$	3
G5	24 x 36 $S_8P_1P_1$	3
G6	21 x 36 $S_1P_4P_1S_1$	3
G7	24 x 36 S_8P_1	3
G8	26 x 28 $S_1P_7P_2$	5
G9	BRRIDhan43	5
G10	BRRIDhan55	7

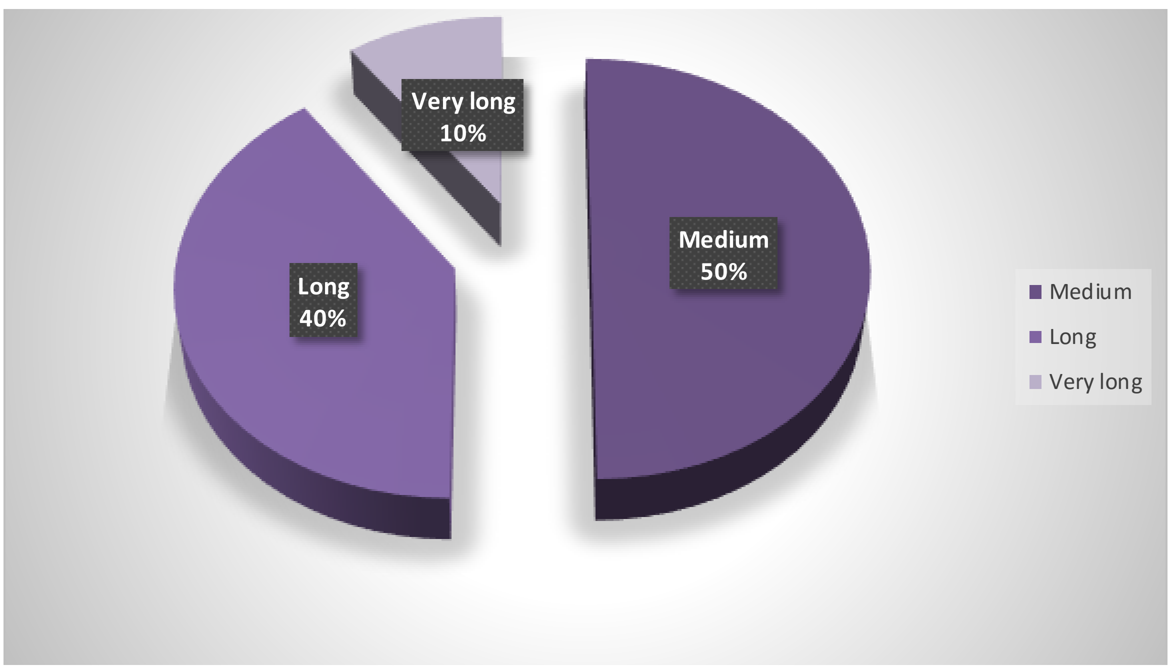


Figure 17. Decorticated grain length after dehulling as observed in Aus rice genotypes

4.1.30 Leaf senescence

For leaf senescence according to descriptor the test genotypes were categorized in three groups like Late and slow-1, Intermediate-5 and Early and fast-9. No variation was observed for this trait in the studied genotypes. All the genotypes showed late and slow type of leaf senescence.

4.1.31 Decorticated grain shape

Grain shape is the ration of grain length to grain width. According to grain shape the genotypes were grouped as Round (L: W <1.5)-1, Bold (1.5-2.0)-3, Medium (2.1-2.5)-5, Medium slender (2.6-3.0)-7 and Slender (>3.0)-9. Two categories of genotypes were found on basis of grain shape. Out of ten genotypes two genotypes (G3 and G7) under the group of medium slender having their length/width ratio between 2.6 to 3.0 and rest eight genotypes (G1, G2, G4, G5, G6, G8, G9 and G10) were under the category of slender having their length/width ratio between more than 3.0.

Determining the physical dimension of rice varieties is very important, since it is produced and marketed according to grain size and shape. The length and width of rice grain are important attributes that determine the shape of the rice (IRRI, 2009b). Takoradi (2008) reported that long grain rice is highly demanded by the rice consuming populace. Hence the long grains obtained in this study can be used in breeding programmes so as to meet the consumers' need. Although the preference for rice grain characteristics varies with consumer groups, medium slender and slender grains are generally preferred and are good valuable attributes that could be exploited to improve the grain characteristics.

