VARIABILITY, CHARACTER ASSOCIATION AND STUDY OF QUALITY CHARACTERISTICS OF 10 F9 AUS RICE LINES

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CERTIFICATE

This is to certify that thesis entitled, "**VARIABILITY, CHARACTER ASSOCIATION AND STUDY OF QUALITY CHARACTERISTICS OF 10 F9 AUS RICE 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 **Registration No. 12-04765** 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
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DEDICATED
TO

FATHER OF THE NATION
BANGABANDHU SHEIKH MUJIBUR RAHMAN

AND
MY BELOVED PARENTS

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ABSTRACT

The present research work was conducted at the central farm, Sher-e-Bangla Agricultural University (SAU), Dhaka during March, 2018- August, 2018 to evaluate the variability, character association and to study of quality characteristics of 10 F9 Aus rice 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 experiment was 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. The maximum number of effective tillers per plant (20.80) was recorded from L7 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 (21.77 cm) was recorded from L2. The highest number of filled spikelets per panicle (119.90) was recorded from L7 while the lowest number of unfilled spikelets per panicle was recorded in L7 (18.93). The highest grain yield (3.83 and 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. The maximum hulling, milling and head rice recovery (26.5 %, 66.67 % and 61.67%) was recorded from L7. The highest kernel length, breadth length/breadth and uncooked rice was observed in L7 (5.93, 2.33 and 2.55, respectively). The highest kernel length, breadth and ration of cooked rice (8.19 mm, 3.17 mm and 2.58) was recorded from L7. The highest kernel elongation ratio and index (1.38 and 1.02) were recorded from L7. The maximum volume expansion (28.04 %), the highest alkaline spreading value (4.33), the highest protein (8.40 %) and the lowest and the lowest amylose (23.93 %) were in L7. Line L7 (BR 21× BRRI dhan29, $S_2P_1S_1$) was better cultivar in terms of quality, yield and yield contributing characters.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

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
Length and Breath Ratio	L/B ratio
Gelatinization temperature	GT

CHAPTER I

INTRODUCTION

Rice is one of the most important food crops in the world, serving as staple food for over one-third of the world's population (Reddy *et al.*, 2013). Rice is a self-pollinated cereal crop belonging to the family Gramineae (synonym-Poaceae) under the order Cyperales and class Monocotyledon having chromosome number 2n=24 (Hooker, 1979). The Oryza includes a complete 25 recognized species out of which 23 are wild species and two are cultivated variety. They are *Oryza sativa* and *Oryza glaberrima* (Brar and Khush, 2003).

Rice (*Oryza sativa* L.) is the staple food of Bangladesh, grown in a wide range of environment. Rice is the second largest produced cereal in the world. It has been cultivated 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 within the average daily diet of the people (Bhuiyan *et al.*, 2002).

Rice occupies a singular position in many nations because for its importance in traditional diets and therefore the main source of income of many people in the world. It is the basis of food security and is intimately associated with traditional culture and customs of Bangladesh. The wide environmental diversity in Bangladesh, attributed mainly to the considerable variation in topographic and seasonal components, is reflected within the range of rice groups cultivated, viz., Aus, transplanted (T.) Aman, broadcast (B.) Aman and Boro, as well as in the distribution of wild and weed races (Nasiruddin and Miah, 1983). Aus season exists from March-April to July-August, T. aman from June-July to November-December and Boro season from October-November to April-May. Land under cultivation for Aus, T. Aman and Boro season is 2583 acres, 13665 acres and

11961 acres, respectively (BBS, 2019) and the production for Aus, T. Aman and Boro season is 2328 MT, 13190 and 19192 MT, respectively (BBS, 2019). The area of production and yield of rice in the country in 2010 were 11.58 million ha, 33.90 MT and 2.92 $MTha^{-1}$ respectively under the diverse ecosystems subject to irrigated, rainfed and deep-water conditions in three distinct seasons namely Aus, Aman and Boro with production of 2.63, 12.74 and 18.53 million MT respectively (AIS, 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 can not 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 in the amount of milled rice. 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 therefore milled rice which contains less food nutrients compared to that of brown rice (unpolished rice or whole grain) (Roy *et al.*, 2008).

Over 90% people depend upon 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 remains growing by two million per annum and should increase by another 30 million over subsequent 20 years. But the average yield of rice is poor (3.13 $MTha^{-1}$) in Bangladesh (BBS, 2019).

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 feature to the rice consumer.

Cooking and eating properties of milled rice play an important role in consumer preference particularly cooked rice texture, aroma and flavor of the cooked rice. Rice composition and/or structure especially that of the starch, which is the major component, have a high correlation with cooking and eating properties rather than with physical characteristics (Mestres *et al.*, 2011). Therefore, the milled rice can be categorized based on amylose content which contributes a different texture to the cooked rice and to gelatinization temperature which relates to cooking time.

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). While the quality of rice grain is related to consumer preference, the quality of rice flour is associated with rice grain characteristics. For example, rice grain containing fine starch structures (Champagne, 2004, Prasert and Suwannaporn, 2009, Vandeputte *et al.*, 2003).

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 to increase the yield of Aus rice having genes from Aus 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 a new rice variety.

OBJECTIVES

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

CHAPTER II
REVIEW OF LITERATURE

Bangladesh produces a large number of rice varieties for regular consumption. Mostly rice varieties have been developed traditionally by selection, hybridization and back crossing with locally adapted high-yielding lines. Some of the important and informative works and research findings related to the characterization and comparative study of rice, so far been done at home and abroad, have been reviewed in this chapter.

2.1 Evaluation of yield performance of 10 F9 lines of Aus rice

2.1.1 Days to 50% flowering

Ashvani *et al.* (2007) studied the genetic parameters of variability and heritability of different characters in 32 genotypes of rice, grown in Ghaziabad, Uttar Pradesh, India, in Kharif 1992. The heritability and high genetic advance as percentage of mean estimates were highest for days to flowering.

Ingale *et al.* (2007) conducted an experiment Effect of seedling age on 50% flowering of parental lines of Sahyadri rice hybrid. The experiment was formulated to assess the effect of seedling age at transplanting on 50% flowering of A, B, and R lines of Sahyadri rice hybrid. The 50% flowering was delayed in both younger and older aged seedlings than the recommended age of seedling (25 days old) at transplanting by approximately half the number of days by which the seedlings are younger and older than the recommended age.

Sharma *et al.* (2006) evaluated 39 upland rice genotypes for the estimation of genetic variability. The significant mean sum square indicated strong variability for days to 50% flowering. Though days to 50% flowering had high heritability (92.8%), it had low GCV.

Sanjeev (2005) conducted an experiment with 19 mutant lines (M3) derived from Pusa Basmati and Taraori Basmati and observed higher heritability for days to flowering compared to other characters.

Bihari *et al.* (2004); who conducted an experiment with seventeen aromatic rice genotypes observed the days to flowering and test weight were highly heritable traits.

Venna *et al.* (2002) found that A few crosses showed heterobeltiosis for days to 50% flowering. The correlation between heterosis over better parent and inbreeding depression showed that yield can be improved by direct selection for days to 50% flowering and number of productive tillers per plant.

Iftekharuddaula *et al.* (2001) reported that days to flowering, days to maturity, plant height and spikelets/panicle had positive and higher indirect effect on grain yield through grain/panicle.

Ganesan (2001) said that days to flowering, plant height, number of tillers/plant, and productive tillers/plant had both positive and negative indirect effects on yield.

2.1.2 Days to maturity

Rafiqul (2014) conducted experiment with 19 genotypes of rice, existence of variance in 14 yield contributing character including days to maturity were found in analysis of variance.

Khush (1999) reported that the optimum growth duration for maximum rice yields in the tropics is thought to be 120 days from seed to seed. Growth duration of about 120 days allows the plant to utilize more soil nitrogen and solar radiation and resulting in high yield. However, for adaptation of various cropping system, varieties with varying growth duration of 100- 130 days are required.

2.1.3 Plant height (cm)

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 various hybrid rice varieties evaluated had significant effects on plant height at maturity.

Selvaraj *et al.* (2011) found High heritability coupled with high genetic advance and high GCV were observed for plant height.

Kole *et al.* (2008) studied variability for twelve morphological characters of 18 morphologically distinct mutants in M4 generation in conjunction with their two mother genotypes (IET 14142 and IET 14143), which were developed from Tulaipanja, an aromatic non-basmati rice cultivar of West Bengal. Genotypic and phenotypic coefficients of variation were high for flag leaf angle and panicle number; moderate for grain number per panicle, straw weight, harvest index and grain yield per plant; and low for days to flower, plant height, panicle length, spikelet number, spikelet fertility (%) and test weight. High heritability amid high to moderate genetic advance for flag leaf angle, panicle number, grain number, straw weight and grain yield indicated the predominance of additive gene action for the expression of these characters.

Shashidhar *et al.* (2005) reported positive association of spikelet yield with plant height, number of productive tillers hill^{-1}, dry matter plant^{-1} and harvest index at 15 phenotypic and genotypic level.

Zahid *et al.* (2005) studied 14 genotypes of basmati rice and observed high heritability couple with high genetic advance for plant height and 1000 grain weight.

Sarma and Bhuiyan (2004) studied genetic variation and divergence in 58 Aus rice genotypes and observed highest broad- sense heritability for plant height.

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

De *et al.* (2002) conducted an experiment and found 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.

Ganesan (2001) observed that plant height, days to flowering, number of tillers/plants, and productive tillers/plant had both positive and negative indirect effects on yield.

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.

Prasad *et al.* (2001) found that days to flowering are negatively correlated with plant height.

Spanu (2001) conducted that plant height ranged from <65 cm in Mirto, Tejo, Gladio, Lamone and Timo, to 80-85 cm. Nine hybrid rice cultivars were resistant to lodging.

Chen-Liang *et al.* (2000) showed that the cross between Peiai 64s and the new plant type lines had longest plant height.

Cristo *et al.* (2000) observed 8 morphological traits. The highest correlation was between the final height and panicle length, and full grains per panicle and yield.

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

2.1.4 Number of effective tillers per plant

Rafiqul (2014) conducted experiment with 19 genotypes of rice, existence of variance in 14 yield contributing character including no. of effective tiller per plant were found in analysis of variance.

Selvaraj *et al.* (2011) found High heritability coupled with high genetic advance and high GCV were observed for number of tillers/plant followed by number of productive tillers per plant.

Tang *et al.* (2007) observed the agronomic traits and heterosis of javanica varieties and the indica- javanica genotypes of rice in Changsha, Hunan, China. Javanica rice exhibited long panicles, big grains, less panicle per plant, a long growth duration and high plant height in Changsha. The hybrid of (Pei`ai RNT 711, RNT 24, RNT 1, PNL 2, PLANTG 1, RTN 2, KJT 2, RNT 3, KJT 147 and RNT 68) were evaluated for heterosis, heterobeltiosis and yield advantages in percent. Heterosis, heterobeltiosis and yield advantages in percent for productive tiller number per plant ranged from - 26.10 to 124.32%, 44.79% to 90.80% and 58.50% to 80.43% respectively.

Sankar *et al.* (2006) conducted an experiment with 34 rice genotypes and high heritability as well as genetic advance was obtained for productive tillers per plant.

Patil and Sarawgi (2005), evaluated 128 aromatic rice accessions and estimate genetic variation and correlation for 7 traits and found that number of ear-bearing tiller hill-1 had high genotypic and phenotypic coefficient of variation. High heritability coupled with high genetic advance was also estimated for this character.

Somnath and Ghosh (2004) reported that the association of yield and yield 9 related traits with the number of effective tillers and had negative association with yield and yield components.

Tahir *et al.* (2002) reported that Grain yield had positive correlations with number of productive tillers/plant.