Plate 11. Photographs showing grain shape and size of different Aus rice genotypes

Table 15. Category of decorticated grain shape of Aus rice genotypes

Sl No.	Pedigree	Decorticated grain shape
G1	24 x 36 $S_8P_1P_1S_2$	9
G2	26 x 28 $S_1P_7P_2S_1$	9
G3	26 x 29 $S_6P_3P_2$	7
G4	26 x 28 $S_1P_7P_2$	9
G5	24 x 36 $S_8P_1P_1$	9
G6	21 x 36 $S_1P_4P_1S_1$	9
G7	24 x 36 S_8P_1	9
G8	26 x 28 $S_1P_7P_2$	9
G9	BRRI dhan 43	7
G10	BRRI dhan 55	9

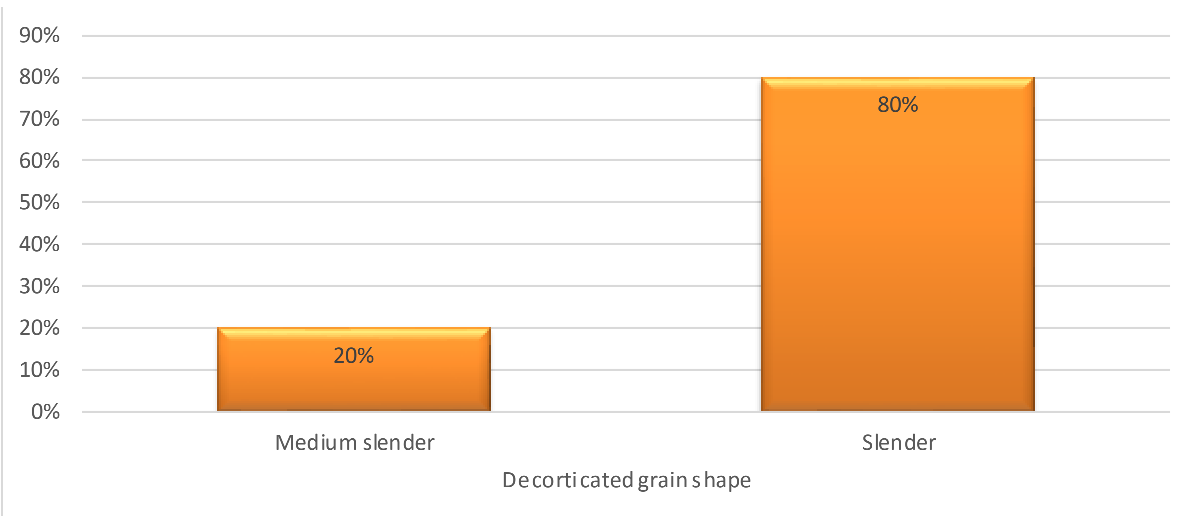


Figure 18. Decorticated grain shape as observed in Aus rice genotypes

4.1.32 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 genotypes. All genotypes showed light brown color of bran of grain (Plate 12).

4.1.33 Polished grain: size of white core or chalkiness (% of kernel area)

The test genotypes were found in two categories like small and medium types of size of white core of polished grain. Four genotypes (G3, G6, G9 and G10) were represented small and six genotypes (G1, G2, G4, G5, G7, G8) were showed medium size of white core of polished grain.

Plate 12. Light brown colored decorticated grain

Table 16. Category of size of white core of Aus rice genotypes

Sl No.	Pedigree	Polished grain: size of white core or chalkiness (% of kernel area)
1	24 x 36 $S_8P_1P_1S_2$	5
2	26 x 28 $S_1P_7P_2S_1$	5
3	26 x 29 $S_6P_3P_2$	3
4	26 x 28 $S_1P_7P_2$	5
5	24 x 36 $S_8P_1P_1$	5
6	21 x 36 $S_1P_4P_1S_1$	3
7	24 x 36 S_8P_1	5
8	26 x 28 $S_1P_7P_2$	5
9	BRRI dhan 43	3
10	BRRI dhan 55	3

4.1.34 Decorticated grain: aroma

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

4.2 Quantitative Traits

Improvement and introduction of varieties with good grain qualities, is one of the major important objective of rice breeding programmes. Grain appearance or marketable quality includes grain length (size), grain shape, grain transparency, grain chalkiness and number of chalky grains (Masoumiasl *et al.*, 2013). Therefore, it is imperative to determine the relevant physical properties of rice grains. Appendix 3 represents means of three traits as obtained for each of the ten rice genotypes. Also it shows the grand means, F-probability and LSD (5%) for each trait. All the traits show a significant difference among the genotypes that were characterized.