Ganesan (2001) reported that plant height, days to flowering, number of tillers/plant, and productive tillers/plant had both positive and negative indirect effects on yield.

Ma *et al.* (2001); experimented that ADTRH1 is a rice hybrid. It tillers profusely (12-15 productive tillers per hill) under 20 x 10 cm spacing, with each panicle 27.5-cm long, producing 142 grains. In different trials, ADTRH1 showed 26.9 and 24.5% higher yield over CORH1 and ASD18, respectively, with an average yield of 6.6 t/ha.

Laza *et al.* (2001) observed 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.

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

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

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

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

2.1.5 Panicle length (cm)

Ullah *et al.* (2011) observed that grain yield was positively and significantly associated with grains per panicle.

Sabouri *et al.* (2008) conducted an experiment with the traits of the parents (30 plants), F1 (30 plants) and F2 generations (492 individuals), which were evaluated at the Rice Research Institute of Iran (RRII) during 2007 and results of selection indices showed that selection for anicle length by using their phenotypic and/or genotypic direct effects (path coefficient) as economic weights should serve as an effective selection criterion for using either the optimum or base index.

Satyanarayana *et al.* (2005) studied variability, correlation and path coefficient analysis for 66 restorer lines in rice and observed low heritability for panicle length as well as high variability, heritability and genetic advance for plant height.

Laza *et al.* (2004) studied was measured with yield-related traits, panicle size had the most consistent and closest positive correlation with grain yield.

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

Sharma (2002) conducted with fine grain rice and reported that there had been significant variation in panicle length.

Tahir *et al.* (2002) studied genetic variability for various traits. He found that these traits are under the genetic control and could be use in the selection of a desirable trait.

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).

Nehru *et al.* (2000) observed that values for test weight and yield differed significantly for hybrids (21-24 g) and varieties (19-23 g). No differences in panicle length were noted between the two groups.

Cristo *et al.* (2000) showed that highest correlation was between the final height and panicle length, and full grains per panicle and yield. There were associations between rice hybrids and their parents.

2.1.6 Filled grain per panicle

Rafiqul (2014) conducted experiment and reported with 19 genotypes of rice, existence of variance in 14 yield contributing character including no. of filled grain of main tiller were found in analysis of variance.

Ullah *et al.* (2011) reported that grain yield was positively and significantly associated with grains per panicle.

Kumar *et al.* (2009) carried out an experiment to observed the selection criteria for selecting high yielding genotypes in two different early segregating F2 and F3 populations by estimating heritability and genetic correlation between yield and its main economic traits in their subsequent F3 and F4 generations of two crosses in rice. The heritability estimates were high for spikelet/main panicle whereas it was low for panicles/plant.

Wang *et al.* (2007) observed the effects of panicle type and source-sink relation on the variation in grain weight (GW) and quality within a panicle were investigated using four japonica (*Oryza sativa* L.) varieties differing in grain density and two source-sink adjusting treatments. There were significantly differences in GW and filling grain percentage (FGP) among superior and inferior grains for compactpanicle varieties (Xiushui 994 and Xiushui 63), while not for loose-panicle ones (Xiushui 11 and Chunjiang 15).

Ismachin and Sobrizal (2006) reaveled 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.

Yuan *et al.* (2005) conducted experiment and observed the variation in fertile grain percentage/panicle in *indica* was greater than that in *japonica*.

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%).

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.

Tahir *et al.* (2002) reported highly significant variation for the grain per panicle for different genotypes. Other factors i.e. soil fertility, plant nutrients, translocation and weather condition might also responsible.

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.

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).

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.

Cristo *et al.* (2000) observed the highest correlation between full grains per panicle, final height and panicle length and yield.

2.1.7 Total grains per panicle

Sabouri *et al.* (2008); studied the traits of the parents (30 plants), F1 (30 plants) and F2 generations (492 individuals), which were evaluated at the Rice Research Institute of Iran (RRII) during 2007 and results of selection indices showed that selection for grain weight and number of panicles per plant by using their phenotypic and/or genotypic direct effects (path coefficient) as economic weights should serve as an effective selection criterion for using either the optimum or base index.

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.

Chen-Liang *et al.* (2000) showed that the cross between Peiai 64s and the new plant type lines had strong heterosis for filled grains per plant, number of spikes per plant and grain weight per plant, but heterosis for spike fertility was low.

2.1.8 1000-grain weight (g)

Kumar *et al.* (2009) carried out an experiment to study the selection criteria for selecting high yielding genotypes in two different early segregating F2 and F3 populations by estimating heritability and genetic correlation between yield and its main economic traits in their subsequent F3 and F4 generations of two crosses in rice. The heritability estimates were high for 100-grain weight, whereas it was medium to low for grain yield.

Karim *et al.* (2007) studied on variability and genetic parameter analysis of 41 aromatic rice genotypes. The phenotypic variance was higher than the corresponding genotypic variance for the characters. These differences were in case of number of panicles per hill, number of primary branches, number of filled grains per panicle, spikelet sterility (%) and grain yield per hill indicating greater influence on environment for expression of these characters. 1000-grain weight and days to maturity showed least difference between phenotypic and genotypic variance, which indicated additive gene action for expression of the characters. High genotypic coefficient of variation (GCV) value was revealed for 1000-grain weight followed by spikelet sterility (%), grain yield per hill and number of filled grains per panicle, whereas days to maturity showed very low GCV.

Patil and Sarawgi (2005) studied genetic variability in traditional aromatic rice accessions and found that the genetic and phenotypic coefficients of variation were high for 100- grain weight.

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 23.8 g. In different trials, ADTRH1 showed 26.9 and 24.5% higher yield over CORH1 and ASD18.

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

2.1.9 Grain yield/plant

Rafiqul (2014) conducted experiment with 19 genotypes of rice, existence of variance in 14 yield contributing character including yield (ton/ha) were found in analysis of variance.

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.

Hairmansis *et al.* (2010) recorded a positive and significant association of grain yield with filled grains per panicle, spikelet per panicle and spikelet fertility.

Selvaraj *et al.* (2011) found High heritability coupled with high genetic advance and high GCV were observed for grain yield / plant.

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.

Pruneddu and Spanu (2001) data are tabulated on grains per plant, days from sowing to maturity, grain yield, and plant height, number of fertile stems per m^2, 1000-grain weight and yield percentages. Yields were generally lower mainly due to unfavorably high temperatures.

Ganesan (2001) reported that grains/plant had the least significant positive direct effect on number of tillers/plant (0.688), panicle exertion (0.172), panicle length (0.167) and plant height (0.149).

Mao (2001) noted that yield improvement of rice grain yield is the main target of breeding program to develop rice varieties for diverse ecosystems. In addition, grain yield also related with other characters such as plant type, growth duration, and yield components.

2.2 Study of milling quality and grain appearance

Singh *et al.* (2005) and Izawa (2008) found that a significant variation in physical, composition, and cooking quality has been shown among rice cultivars produced in different parts of world with the influence of diverse genetic and environmental factors.

Peng *et al.* (2005) reported that threshing on the day of harvest gave highest HRR and lowest broken rice, and delay will lead to reduction in milling recovery and also studied the relationship between milling recovery and grain moisture at harvesting and reported that high recoveries of total milled and head rice and good cooking quality were obtained from grains harvested at 20-23% grain moisture content.

Marassi *et al.* (2004) observed that long kernel varieties had lower hulling and milling recovery percentage than short kernel varieties, but better water uptake during cooking. Varieties with high protein content also suffer less breakage. Sun cracking is caused by alternate drying and wetting of grains due to delayed harvest also aids in more breakage of grain. High gelatinization temperature types are less prone to cracking.

Yang *et al.* (2001) reported that milling quality was slightly affected by locality, moderately affected by year and mostly affected by grain type. Chalky grains are not as hard as the translucent one and more prune to breakage during milling. In general, varieties with long or long bold grains and those having white centers give lower head rice yields. Varieties possessing medium slender, long slender and translucent grains give high head rice yields.

Tan *et al.* (2001) reported that milling properties, protein content, and flour color are important factors in rice. The milling properties were controlled by the same few loci that are responsible for grain shape.

2.2.1 Hulling (%)

Sandeep (2003) found 71.67% to 84.56% hulling per cent during characterization of 20 new plant type genotypes in rice.

Sujatha *et al.* (2004) expressed that advantages of parboiling over raw milled rice are a better recovery of whole grains during milling, making a translucent hard grain, resistant to breakage, inactivation of enzymes, biological sanitation, easier removal of the hull during milling, better grain swelling during cooking, less starch in the cooking water, change in taste and texture of rice.

2.2.2 Milling outturn (%)

Tabien *et al.* (2012) reported that two newly released high yielding rice varieties, Antonio and Colorado would be the new choices for rice farmers in Texas for commercial production in the future. Both inbred varieties show great promise of good milling qualities. These could also be good recipients of important traits needed in future climate or environment. The screening and yield performance trials identified donors for tolerance to higher rate of herbicide.

Satish *et al.* (2004) observed that eating quality of rice is a great concern to consumer, millers and rice breeders. It is influenced by varietal characteristics, conditions of cultivation and post-harvest storage and processing operations. The degree of milling and cooking methods influence the cooking quality of rice to a significant extent.

Begum *et al.* (2001) found that milling outturn of Iranian varieties ranged from 61 to 70% and BRRI varieties from 66 to 71%.

Biswas *et al.* (2001) found milling outturn some Binni rice varieties and compared with BR25 and Nizersail varied 67 to 71% and head rice outturn from 88 to 97%.

Chun and Jun (2001) reported that the milling quality characters in F_2 are influenced by genes of F_1 plants and F_2 seeds.

2.2.3 Head rice recovery

Rui *et al.* (2005) observed that long kernel varieties had lower hulling and milling recovery percentage than short kernel varieties, but better water uptake during cooking. Varieties with high protein content also suffer less breakage. Sun cracking is caused by alternate drying and wetting of grains due to delayed harvest also aids in more breakage of grain. High gelatinization temperature types are less prone to cracking.

Sandeep (2003) reported that the value of rough rice is often determined by the percentage of head rice and total milled rice produced after milling. GCA effects were more important than SCA effects for head rice percentage, indicating the importance of additive genetic effects in the inheritance of head rice percentage. Although in the initial years, some of the hybrids recorded low head rice recovery, studies have shown that hybrids with higher head rice recovery can be obtained when the parents are selected carefully. If the parents are prone to enhance grain breakage, the F1 would normally record lower head rice recovery than the better parent.

Shobha Rani (2003) found that for the commercial success of a rice variety it must possess high total milled rice and whole kernel (HRR) turnout. If a variety has a higher broken percentage, its marketability will be reduced. Head rice recoverability is an inherited trait, although environmental factors such as temperature and humidity during ripening and postharvest stages are known to influence grain breakage during milling.

Shobha Rani *et al.* (2002) reported that GCA effects were more important than SCA effects for head rice percentage, indicating the importance of additive genetic effects in the inheritance of head rice percentage. Although in the initial years, some of the hybrids recorded low head rice recovery, studies have shown that hybrids with higher head rice recovery can be obtained when the parents are selected carefully. If the parents are prone to enhance grain breakage, the F_1 would normally record lower head rice recovery than the better parent. Improvement of this trait is increasingly evident with many recently tasted experimental hybrids exhibiting high head rice yields.

Arf *et al.* (2002) reported that head rice yield indicates the weight of whole grains obtained after industrial processing. This is one of the most important parameters in rice commercial value determination.

2.2.4 Grain dimensions

The milling and marketable qualities depend upon the size and the shape of the grain. Grain dimension is expressed as length, breadth and thickness, whereas shape is generally expressed as the ratio between the length and breadth.

Shobha Rani (2003) reported that bold grains give low head rice recovery because of high breakage. Grains with short to medium length break less than long grains during milling. Thus, grain size and shape have direct effect of head rice.

Begum *et al.* (2001) reported on some Iranian and BRRI rice varieties and found that length of Iranian varieties varied from 6.19 to 7.83mm and L/B ratio from 3.0 to 4.1. BRRI varieties were from 3.60 to 6.82mm long and had L/B ratio from 2.10 to 3.61.

Biswas *et al.* (2001) estimated the length and L/B ratio of milled rice samples range from 4.7 to 6.2 and 2.1 to 3.2mm, respectively in some Binni rice varieties and compared with BR25 and Nizersail.

2.3 Cooking and eating characteristics of the grain

Bocevska *et al.* (2009) and Moongngarm *et al.* (2010) told that rice grain quality is reported to be influenced by various physicochemical characteristics that determine the cooking behavior as well as the cooked rice texture.

Rui *et al.* (2005) found that the cooking and eating quality of rice has attracted more attention recently. Cooking and eating characteristics are largely determined by the properties of the starch that makes up 90% of milled rice. Gelatinization temperature, amylose content and gel consistency are the important starch properties that influence cooking and eating characteristics. In combination with previous reports, confirmed that either the waxy gene the waxy gene itself or a genomic region tightly linked to it plays a major role in determined the cooking and eating quality of rice.

Staish *et al.* (2004) observed that cooking index (CI) was formulated as a function of optimum cooking time. Most of the short - grain rices, as well as some of the medium and long varieties, have a rather sticky texture when cooked. The sticky type is preferred by some people,
especially those who eat rice with chopsticks, because the grains cling together.

2.3.1 Kernel elongation ratio

Shalidulla *et al.* (2009) reported that higher elongation ratio of the cooked rice is preferred by the consumer than that with lower elongation ratio.

Shabbir *et al.* (2006) told that the elongation ratio is greatly determined by the storage interval and treatment.

Faruq *et al.* (2003) reported that different type of Indian and Pakistani Basmati, Afghanistan's Sadri and Myanmar's D25-4 (Nga Kyee) possess this extreme elongation property. Later on, it becomes more popular for its high cooked kernel elongation ratio.

Gua *et al.* (2003) reported that the hybrid rice combination with good quality of appearance and cooking, the genetic improvement of parents could be conducted through the increase of length/width and decrease of amylase content and chalkiness, and the differences of endosperm character between parents should be small.

Biswas *et al.* (2001) studied the ratio of elongation of cooked to uncooked rice ranged from 1.2 to 1.6 and 3.0 to 4.3 respectively.

Begum *et al.* (2001) reported that Iranian varieties had elongation ratio of 1.18 to 1.60 and that of BRRI rice varied from 1.35 to 1.39.

2.3.2 Water absorption (uptake) percentage and volume expansion

Ge *et al.* (2005) reported that the traits of elongation water absorption are very important in determining the quality of cooked rice grains.

Singh *et al.* (2000) reported that lower VER is preferred than higher VER. On the other hand, higher ER is preferred than lower ER for quality of cooked rice.

Chauhan (2000) told correlation co-efficient of grain physical characters were correlated with uptake and volume expansion.

2.3.3 Gelatinization temperature (GT)

Gelatinization Temperature of the rice grain is recognized as one of the most important determinants of cooking quality (Rao *el al,* 2004). It is generally indirectly tested by dispersal in dilute alkali using the alkali spreading value (ASV) test of Little *ct al.,* (1958). The time required for cooking milled rice is determined by gelatinization temperature. Environmental conditions such as temperature during ripening influence GT: In many rice growing countries there is a distinct preference for rice with intermediate gelatinization temperature (IRRI, 2004).

Yang *et al.* (2003) reported that the degree of gelatinization varied among the different parts of the grain and cultivars. The gelatinization in the dorsal side was the most complete, with cells that were decomposed totally into puff like of flocculent materials. High quality cultivar had more thoroughly gelatinized cells on all sides than low quality ones. Varietal differences in the dorsal sides were less distinct than those at the middle and ventral sides. Grain quality was positively correlated with the rate of water absorption and extension.

2.3.4 Protein (%)

Kennedy and Burlingame (2003) reported that protein is the second most abundant constituent in rice. The protein content in milled rice ranges from 6.3 to 7.1%.

Zhou *et al.* (2001) and Zhou *et al.* (2003) told that many factors like rice cultivars, moisture content, proteins content, lipid, amylose content, processing methods, prolamin, pH affect the amylose content of rice.

Wang *et al.* (2002) and Fitzgerald *et al.* (2003) suggested that comparing rice flour and its starch, distinct viscosity was observed mainly due to the influence of proteins.

Batey *et al.* (2000) reported that the variation among rice varieties and their pasting properties is greatly affected by starch and water concentration, protein and operating conditions of the experimental instrument.

2.3.5 Amylose (%)

Asghar *et al.* (2012) reported that amylose content can play a significant role in determining the overall cooking, eating and pasting properties of a rice variety.

Cai *et al.* (2011) conducted that apart from the amylose content, the cooking quality of rice can also be influenced by components such as: proteins, lipids or amylopectin.

Magdy *et al.* (2010) reported that feeding with cooked rice high in amylose instead of cooked rice low in amylose may be effective to control serum blood glucose and lipid.

Shabbir (2008) observed that the rice variety, amylose content, gelatinization temperature and cooking methods are the factors affecting the rice texture. Rice texture is soft and sticky for varieties having low amylose content while rice varieties become stiff and fluffy on cooking having high amylose content.

Shabbir *et al.* (2008) told that the amylose content in the range of 18.60-28.0% for different rice varieties.

Cristiane *et al.* (2007) reported that serum triglyceride and cholesterol levels significantly decreased after consumption of a diet rich in amylose compared to a diet rich in amylopectin (Low amylose). Rice varieties high in amylose would invariably be low in amylopectin content.

Vandeputte *et al.* (2003) reported that amylose content is the main factor for pasting viscosity, however, other results showed two similar amylose content rice flours expressed very different pasting properties.

Nayak *et al.* (2003) observed that earlier, a strong positive correlation has also been reported between amylose content and elongation of rice.

Frei and Becker (2003) told that since starchy foods with high amylose level are associated with lower blood glucose level and slower emptying of the human gastrointestinal tract compared to those with low levels of this macromolecule.

Wang and Porter (2002) reported that the difference in physicochemical characteristics of six wild rice varieties was due to the difference in branch chain length distribution of amylose and amylopectin.

Many factors like rice cultivars, moisture content, proteins content, lipid, amylose content, processing methods, prolamin, pH affect the amylose content of rice (Lai, 2001).

Krossmann and Lloyd (2000) reported that the activity of the enzymes involved in starch biosynthesis may also be responsible for the variation in amylose content among the various starches.

CHAPTER III

MATERIALS AND METHODS

In this chapter the details of the different experimental materials and methodologies which are followed during the course of research are presented. A brief description of the experimental site and duration, experimental treatment, materials, sampling procedure and technologies used for the production, the procedure of data collection, recording and statistical analysis are explained under the following headings:

3.1 Description of the experimental site

3.1.1 Location and duration of the experiment

The present research work was conducted at the agronomic farm, Sher-e-Bangla Agricultural University (SAU), Dhaka during **March, 2018- August, 2018**. The location of the site is 23° 74' N latitude and 90° 35' E longitude with an elevation of 8.2 meter from sea level (Appendix I).

3.1.2 Climate and soil

The experimental site was situated in the sub-tropical zone. The soil of the experimental site lies in Agroecological region of “Madhupur Tract” (AEZ No. 28). Its top soil is clay loam in texture and olive gray with common fine to medium distinct dark yellowish-brown mottles. The pH is 6.1 and organic carbon content is 0.82% (Appendix II)

3.1.3 Climatic condition of the experimental site

The experimental area is under the sub-tropical climate that characterized by the three distinct seasons. The monsoon or rainy season extending from June to October, winter or dry season from November to February and the pre-monsoon period or hot season from March to May. Information regarding monthly maximum and minimum temperature, rainfall, relative humidity, soil temperature and sunshine hours are recorded by Sher-e-Bangla Agricultural University Weather Station, Sher-e-Bangla Nagar Dhaka-1207, during the period of study (Appendix III).

3.2 Planting materials used

Ten Aus rice advance lines (F9 generation) were used for this present study. The physically healthy seeds of these genotypes were obtained from the Department of Genetics and Plant Breeding (GEPB), Sher-e-Bangla Agricultural University, Dhaka. The name and origin of these advance lines are presented 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

3.3 Methods

The following precise methods have been followed to carry out the experiment:

3.3.1 Germination of seed

Seed of all collected rice genotypes soaked separately for 24 hours in clothes bag. Soaked seeds were picked out from water and wrapped with straw and gunny bag to increase the temperature for facilitating germination. After 72 hours seeds were sprouted properly.

3.3.2 Seedbed preparation and seedling rising

The experimental plot was prepared by three successive ploughing and cross ploughing. Each ploughing was followed by laddering to have a good puddled field. All kinds of weeds and residues of previous crop were removed from final ploughing. Individual plots were cleaned and finally leveled. Ten separate strips were made and sprouted seeds were sown in 13th March, 2018. The seedlings were raised by maintaining irrigation with regular intervals and protecting from birds and insects and infestation of pest and diseases.

3.3.3 Preparation of main land and application of manure and fertilizer

The experimental plot was prepared by ploughing with rotary disk plough followed by laddering. Weeds and stubbles were removed from the field. The land was mudded and leveled well before transplanting. First split of urea and full portion of all other fertilizers recommended by BRRI were added to the main land before final ploughing. The doses of fertilizer are presented in the Table 2.

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).

3.3.4 Experimental design and layout

A Randomized Complete Block Design (RCBD) with three replications was used to carry out the experiment. The experimental field was divided into three blocks, representing three replications. **Each replication size was 15m x 12m,** and the distance between replication to replication was 50 cm. **The individual plot size was 5m×4m (20 m^2). Total number of plots was 10 × 3 = 30.**

3.3.5 Transplanting

One seedling per hill was transplanted to the main plot on the **4th April, 2018** when they were 22 days old. Row to row and plant to plant distance were 25 cm and 15 cm, respectively. Ten rice genotypes were distributed in each of the block through randomization process.

3.3.6 Intercultural operation

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

3.3.6.1 Irrigation and drainage

Flood irrigation was given to maintain a constant level of standing water up to 6 cm in the early stages to enhance tillering, proper growth and development of the seedlings and 10-12 cm in the later stage to discourage late tillering. The field was finally dried out 15 days before harvesting.

3.3.6.2 Gap filling

First gap filling was done for all of the plots at 10 days after transplanting (DAT).

3.3.6.3 Weeding

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

3.3.6.4 Top dressing

After basal dose, the remaining doses of urea were top-dressed in 2 equal installments. The fertilizers were applied on both sides of seedlings rows with the soil.

3.3.6.5 Plant protection measures

Plants were infested with rice stem borer, leafhopper, and rice hispa, rice bug to some extent, which was successfully controlled by application of insecticides such as Diazinon, and Ripcord @ 10 ml/ 10 liters of water for 5 decimal lands. Crop was protected from birds by providing exclusive netting around the field during the grain-filling period. Field trap and phostoxin which is a poisonous bait were used to control the rat.

3.3.7 Crop harvesting

Different genotypes matured at different times from **28th June to 5th July, 2018.** Harvesting was done when 80% of the plant population of each plot reached to maturity, i.e. straw color of panicles, leaves, stems desirable seed color, the crop was assessed to attain maturity. Ten plants were selected at random from F9 progenies in each replication and also harvested 1m^2 area. The plants were harvested by uprooting and then they were tagged properly. A pictorial view of field experiment is presented in plate 1.