4.2.1 Stem length (culm length) (cm)

Culm length means the length of a stem from ground level to panicle base. Culm lengths of test genotypes ranged from 64.867 cm to 103.753 cm. On the basis of this character, the genotypes were categorized into seven groups as Very short (<40 cm)-1, short (41–60 cm)-3, medium (61–80 cm)-5, long (81–110 cm)-7 and very long (>110 cm)-9 as the guided descriptors (Plate 13 and Figure 19). Two types of genotypes were found viz. medium and long type of culm length. Six genotypes (G2, G4, G6, G8, G9, G10) were represented medium type of culm length. Four genotypes (G1, G3, G5, G7) were represented long type of culm length.

Table 17. List of quantitative traits and their stages of observation for DUS test of Aus Rice

Quantitative traits				
Sl No.	Trait	Description	Scale	Time/stage of observation
1	Stem length(Culm length)	Very short (<40 cm) Short (41-60 cm) Medium (61-80 cm) long (81-110 cm) Very long (>110 cm)	1 3 5 7 9	70
2	Panicle length (cm)	Short (<20 cm) Medium (21-25 cm) Long (26-30 cm) Very long (>30 cm)	3 5 7 9	72-90
3	No. of effective tiller/plant	Few (<6) Medium (6-10) Many (>10)	3 5 7	75-90