3.3.8 Data collection

Ten plants were randomly selected from each unit plot for the collection of data. The plants in the outer rows and the extreme end of the middle rows were excluded from the random selection to avoid the border effect. However, the yield of all plants was considered per plot yield. Data have been collected on the basis of three attributes like- growth related parameters, yield attributing parameters and quality attributes parameters.

3.3.8.1 Evaluation of the yield performance of different F9 line of Aus rice lines

3.3.8.1.1 Plant height (cm)

The length of five main culms of ten randomly selected plants from the ground level to tip of its panicle was measured and average was taken.

3.3.8.1.2 Days to flowering

Recorded as days from sowing to flowering when 50% of the plant of each plot flowered.

3.3.8.1.3 Days to maturity

Recorded as days on plot basis from sowing to the time when about 80% of the plant were ready for harvesting. Number of days required from sowing to physical maturity was recorded.

3.3.8.1.4 Number of tillers per plant

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

3.3.8.1.5 Number of effective tillers per plant

The number of effective tillers per plant was counted as the number of panicles bearing tillers per plant and average value was recorded.

3.3.8.1.6 Panicle length (cm)

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

3.3.8.1.7 Number of primary branches per panicle

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

3.3.8.1.8 Number of secondary branches per panicle

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

3.3.8.1.9 Number of filled grains per panicle

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

3.3.8.1.10 Number of unfilled grains per panicle

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

3.3.8.1.11 Number of spikelets per panicle

The total number of filled grains and unfilled grains were collected randomly from selected 10 plants of a plot and then average numbers of total spikelet per panicle was recorded.

3.3.8.1.12 Thousand seeds weight (g)

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

3.3.8.1.13 Grain yield (MT 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 MT ha^{-1} in both locations.

3.3.8.1.14 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):

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

3.3.8.2 Study of the milling and grain quality of the lines

3.3.8.2.1 Hulling percent

The samples of 200g well dried paddy from each entry were de hulled in mini "Satake Rice Machine" and the weight of brown rice was recorded. Hulling was worked out as,

$$\text{Hulling (\%)} = \frac{\text{Weight of brown rice}}{\text{Weight of rough rice}} \times 100$$

3.3.8.2.2 Milling percent

The brown rice obtained after de hulling was passed through "Satake Rice Whitening and Caking Machine" for 5 minutes to obtain uniformly polished grains and the weight of polished grains was recorded. Milling percent was calculated as,

$$\text{Milling outturn} = \frac{\text{Weight of milled rice}}{\text{Weight of rough rice}} \times 100$$

3.3.8.2.3 Head rice recovery

The milled samples were sieved to separate whole kernels from the broken ones. Small proportion of whole kernels which passed alone with broken grains was hand separated. Head rice recovery was calculated in percentage as,

$$\text{HRR(\%)} = \frac{\text{Weight of whole milled rice}}{\text{Weight of rough rice}} \times 100$$

3.3.8.2.4. Length of rough rice (mm)

The length of rough rice was recorded.

3.3.8.2.5. Breadth of rough rice (mm)

The breadth of rough rice was recorded.

3.3.8.2.6. L/B ratio of rough rice

L/B ratio was computed according to following formula:

$$\text{L/B ratio} = \frac{\text{Length of rough rice}}{\text{Breadth of rough rice}}$$

3.3.8.2.7. Length of milled rice (mm)

The length of milled rice was recorded.

3.3.8.2.8. Breadth of milled rice (mm)

The breadth of milled rice was recorded.

3.3.8.2.9. L/B ratio of milled rice

L/B ratio was computed according to following formula:

$$\text{L/B ratio} = \frac{\text{Grain length}}{\text{Grain breadth}}$$

Grain type: Grain types (polished rice) were classified by using the following classification proposed by Ramaiah committee in 1965 for the purpose of trade and commerce approved by Ministry of Food. Govt. of India. is given below:

On the basis of average length of kernel, milled rice is classified into following categories.

Table 3. Classification of milled rice on the basis of average length

Scale	Size	Length (mm)
1	Extra long	>7.50
2	Long	6.61 to 7.50
3	Medium	5.51 to 6.60
4	Short	5.50 to less

Grain shape: Grain shape is estimated by length/breadth ratio of kernels as:

Table 4. Classification of milled rice on the basis of length/breadth of kernels

Scale	Size	Length (mm)
1	Slender	Over 3.0
2	Medium	2.1 to 3.0
3	Bold	1.1 to 2.0
4	Round	1.0 to less

(Source: Ahuja *et al.*, 1995)

Grain types were classified by using the following classification proposed by Ramaiah committee in 1965(Table 5)

Table 5. Systematic classification of grain types of rice proposed by Ramaiah committee in 1965

Class	Designation	Description	
		Length	**Length/Breadth ratio**
1. Long Slender	LS	Length 6 mm and above	Length/Breadth ratio 3 and above
2. Short Slender	SS	Length less than 6 mm	Length/Breadth ratio 3 and above
3.Medium Slender	MS	Length less than 6 mm	Length/Breadth ratio 2.5 to 3
4. Long Bold	LB	Length 6 mm and above	Length/Breadth ratio less than 3
5. Short Bold	SB	Length less than 6 mm	Length/Breadth ratio less than 2.5

(Source: Shoba Rani, 2003)

3.3.8.3 Determination of cooking and eating characteristics of the grain

Kernel length and breadth of cooked rice: Individual kernels of the sample were taken separately in long labeled test tubes and presoaked in 5 ml of tap water for 30 minutes. After that, the tubes were placed in a water bath maintained at boiling temperature, for 8-9 minutes. After cooking the test tube were taken out and cooled under running water for two minutes. Cooked kernels were taken out of the tubes and excess water was removed with a blotting paper. Length and breadth of cooked kernels were measured as above.

3.3.8.3.1 Kernel length/ breadth ratio of cooked rice

L/B ratio of cooked kernel was computed according to following formula:

$$\text{L/B ratio} = \frac{\text{Grain length}}{\text{Grain breadth}}$$

3.3.8.3.2 Kernel elongation ratio

Elongation ratio was calculated by dividing the length of cooked kernel by its original length.

$$\text{Elongation ratio (ER)} = \frac{(L_I)}{(L_0)}$$

Where, Lo and L1 are kernel length before and after cooking, respectively.

3.3.8.3.3 Kernel elongation index

Elongation index was calculated by dividing the length/breadth ratio of the cooked kernel by length breadth ratio of the original raw kernel.

$$\text{Elongation index (EI)} = \frac{L_I / B_1}{L_0 / B_0}$$

3.3.8.3.4 Volume expansion (%)

The same sample of one-gram rice kernels that was used for the study of water absorption was used for this study as well. After recording the weight of uncooked samples, their volume was determined by displacement of water method using a finely graduated narrow cylinder of 5 ml capacity. After cooking, final volume of the above sample was recorded and volume expansion percentage was calculated-

$$\text{Volume expansion \%} = \frac{V_2 - V_1}{V_1} \times 100$$

3.3.8.3.5 Alkali spreading value

Alkali spreading value was determined according to procedure of Little *et al.* (1958). A sample of eight whole milled rice kernels from each entry was placed in small petriplates (5 cm wide) containing 10 ml of 1.7% potassium hydroxide (KOH) solution. The petriplates were covered and placed in an incubator maintained at 30 ^{0}C or at ambient temperature for 23 hours. After 23 hours of incubation, the petriplates were gently taken out from the incubator. Alkali spreading values of six grains of each entry were recorded separately and mean was calculated on a 7 point numerical scale (Table 6) proposed by Jennings *et al* (1979) and IRRI (1980). The degree of spreading is measured using a seven-point scale presented in (Table 6):

Table 6: Numerical scale for scoring gelatinization temperature of rice

Score	Spreading	Clearing	Alkali digestion	Gelatinization temperature
1	Kernel not affected	Kernel chalky	Low	High
2	Kernel swollen	Kernel chalky; collar powdery	Low	High
3	Kernel swollen with collar incomplete and narrow	Kernel chalky; collar cottony or cloudy	Low or intermediate	High or intermediate
4	Kernel swollen with collar complete and wide	Centre cottony; collar cloudy	Intermediate	Intermediate
5	Kernel split or segmented with collar complete and wide	Centre cottony; collar clearing	Intermediate	Intermediate
6	Kernel dispersed merging with collar	Centre cottony; collar clear	High	Low
7	Centre and collar clear	Centre and collar clear	High	Low

According to the alkali spreading score the G.T. types were classified as follows:

Table 7. Classification of GT types according to the alkali spreading score

Category	Temp ranges (^{o}C)	Alkali Spreading Value
Low	55-69	6-7
Intermediate	70-74	4-5
High	75-79	2-3

3.3.8.3.6 Protein (%)

Protein content was determined by micro Kjeldahl method (AOAC 1970). Fifty (50) mg samples in powdered form were weighed and introduced into 30 ml Kjeldahl flasks. Then 1.95g catalyst (a mixture of K_2SO_4 and HgO) and 2.3 ml concentrated H_2SO_4 were added. The digested mixture was cooled and minimum amount of water was added to dissolve the solids and cool again. The flasks were connected to the distillation set up. A 125 ml Erlenmeyer flask containing 10 ml boric acid solution plus one drop of mixed indicator (Methyl red) under the condenser with the tip of the condenser extending below the surface of solution was placed. About 9.0 ml of NaOH-$Na_2S_2O_3$ solution was slowly added to the digest. The flask was connected to the steam source and distilled until about 30 ml distillate was collected (10-15 minutes). The receiver and distill was lowered for another mixture. The tip of the condenser was washed with distilled water into the receiver. The distillate was titrated immediately with standard HCl solution to the first appearance of the violet or reddish color. A blank determination was made and simultaneously percent N was calculated with the following formula,

$$\mathrm{N}\ (\%) = \frac{\text{Amount of HCl X Normality of HCl X 0.014}}{\text{grams of sample}} \times 100$$

Protein percentage was determined by multiplying the N (%) with conversion factor of 6.4.

3.3.8.3.7 Amylose (%)

Amylose content of rice was determined according to Juliano (1979). 100 mg of rice powder was taken into a 100 ml volumetric flasks and 1 ml of 95% ethanol and 9 ml of 1N sodium hydroxide were added. The contents were heated in a boiling water bath to gelatinize the starch for 10 minutes. After cooling, distilled water was added to make the sample up to volume. Five ml of starch solution was put in a 100 ml volumetric flask with a pipette. 1 ml of 1 N acetic acid and 2 ml of iodine solution were added and the volume was made up with distilled water. The contents were shaken well and left to stand for 20 minutes. Absorbance of the solution was measured at 620 nm with a spectrophotometer such as the Bausch and Lomb spectronic 20. Amylose content was determined by using a conversion factor and the results were calculated on a dry basis. The moisture content of the samples was essentially constant and need not to be determined if the relative humidity and temperature of the laboratory are controlled. Based on amylose content, milled rice was classified as-

Table 8. Classification of amylose according to amylase%

SI	Class	Amylose %
1	Waxy	1-2
2	Very low	>2-9
3	Low	>9-20
4	Intermediate	>20-25
5	High	>25-30

Source: (Juliano 1972)

3.4 Experimental designs and data analysis

The experiments were designed in a randomized complete block design (RCBD). All data were analyzed by one-way analysis of variance (ANOVA) using MSTATC. Comparisons of the mean were determined by LSD tests at $p \leq 0.05$ level of significance.

CHAPTER IV
RESULTS AND DISCUSSION

The present study was conducted to evaluate for their performance of yield and yield contributing traits, quality contributing traits, interrelationships of these traits and comparison for commercial cultivation.