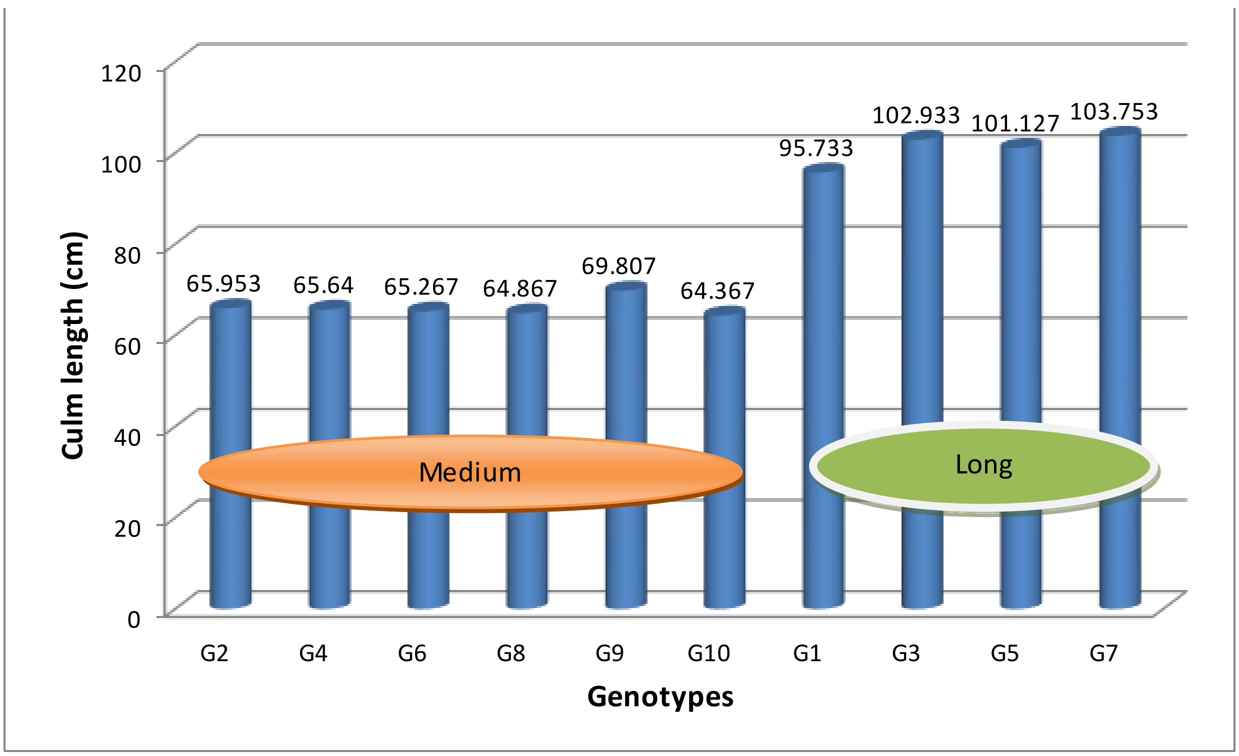


Figure 19. Culm length as observed in Aus rice genotypes

G3

G5

Plate 13. Showing long type culm length

4.2.2 Panicle length (cm)

The shortest panicle length of 21.340 cm was recorded for G6 whereas the longest panicle length of 29.473 cm was recorded for G1. The genotypes were grouped as Short (<20 cm)-3, Medium (21-25 cm)-5, Long (26-30 cm)-7 and Very long (>30 cm)-9 according to descriptor. The panicle length and number of panicle per plant directly control the yield of a particular variety (Ashfaq, *et al.*, 2012). Two category of panicle length was observed in these studied genotypes. Six genotypes (G2, G4, G6, G8, G9, G10) were observed having medium panicle and rest four genotypes (G1, G3, G5, G7) were observed long panicle as length between 21-25 cm represent medium panicle and between 26-30 cm is long (Figure 20). Similar results were obtained by Sarma *et al.* (2004) and found that eight genotypes showed more than 25 cm panicle length and the remaining genotypes were recorded lesser panicle length.

4.2.3 No. of effective tiller per plant

The highest no. of effective tiller per plant (13.400) was recorded for G8 whereas the lowest no. of effective tiller per plant (9.400) was recorded for G1. The genotypes were grouped as Few (<6)-3, Medium (6-10)-5 and Many (>10)-7 according to descriptor. Two category of no. of effective tiller per plant was observed in these studied genotypes. Five genotypes (G1, G3, G5, G7, G10) were observed having medium category of no. of effective tiller per plant and rest five genotypes (G2, G4, G6, G8, G9) were observed many category of effective tiller per plant as effective tiller number between 6-10 represent medium category and more than 10 represent many category (Figure 21).