4.1 Evaluation of the yield performance of different F9 lines of Aus Rice

4.1.1 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 L4 showed the lowest plant height which was statistically similar with L1, L2, L3, L5, L6, L7, L8 and L10 (Table 9). Height of L9 was different from other nine lines. It was seen that plant height had a significant positive relationship with days to maturity. As the days to maturity (145 days) of L9 line was highest, its height (123.57 cm) is also highest.

L7, L8, L9 sequentially

Plate 1: Photograph showing variation in plant height in different lines

Table 9. 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, $S_8P_1P_1S_1$.

4.1.2 Days to 50% flowering

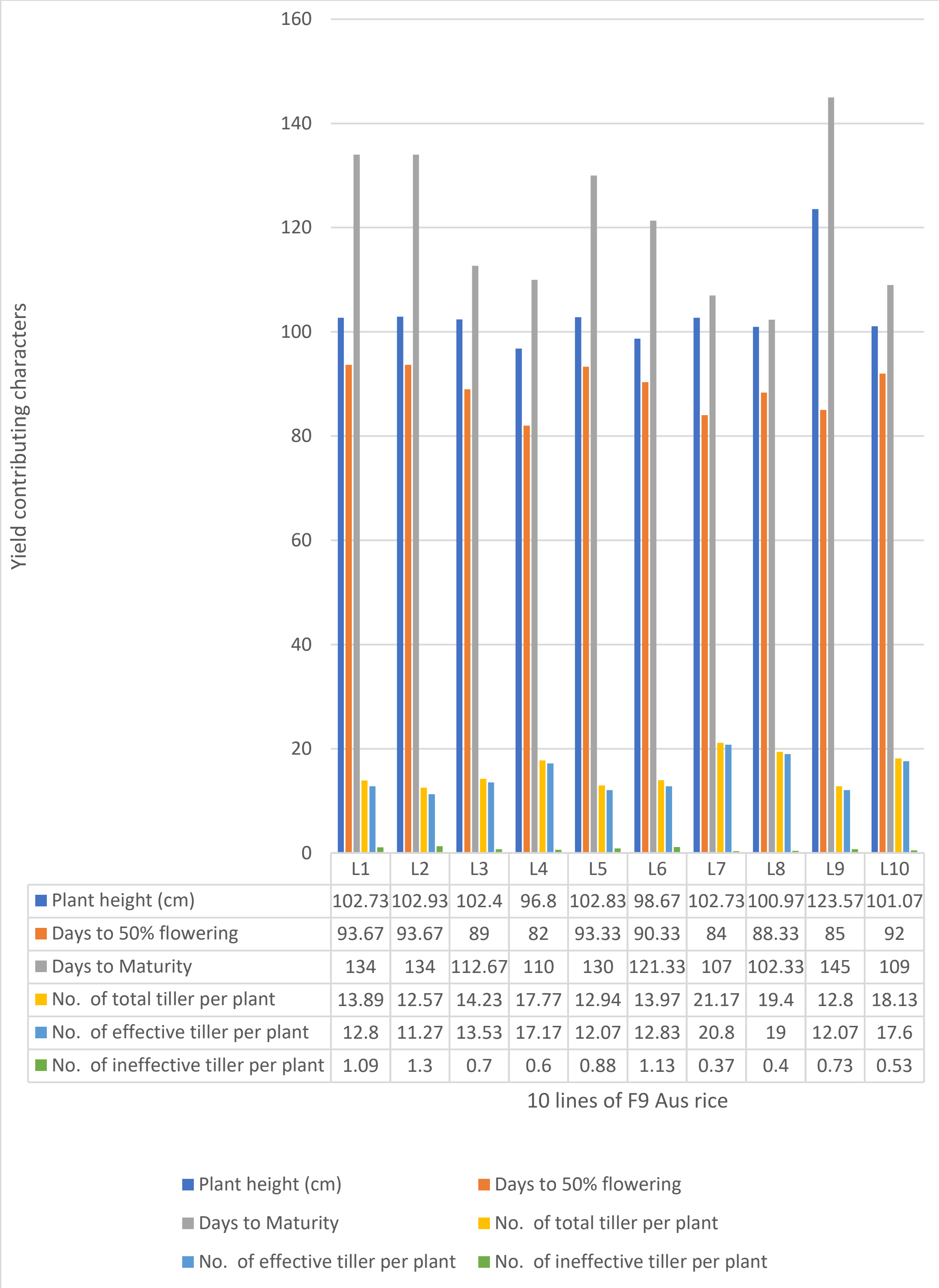
Days to 50% flowering of 10 different lines of rice varied significantly (Appendix IV). The maximum days to 50% flowering (93.67 days) was recorded from L1 (BRRI dhan29× BRRI dhan36, $S_2P_2P_4S_6$) and L2 (BRRI dhan29× BRRI dhan36, $S_2P_2P_4S_6$) which was statistically similar with L5 and L10 line 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 9). Days to 50% flowering has no significant co-relation with other growth and yield contributing characters.

		
L7	**L8**	**L10**

Plate 2: Photograph showing variation in flowering among different lines

4.1.3 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 9). These short duration lines could be 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. Plants with higher height tends to took 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 per plant	13.89	12.57	14.23	17.77	12.94	13.97	21.17	19.4	12.8	18.13
No. of effective tiller per plant	12.8	11.27	13.53	17.17	12.07	12.83	20.8	19	12.07	17.6
No. of ineffective tiller per plant	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

The ber graph (figure 1) shows performance of growth and yield of 10 F9 advance lines. Plant height, days to 50% flowering, days to maturity, number of tillers per plant, number of effective tillers per plant and number of ineffective tillers per plant of 10 F9 lines have been presented.

This figure shows there is an exponential relation with plant height and days to maturity. L9 showed maximum days to mature (145 days) as well as highest plant height (123.57cm).

This figure also shows a positive co-relation between number of tiller^{-1} plant and number of effective tillers^{-1} plant. L7 showed highest number of tiller^{-1} plant (21.17) so as highest number of effective tiller^{-1} plant (20.8).

L7

L8

L10

Plate 3: Photograph showing variation in days to maturity in different lines

4.1.4 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 11).

4.1.5 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, L4, L5, L6 and L9 (Table 9). 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).

4.1.6 Number of ineffective tillers plant^{-1}

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 9).

L7	L8	L10

Plate 4: Photograph showing variation in number of tillers per plant in different lines

4.1.7 Panicle length (cm)

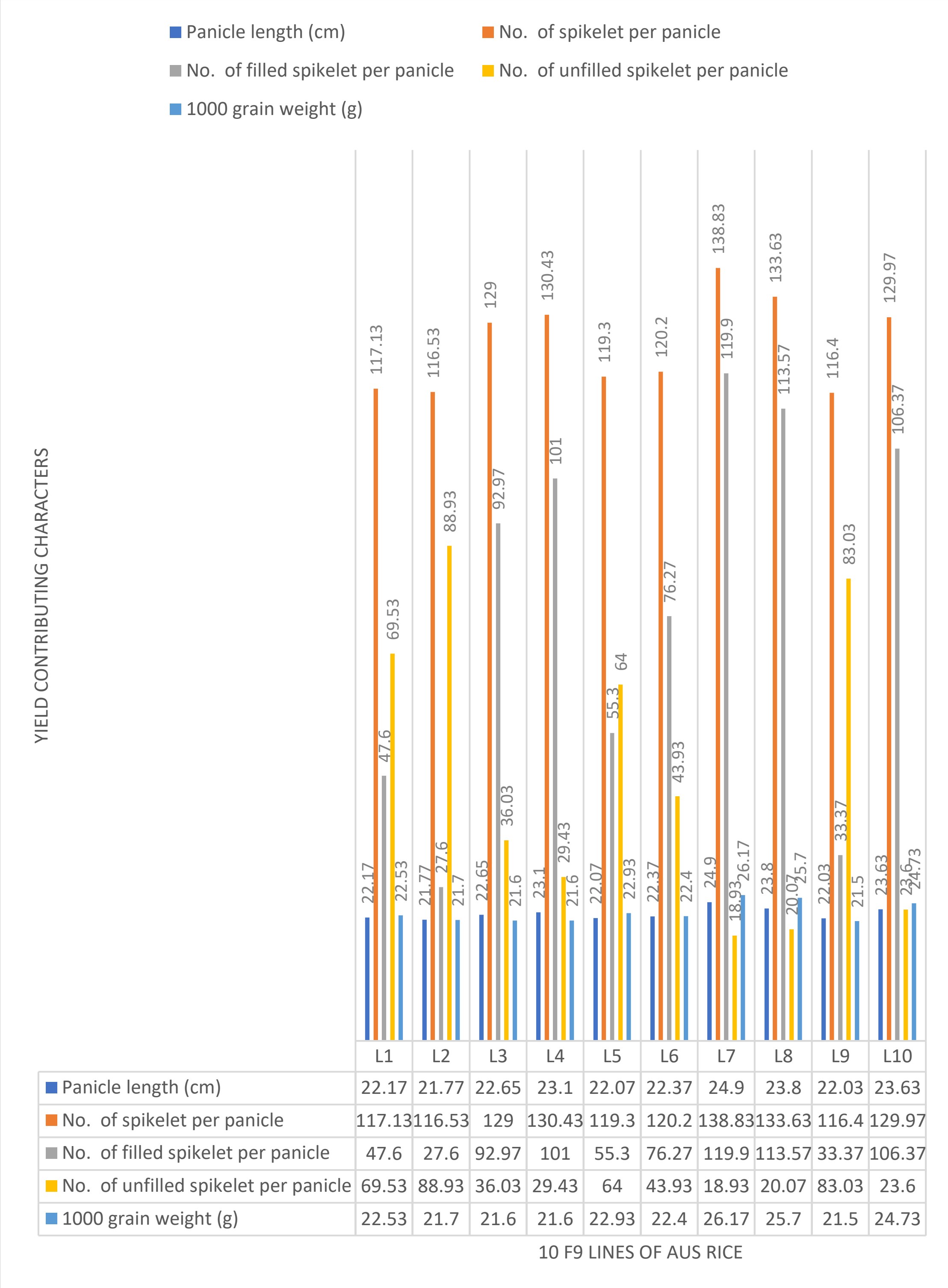
Panicle length was significantly varied on different F9 lines of Aus rice (Appendix V). The highest panicle length (24.90 cm) was recorded from L7 (BR 21× BRRI dhan29, $S_2P_1S_1$) and the lowest panicle length (21.77 cm) was recorded from L2 (BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_6$) which was statistically 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 11).

Table 10. 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 spikelet per panicle	117.13	116.53	129	130.43	119.3	120.2	138.83	133.63	116.4	129.97
No. of filled spikelet per panicle	47.6	27.6	92.97	101	55.3	76.27	119.9	113.57	33.37	106.37
No. of unfilled spikelet per panicle	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

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

The ber graph (figure 2) shows performance of growth and yield of 10 F9 advance lines. Penicle length (cm), number of spikelets panicle^{-1}, number of filled spikelets panicle^{-1}, number of unfilled spikelets panicles^{-1} and 1000 grain weight (gm) of 10 F9 lines is presented.

As the panicle length increases, the number of spikelets panicle^{-1} increases. L7 showed highest panicle length (24.90 cm) so as the number of spikelets panicle^{-1} was also maximum (138.83).

According to the graph, L7 showed the maximum number of filled spikelets panicle^{-1} (119.90) and minimum number of unfilled spikelets panicles^{-1} (18.93). Since the maximum number of filled spikelets panicle^{-1} was highest in L7, thousand grain weight (26.17gm) was also maximum in L7 among the lines.

4.1.8 Number of spikelets/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 10). 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).

4.1.9 Number of filled spikelet panicle^{-1}

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 10). Rest of the population showed different number of filled grains per panicle.

4.1.10 Number of unfilled spikelets panicle^{-1}

The highest number unfilled spikelet per panicle was recorded in L2 (83.93) 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 10).

4.1.11 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 10).

4.1.12 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 (L2= BRRI dhan29× BRRI dhan36, $S_5P_2P_4S_6$) 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 11). 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 11. 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, $S_8P_1P_1S_1$.

4.1.13 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, $S_5P_2P_4S_6$). Rest of population showed different yield per plant (Table 11).

4.1.14 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, $S_5P_2P_4S_6$). Rest of population showed different yield per plant (Table 11).

4.1.15 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).

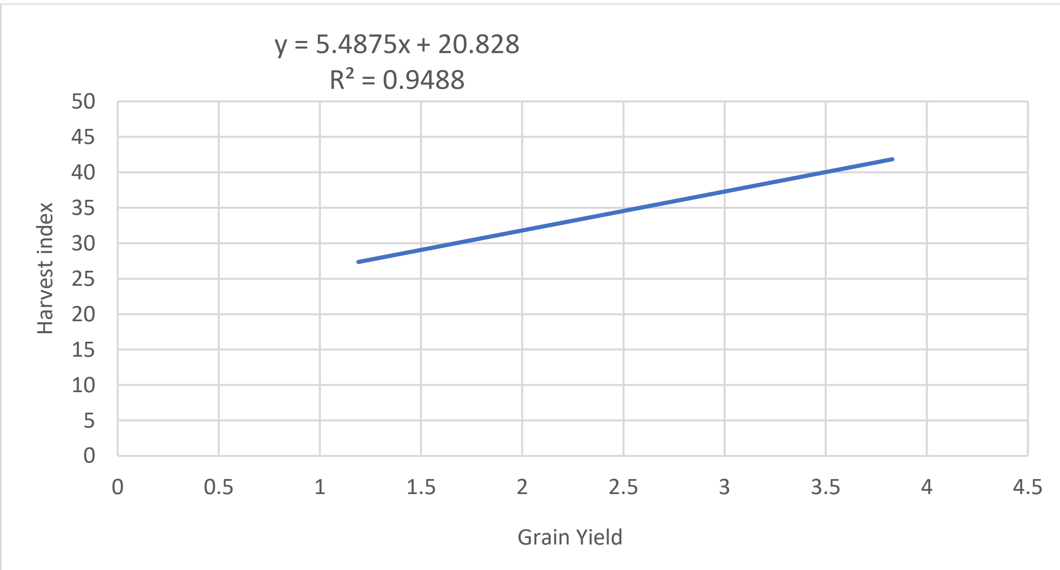


Figure 3. Correlation and regression study between grain yield and harvest index

4.2 Milling and grain quality characters of F9 lines of Aus rice

Paddy or rough rice is the similar term for paddy, or rice retaining its husk after threshing and Brown rice or husked rice is the paddy from which the husk has been removed. Further milling removes the bran (the seed coat, embryo, and some endosperm) to produce milled rice. A milled rice grain contains approximately 85% starch and 5% protein. The quality of rice is determined by grain appearance, cooking quality and nutritional value. Quality in rice is a combination of several physico-chemical characters of the grain. The physical properties of the rice grain are determined by grain color, shape and size, grain weight, hardness of the endosperm, appearance of the milled kernels, hulling and milling recovery. Starch, proteins, minerals and vitamins constitute the chemical components of the rice grain.

4.2.1. Hulling (%)

Hulling percentage of rice for different F9 lines of Aus rice not significantly varied (Appendix VII). Numerically, the maximum hulling (26.5 %) was recorded from L7 and the lowest hulling (25.80 %) recorded from L10 (Table 12).

4.2.2. Milling outturn (%)

Milling outturn tells the actual yield of consumable product. A good milling quality includes high whole kernel recovery and less of broken rice. While milling recovery as a whole mainly depends upon the hull content which varies from 18 to 26 percent and the nature of alluron layer. Milling outturn of rice for different F9 lines of rice were varied not significantly (Figure 5). Numerically, the highest milling outturn (66.67 %) was found from L7 and lowest milling outturn (65.50 %) was found from L10 (Table 11).

Table 12. Performance of milling and grain quality of F9 lines of Aus rice

Genotype	Hulling (%)	Milling outturn (%)	Head rice recovery (%)	Length of uncooked rice (mm)	Breadth of uncooked rice (mm)	L/B ratio of uncooked rice
L7	26.30a	65.50a	61.67a	5.93a	2.27a	2.62a
L8	26.53a	65.60a	43.40c	5.68b	2.21b	2.57b
L10	25.80a	66.67a	57.60b	5.61b	2.17b	2.59b
LSD (0.05)	1.86	3.367	3.35	0.23	0.05	0.04
CV (%)	3.56	2.56	8.79	3.43	2.48	3.94

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.

L7= BR 21× BRRI dhan29, $S_2P_1S_1$, L8= BR 21× BRRI dhan29, $S_6P_1P_1S_2$, L10= BR 24× BRRI dhan36, $S_8P_1P_1S_1$.

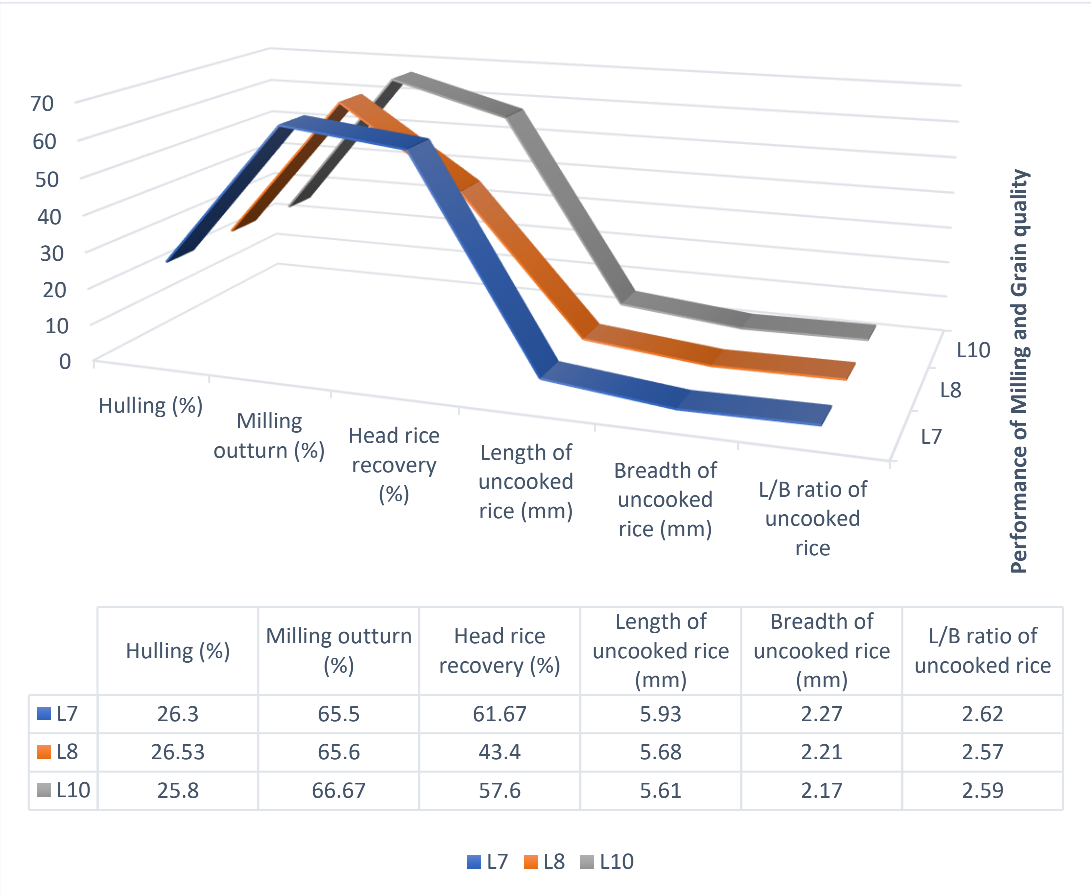


Figure 4. Performance of milling and grain quality of F9 lines of Aus rice

The graph (figure 4) shows different qualitative traits of selected 3 F9 advance lines. Hulling, milling outturn, head rice recovery, length of uncooked rice, breadth of uncooked rice and L/B ratio of uncooked rice of selected 3 F9 lines have been shown.

L7, L8 and L10 do not show any statistical difference in hulling and milling outturn.

During calculation of head rice recovery, all the 3 lines have showed significant difference. L7 showed maximum head rice recovery where as L10 showed comparatively lower grade and L8 showed least grade statistically.

The statistical data of length of uncooked rice, breadth of uncooked rice and L/B ratio of uncooked rice of L7, L8 and L10 showed some type of similarities. In these three quality contributing factors L7 stood out. L7 showed statistical significance where as L8 and L10 showed similar category but lower than L7.

4.2.3. Head rice recovery (%)

Head rice is the proportion of the whole grain in the milled rice. Head rice recovery (HRR) of rice for different F9 line of Aus rice varied significantly (Appendix VII). The maximum head rice recovery was recorded from L7 (61.67%) while the lowest recorded from L10 (53.40%) (Table 12). For the commercial success of a rice variety it must possess high total milled rice and whole kernel (HRR) turnout. L7 had higher hulling%, milling outturn and higher HRR%. The higher milling percentage may not yield higher head rice recovery as it depends on grain dimension also. Grain size and shape, hardness. percentage or absence of abdominal white, moisture content, harvest precision, storage conditions, processing and type of mills employed have direct effect on head rice recovery, (Bhattacharya, 1980). In general, varieties with long bold grains and those having white centers give lower head rice yields. Varieties possessing medium slender, long slender and translucent grains give high head rice yields. Varieties with high protein content also suffer less breakage. Sun cracking which is caused alternate drying and wetting of grains due to delayed harvest also adds more breakage of grain (Shobha Rani, 2003). Viraktamat (1987) and Yadav and Singh (1989) reported an inverse relationship between HRR% and grain L/B ratio. Plate 7 showing variation in head rice recovery in different lines.

4.2.4. Kernel length, breadth and length/breadth of uncooked rice

Kernel length breadth ratio of uncooked rice for different F9 lines of Aus rice varied significantly. The highest kernel length, breadth length/breadth and uncooked rice was observed in L7 (5.93, 2.33 and 2.55, respectively) whereas the lowest breadth (5.55, 2.20 and 2.52, respectively) was recorded in L10 (Table 12).

4.2.5 Grain dimension

The length and width of the rice grain are important attributes that determine the classes of rice. Rice grains may be objectively classified into grain-type categories based upon three physical qualities: length, shape, and weight. Length is a measure of milled-rice kernel in its greatest dimension. With respect to grain dimension, variation is found in materials studied, as we can see from performance of each genotype (Table 13). Grain length is an important physical property, which attracts consumer’s attention. In present study, the grain shape and size are characterized (Table 13) following Ramaiah Committee classification (1965).

Table 13. Classification of grain types of 3 selected F9 lines varieties on the basis of systematic classification of rice proposed by Ramaiah Committee (1965).

Long slender (LS) (Length 6 mm & above and L/B ratio 3 and above)	Short slender (SS) (Length less than 6 mm and L/B ratio 3 and above)	Medium slender (MS) (Length 6 mm & above and L/B ratio 2.5 to 3)	Long Bold (LB) (Length 6 mm & above and L/B ratio less than 3.0)	Short bold (SB) (Length less than 6 mm L/B ratio less than 2.5)
-	-	-	-	L7
-	-	-	-	L9
-	-	-	-	L10

4.3 Determination of cooking and eating characteristics of the grain

4.3.1 Kernel length, breadth and ratio of cooked rice

Kernel length, breadth and their ratio of cooked rice for different F9 lines varied significantly (Appendix VIII). The longest kernel of cooked rice (8.19 mm) was recorded from L7 and the shortest (7.00 mm) from L10 which was statistically similar with L8 (7.20 mm). During cooking rice grains absorb water and increase in volume through increase in length or breadth alone length and breadth both. The highest breadth was recorded from L7 (3.17 mm) and lowest breadth was recorded from L10 (2.91 mm). The highest ratio of kernel length and breadth (2.58) was recorded from L7 and the lowest ratio (2.33) from L8. Plate 8 showing variation in rough rice, uncooked rice and cooked rice ((Table 14).