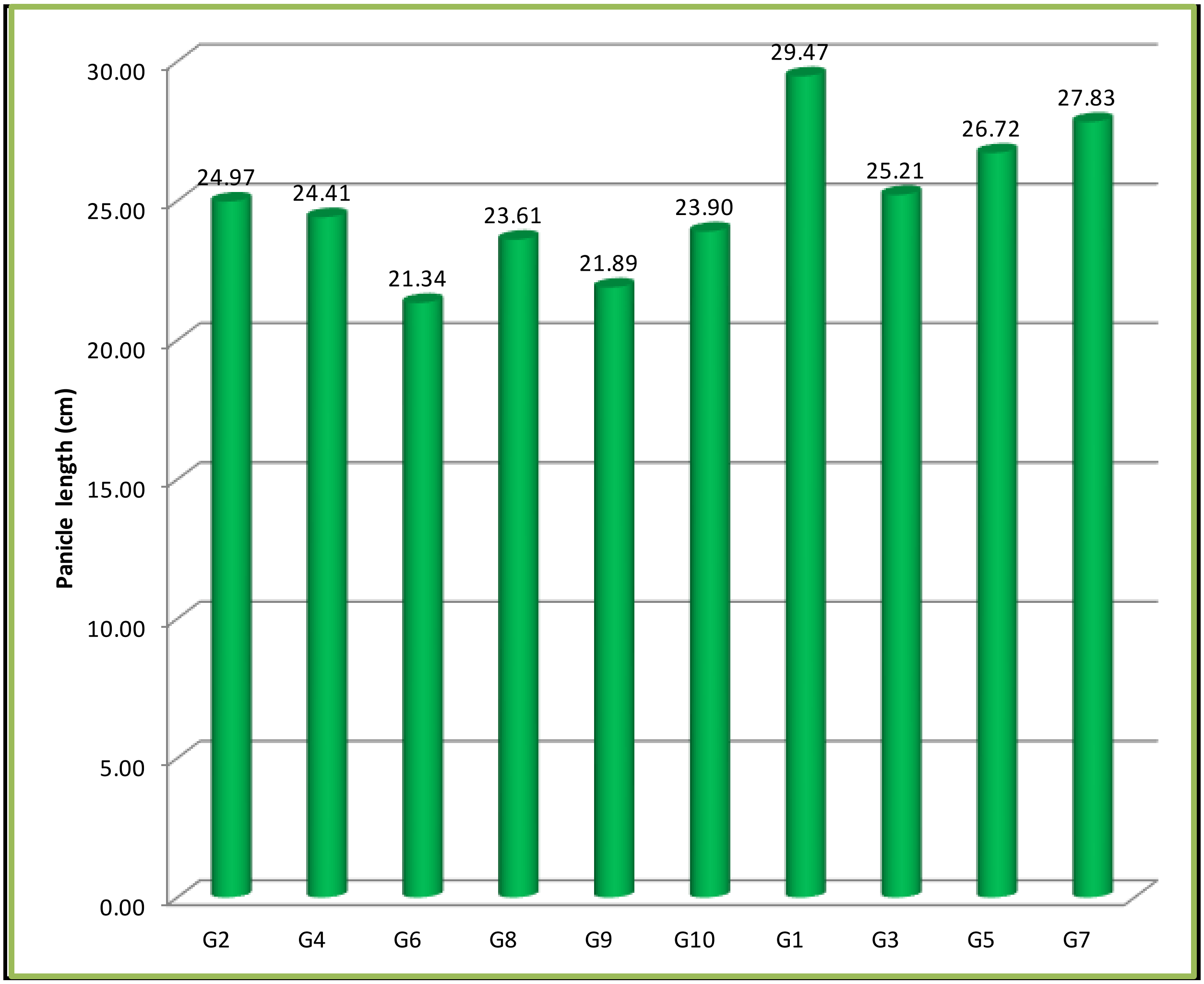


Figure 20. Panicle length as observed in Aus rice genotypes

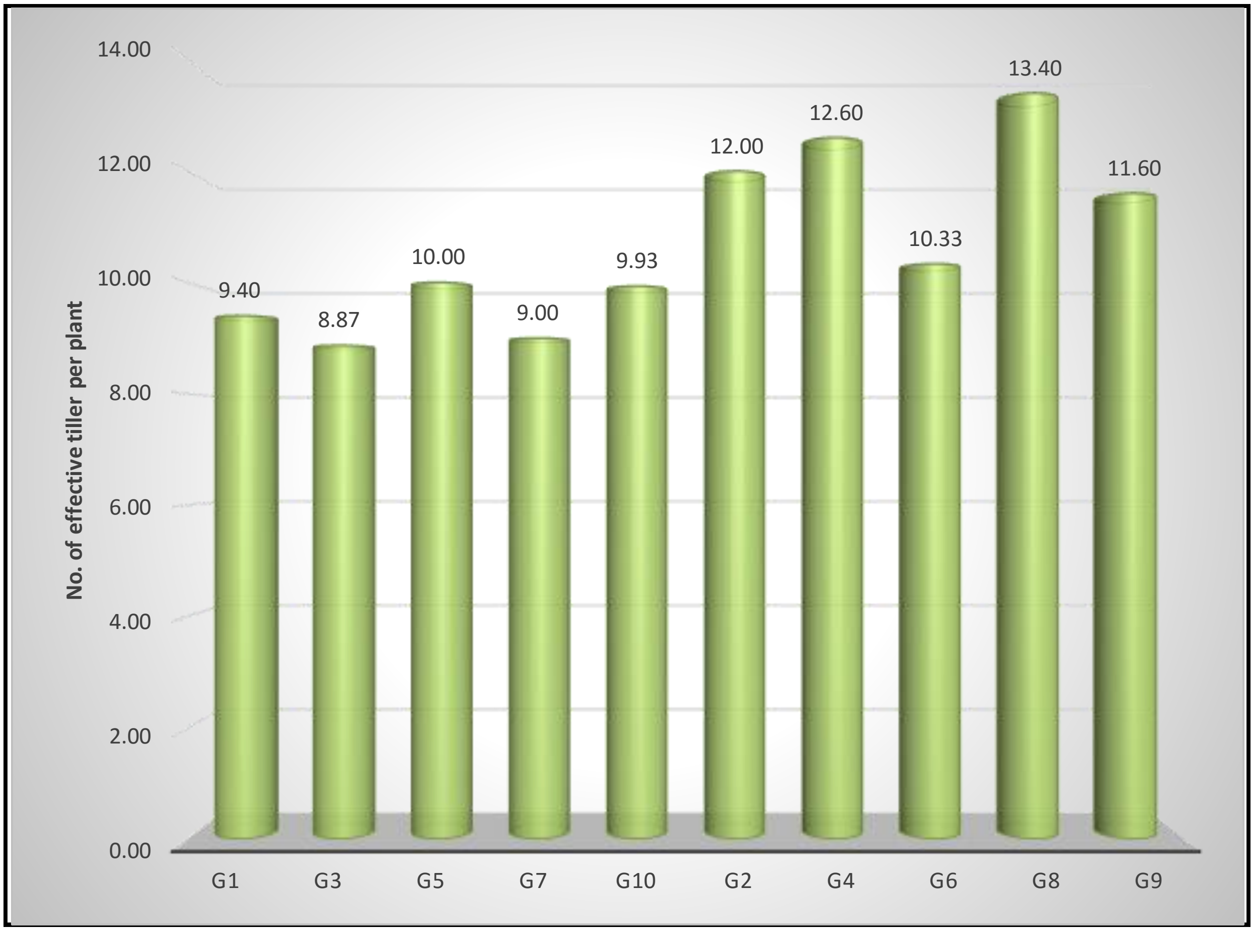


Figure 21. Number of effective tiller per plant as observed in Aus rice genotypes

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from May to August 2017 to study the characterization of ten Aus rice genotypes including two check varieties. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. To establish distinctiveness among rice genotypes qualitative characters have been used.

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

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

Six genotypes (G2, G4, G6, G8, G9, G10) showed early time of heading. All ten genotypes showed well exerted panicle hence they are good for grain yield improvement. Six genotypes (G2, G4, G6, G8, G9 and G10) were early maturing type. Two genotypes (G9 and G10) showed very high category of 1000-grain weight. One genotype (G10) was performed very long type grain length with more than 7.5 mm of grain length. Genotypes G1, G2, G8 and G9 showed long type of grain length.

Six genotypes (G2, G4, G6, G8, G9, G10) were represented medium type of culm length. Four genotypes (G1, G3, G5, G7) were represented long type of culm length. Four genotypes (G1, G3, G5, G7) were observed long panicle as length between 26-30 cm is long. Five genotypes (G2, G4, G6, G8 and G9) were observed more effective tiller per plant (more than 10).

Conclusions

The present study was done with an objective of characterizing the rice lines in qualitative and quantitative basis for fulfilling the requirements of the DUS test. The rice genotypes used in the study exhibited maximum variability for 12 traits. Out of 37 morphological traits observed, shape of the ligule, attitude of the blade of flag leaf, days to heading, days to maturity, 1000-grain weight, grain length (without dehulling), sterile lemma length, decorticated grain length (after dehulling), decorticated grain shape, culm length, panicle length and no. of effective tiller per plant showed most variation among the genotypes.

Recommendations

Future work to be carried out on bio-chemical characterization of grain quality, cooking and eating properties of the studied rice genotypes to meet the consumers demand. Rice genotypes with lowest genetic similarity and traits of interest can be selected and used in breeding programmes and screening for higher yield and superior grain quality rice varieties. Further work on molecular basis by using up suitable markers to carry out fingerprinting study.