Table 14. Performance of grain quality of 3 selected F9 lines of Aus rice

Line	Kernel length of cooked rice (mm)	Kernel breadth of cooked rice (mm)	Kernel L/B ratio of cooked rice	Kernel elongation ratio	Kernel elongation index
L7	8.19a	3.17a	2.58a	1.38a	1.02a
L8	7.20b	3.09b	2.33b	1.27b	0.92b
L10	7.00b	2.91c	2.40b	1.26b	0.96b
$LSD_{(0.05)}$	0.23	0.05	0.04	0.10	0.05
CV(%)	3.43	2.48	3.94	3.19	4.13

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.

L7= BR 21× BRRI dhan29, $S_2P_1S_1$, L8= BR 21× BRRI dhan29, $S_6P_1P_1S_2$, L10= BR 24× BRRI dhan36, $S_8P_1P_1S_1$.

4.3.2 Kernel elongation ratio

Kernel elongation ratio for different F9 lines of Aus rice varied significantly (Appendix VIII). The highest kernel elongation ratio (1.38) was recorded from L7 and the lowest ratio (1.26) recorded from L10 was statistically similar with L8 (Table 14). Elongation ratio (L_1/L_0) is a measure of kernel elongation upon cooking resulting from swelling *of* starch granules by uptake of water (Juliano, 1979). Pilaiyar (1988) proposed elongation ratio to be best index of quality compared to elongation index and proportionate change. Significant association of L/B ratio with kernel elongation was reported by Deosarker and Nerker (1994). Chauhan *et al.*, (1995) pointed out significant positive correlation between elongation and cooked kernel length. Kernel elongation was primarily influenced by kernel shape and size. Therefore, elongation ratio (L_1/L_0) which indicates length wise elongation will be a better measure of cooking quality than elongation index which indicates both length and breadth wise elongation. Kernel elongation after cooking is an important characteristic of slender rice and most rice consumers prefer length-wise elongation. During cooking, rice kernels absorb water and increase in volume through an increase in length and/or breadth

(Hogan and Planck, 1958). A breadth-wise increase is not desirable (fatter-shorter rice), whereas a length-wise increase without an increase in girth (longer-thinner rice) is a desirable characteristic in high-quality premium rice (Hossain *et al.*, 2009).

4.3.3 Kernel elongation index

Kernel elongation index for different F9 lines of rice varied significantly (Appendix VIII). The highest kernel elongation index (1.02) was recorded from L7 and the lowest ratio (0.92) recorded from L8 which was statistically similar with L10. Rest of the populations showed different elongation index (Table 14).

4.3.4 Volume expansion (%)

Volume expansion of kernels on cooking is considered another important measure of consumer preference. Volume expansion for different new F9 lines of Aus rice varied significantly (Appendix IX). The maximum volume expansion (28.04 %) was recorded from L7 and the minimum (27.04 %) recorded from L8 (Table 15). Volume expansion by and large is determined by water uptake, however, subject to the influence of kernel texture (Zaman, 1981). He also reported that the varieties which tend to show high volume expansion are sticky and give a pasty appearance on cooking. Invariably all the pasty cooking types have been found to be associated with higher water absorption. He concluded that pasty cooking closely related to high water absorption. Therefore, hybrids with low water absorption and high-volume expansion are more desirable. The volumetric expansion ratio is the change in volume of a rice sample after cooking compared to its original milled rice volume. Rice expansion during cooking is closely correlated with amylose content, gelatinization temperature, equilibrium moisture content, and water uptake over many cooking temperatures (Sowbhagya *et al.*, 1994). Volumetric expansion is related to each starch granule’s gelatinization characteristics and degree of crystallinity. Rice with a high amylose content showed high volume expansion during cooking and resulted in dry, less tender rice that became harder upon cooling, whereas low-amylose varieties resulted in moist and sticky cooked rice (Golam and Prodhan, 2013). Cooking water and cooked rice in each cooking vessel has been placed on a filter paper sheet combined with a vacuum flask due to sucking the cooking water. The cooked samples were then weighed accurately and the water uptake ratio was calculated as the ratio of final cooked weight to the uncooked weight (Singh *et al.*, 2005).

Table 15. Performance of grain quality of 3 selected F9 lines of Aus rice

Genotype	Kernel elongation Index	Volume expansion (%)	Cooking time (min.)
L7	1.02a	27.49a	19.33ab
L8	0.92b	27.04a	20.33a
L10	0.96b	28.04a	17.67b
LSD (0.05)	0.05	2.43	2.57
CV(%)	4.13	4.43	4.76

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.

L7= BR 21× BRRI dhan29, $S_2P_1S_1$, L8= BR 21× BRRI dhan29, $S_6P_1P_1S_2$, L10= BR 24× BRRI dhan36, $S_8P_1P_1S_1$.

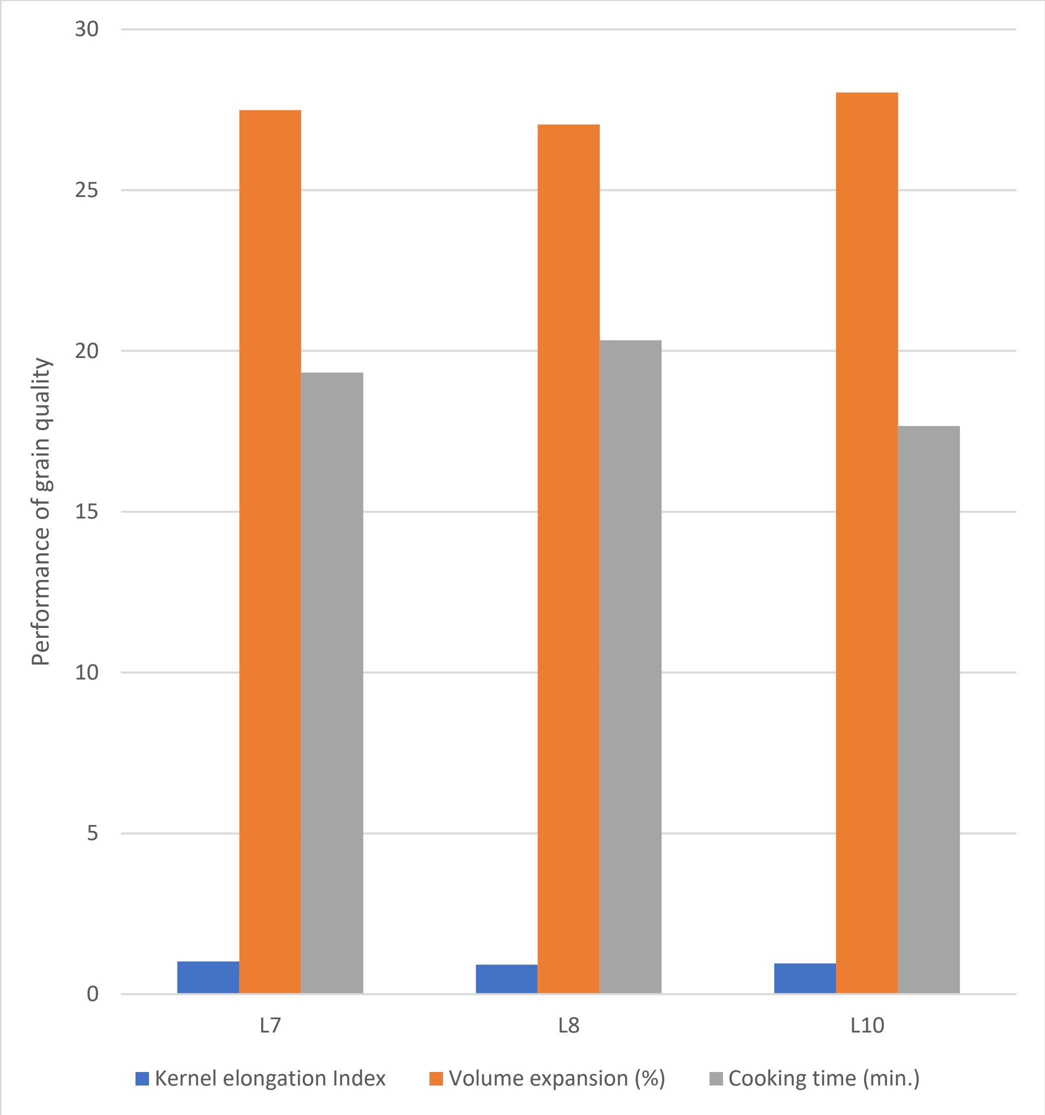


Figure 5. Performance of grain quality of 3 selected F9 lines of Aus rice

4.3.5 Cooking time

Cooking time is considered another important measure of consumer preference. Cooking time for different new F9 lines of Aus rice varied significantly (Appendix IX). The maximum cooking time (20.33 min) was recorded from L8 and the minimum (17.67 min) recorded from L8 (Table 15). Previous studies in cooking properties of polished rice revealed a major positive correlation of amylose content to cooking time (Altheide *et al.*, 2012, Park *et al.*, 2001). The low amylose content might require a shorter cooking time, however, the MCT and elongation ratio of unpolished low amylose content rice samples (MG and RR1) was significantly different ($p \leq 0.05$). This demonstrated they might have other factors influencing the cooking time of unpolished rice. A different grain structure between unpolished rice and polished rice is a presence of bran layers. Therefore, the cooking behavior of unpolished rice is related to histological structures of rice caryopsis which is composed of cuticular layer, aleurone layer, and endosperm layer (Wu *et al.*, 2016). The time when minimum of 95% of the 10 collected boiled grains no longer displayed opaque core or un-gelatinized centers was recorded as the minimum cooking time (MCT). The cooked sample was then allowed to simmer for another 2 min to ensure that the core of all grains had been gelatinized. This additional 2 min after the MCT is referred to as optimum cooking time (Mohapatra and Bal, 2006).

4.3.6 Alkali spreading value (ASV)

The gelatinization temperature (GT) is considered to be yet another major index of cooking quality of rice. The time required for cooking is determined by the gelatinization temperature. Alkali spreading value is inversely related to gelatinization temperature (Table 16). It is the range of temperature within which granules begin to swell irreversibly in hot water. The GT of rice varieties ranging from 55'C to 79°C are grouped into low (55- 69°C), intermediate (70-74°C) and high (74-79°C) (Juliano *et.al.*, 1965; Kongserce and Juliano. 1972; Juliano, 1979). High GT rice becomes excessively soft when overcooked, elongate less and requires mire water and time for cooking as compare to those with low or intermediate GT. Rice varieties that have low GT start to swell at low temperature during cooking than rice varieties that have intermediate or high GT (Nagato, and Kishi, (1966). Rice varieties having intermediate GT produces good quality cooked rice. In the present study, statistically significant variation was recorded for alkaline spreading value for different F9 line of rice (Table 16). The highest alkaline spreading value (4.33) was recorded from and L7 and the lowest (3.33) was recorded from L10 (Table 4.8). The gelatinization temperature (GT) is determined by the temperature at which the crystalline structures of the starch begin to melt. Rice with a high GT has a more crystallinity structure according to contain a high amount of long chain amylopectin (Singh *et al.*, 2006). Therefore, it requires more time to cook. The long chain amylopectin is also positively correlated with a setback viscosity (Aoki *et al.*, 2006) which is a parameter to determine a firmness of cooked rice. Because of this characteristic, rice with a high GT tend to be harder and fluffy (an unacceptable texture) after cooking in a long period.

Table 16. Classification of 3 selected F9 lines on the basis of alkali spreading score, alkali spreading value and GT types

Sl. No.	Lines	Alkali spreading value	Alkali digestion	GT types
1.	L7	4.33a	High	High
2.	L8	4.00b	High	High
3.	L10	3.00c	High	High
	$LSD_{(0.05)}$	0.65		
	CV(%)	7.54		

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.

L7= BR 21× BRRI dhan29, $S_2P_1S_1$, L8= BR 21× BRRI dhan29, $S_6P_1P_1S_2$, L10= BR 24× BRRI dhan36, $S_8P_1P_1S_1$.

4.3.7 Protein (%)

Protein content of rice is important from nutritional point of view. Protein% for different F9 lines of rice varied significantly (Appendix X). The highest protein (8.40 %) was recorded from L7 and the lowest (7.97%) recorded from L10 (Table 17). Several factors such as variety, environment and cultural practices might influence on the protein content of the grain (Gomez 1979).

Table 17. Performance of grain quality of 3 selected F9 lines of Aus rice

Line	Protein%	Apparent amylose content	Moisture%
L7	8.40a	23.93a	13.97a
L8	8.13ab	24.33a	11.10b
L10	7.97b	24.13a	13.47a
$LSD_{(0.05)}$	0.33	2.22	1.23
CV(%)	2.08	2.08	4.22

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.

L7= BR 21× BRRI dhan29, $S_2P_1S_1$, L8= BR 21× BRRI dhan29, $S_6P_1P_1S_2$, L10= BR 24× BRRI dhan36, $S_8P_1P_1S_1$.

4.3.8 Amylose (%)

Amylose content of the different F9 lines of Aus rice varied not significantly (Appendix X). Numerically, the highest amylose (24.33 %) was estimated in L8 and the lowest (23.93 %) were in L7 (Table 17). Amylose content of rice determines the hardness and stickiness of cooked rice. Amylose content higher than 20% -25% amylose gives soft, and relatively sticky cooked rice. Rice having 20-25% amylose gives soft, and relatively sticky cooked rice (Anonymous, 1997). The majority people of Bangladesh prefer high amylose rice. A section of its still prefers low amylose rice for making their special dishes on special occasions.

Table 18. Classification of 3 selected F9 lines on the basis of amylose content followed by Juliano(1972).

Waxy (1-2% amylose)	Very low (>2-9% amylose)	Low (>9-20% amylose)	Intermediate (>20-25% amylose)	High (>25-33% amylose)
-	-	-	L7	-
-	-	-	L8	-
-	-	-	L10	-

L7= BR 21× BRRI dhan29, $S_2P_1S_1$, L8= BR 21× BRRI dhan29, $S_6P_1P_1S_2$, L10= BR 24× BRRI dhan36, $S_8P_1P_1S_1$.

4.3.9 Moisture (%)

Moisture content of rice is important from nutritional point of view. Moisture% for different F9 lines of rice varied significantly (Appendix X). The highest moisture (13.97 %) was recorded from L7 and the lowest (11.10%) recorded from L8 (Table 17).

CHAPTER V

SUMMARY AND CONCLUSION

The present research work was conducted at the central farm, Sher-e-Bangla Agricultural University (SAU), Dhaka during March, 2018- August, 2018 to evaluate the variability, character association and to study of quality characteristics of 10 F9 Aus rice lines. Ten rice Aus 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. Comparisons of the mean were determined by LDS tests at $p \leq 0.05$ level of significance.

The highest plant height (123.57 cm) was recorded in L9 (BR 21× BRRI dhan29, $S_6P_1P_1S_1$) and L6 (BRRI dhan26× BRRI dhan28, $S_1P_9P_4S_1$) showed the lowest. The maximum days to 50% flowering and days to maturity (93.67 and 145.00 days) was recorded from L1 and L9. The minimum days (102 and 107 days) was recorded from L8 and L7, respectively.

The maximum number of tillers and the maximum number of effective tillers per plant (21.17 and 19.00) were recorded from L7 and the minimum number (12.57 and 11.27) 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 (22.17 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 (3.83 and 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 L2.

The maximum hulling, milling and head rice recovery (26.5 %, 66.67 % and 61.67%) was recorded from L7 and the lowest hulling (25.80 %, 65.50% and 53.40%) recorded from L10. The highest kernel length, breadth length/breadth and uncooked rice was observed in L7 (5.93, 2.33 and 2.55, respectively) whereas the lowest breadth (5.55, 2.20 and 2.52, respectively) was recorded in L10. The highest kernel length, breadth and ration of cooked rice (8.19 mm, 3.17 mm and 2.58) was recorded from L7 and was recorded from L10 (7.00 mm, 2.91 mm and 2.33). The highest kernel elongation ratio and index (1.38 and 1.02) were recorded from L7 and the lowest ratio (1.26 and 0.92) recorded from L10.

The maximum volume expansion (28.04 %) was recorded from L7 and the minimum (27.04 %) recorded from L8. The maximum cooking time (20.33 min) was recorded from L8 and the minimum (17.67 min) recorded from L8. The highest alkaline spreading value (4.33) was recorded from and L7 and the lowest (3.33) was recorded from L10. The highest protein (8.40 %) and the lowest and the lowest amylose (23.93 %) were in L7. Significant, the highest moisture (13.97 %) was recorded from L7 and the lowest (11.10%) recorded from L8.

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 yield and yield contributing characters.

ii. In terms of quality, line L7 (BR 21× BRRI dhan29, $S_2P_1S_1$) was found better among the tested 3 lines.

CHAPTER VI

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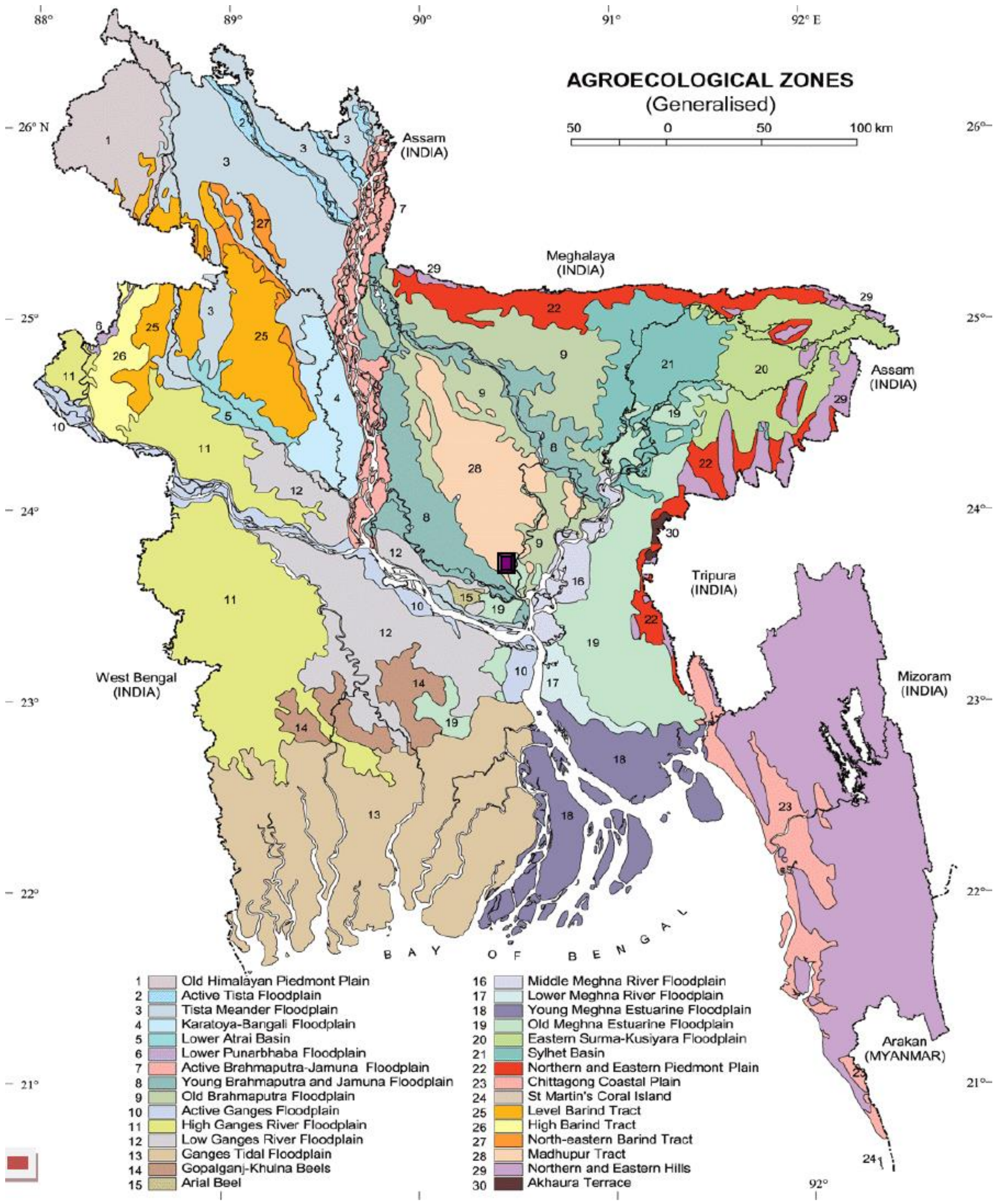
APPENDICES

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	%	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)	Mean Square					
		Plant height (cm)	Days to 50% flowering	Days to Maturity	No. of total tiller plant^{-1}	No. of effective tiller plant^{-1}	No. of ineffective tiller plant^{-1}
Replication	2	20.748	12.13	27.233	2.55	2.24	0.014
Treatment	9	162.13**	54.45**	561.94**	29.34**	34.61**	0.305**
Error	18	13.315	3.39	7.863	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			

Appendix VII. Analysis of variance (anova) of milling and grain quality of F9 lines of Aus rice

Source of variance	Degree of freedom (d.f)	Mean Square					
		Hulling (%)	Milling outturn (%)	Head rice recovery (%)	Length of uncooked rice (mm)	Breadth of uncooked rice (mm)	L/B ratio of uncooked rice
Treatment	2	0.281^{NS}	0.772^{NS}	192.35**	15.932**	0.072*	0.053*
Error	6	1.045	3.40	19.487	1.68	0.011	0.015
Total	8						

Appendix VIII. Analysis of variance (anova) of grain quality of F9 lines of Aus rice

Source of variance	Degree of freedom (d.f)	Mean Square				
		Kernel length of cooked rice (mm)	Kernel breadth of cooked rice (mm)	Kernel L/B ratio of cooked rice	Kernel elongation ratio	Kernel elongation index
Treatment	2	0.196**	0.073**	0.0443**	0.0303**	0.018**
Error	6	0.021	0.001	0.0015	0.002	0.002
Total	8					

Appendix IX. Analysis of variance (ANOVA) of grain quality of 3 F9 lines of Aus rice

Source of variance	Degree of freedom (d.f.)	Mean Square		
		Kernel elongation Index	Volume expansion (%)	Cooking time (min.)
Treatment	2	0.018**	7.493**	5.444**
Error	6	0.002	0.734	0.854
Total	8			

Appendix X. Analysis of variance (ANOVA) of grain quality of 3 F9 lines of Aus rice

Line	Degree of freedom (d.f)	Mean Square		
		Protein%	Apparent amylose content	Moisture%
Treatment	2	0.143*	0.12NS	7.034*
Error	6	0.201	1.23	2.134
Total	8			