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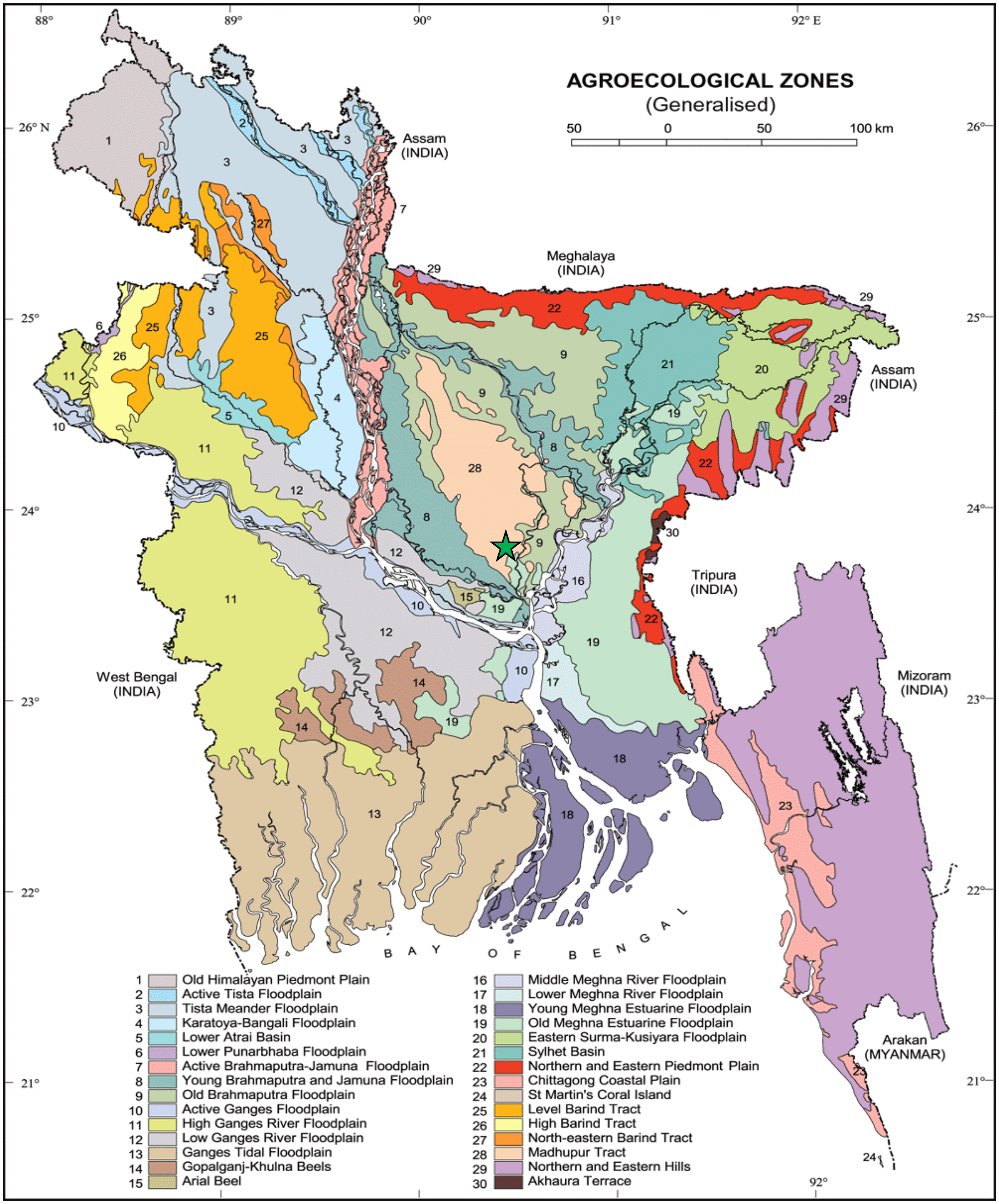
APPENDICES

Appendix I: Means of three quantitative traits obtained in 10 rice genotypes

Genotype No.	Genotype	Stem length (cm)	Panicle length (cm)	No. of effective tiller per plant
G1	24 x 36 $S_8P_1P_1S_2$	95.733	29.473	9.400
G2	26 x 28 $S_1P_7P_2S_1$	65.953	24.973	12.000
G3	26 x 29 $S_6P_3P_2$	102.933	25.213	8.867
G4	26 x 28 $S_1P_7P_2$	65.640	24.413	12.600
G5	24 x 36 $S_8P_1P_1$	101.127	26.720	10.000
G6	21 x 36 $S_1P_4P_1S_1$	65.267	21.340	10.333
G7	24 x 36 S_8P_1	103.753	27.833	9.000
G8	26 x 28 $S_1P_7P_2$	64.867	23.607	13.400
G9	BRRIDhan43	69.807	21.893	11.600
G10	BRRIDhan55	64.367	23.900	9.933
Grand Mean		79.945	24.937	10.713
F-probability		**	**	*
LSD (5%)		8.872	2.504	2.869

Appendix II. Map showing the experimental site under the study



★ Showing experimental location

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

A. Morphological characteristics of the experimental field

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

B. Physical composition of the soil

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

C. Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.45	Walkley and Black, 1947
2	Total N (%)	0.03	Bremner and Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lanester, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner, 1965
6	Available P (ppm)	20.54	Olsen and Dean, 1965
7	Exchangeable K (me/100 g soil)	0.10	Pratt, 1965
8	Available S (ppm)	16.00	Hunter, 1984
9	pH (1:2.5 soil to water)	5.6	Jackson, 1958
10	CEC	11.23	Chapman, 1965

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

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

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

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