COMPARATIVE STUDY AND CHARACTERIZATION OF 13 F_6 LINES OF BORO RICE

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COMPARATIVE STUDY AND CHARACTERIZATION OF 13 F_6 LINES OF BORO RICE

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CERTIFICATE

This is to certify that thesis entitled, **"COMPARATIVE STUDY AND CHARACTERIZATION OF 13 F_6 LINES OF BORO RICE "** submitted to the ***INSTITUTE OF SEED TECHNOLOGY***, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of ***MASTER OF SCIENCE in SEED TECHNOLOGY*** **,** embodies the result of a piece of bona fide research work carried out by *ESHATH TAHMINA* , **Registration No. 10-04001** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2016

Place: Dhaka, Bangladesh

Prof. Dr. Md. Shahidur Rashid Bhuiyan
Supervisor

LIST OF ABREVIATIONS

Full Name	Abbreviation
Percent	%
Degree Celsius	ºC
Agro-Ecological Zone	AEZ
Agriculture	Agric.
Agricultural	Agril.
Anonymous	Anon.
Analysis of variance	ANOVA
Bangladesh Agricultural Research Institute	BARI
Bangladesh Bureau of Statistics	BBS
Bangladesh	BD
Bangladesh Rice Research Institute	BRRI
Centimeter	cm
Percentage of Coefficient of Variation	CV%
Degrees of Freedom	Df
And others	*et al.*
Etcetera	etc.
The 6th generation of a cross between two dissimilar homozygous parents	F6
Food and Agricultural Organization	FAO
Gram	gm
Genotype	G
Genetic Advance	GA
Genotypic coefficient of variation	GCV
Journal	J.
Kilogram	kg
Meter	M
Mean sum of square	MSS
Murate Potash	MP
Ministry of Agriculture	MoA
Square meter	m^2
Phenotypic coefficient of variation	PCV
Randomized Complete Block Design	RCBD
Sher-e-Bangla Agricultural University	SAU
Triple Super Phosphate	TSP

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SAU, Dhaka *The Author*

TABLE OF CONTENTS

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

TABLE OF CONTENTS (CONT'D)

LIST OF TABLES

LIST OF TABLES (CONT'D)

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

COMPARATIVE STUDY AND CHARACTERIZATION OF 13 F_6 LINES OF BORO RICE

BY

ESHATH TAHMINA

ABSTRACT

The experiments were carried out at the Sher-e-Bangla Agricultural University Farm, Bangladesh during December, 2014- May, 2015. The study was attempted to identify short duration and high yielding rice genotypes amongst 13 F6 lines of Boro rice by comparing with 2 check varieties. The performance of studied genotypes, association among various morpho-physiological, yield contributing and quality contributing traits among the genotypes were evaluated under the field condition and lab condition. The performance of 13 F6 lines compared with 2 check varieties and these were compared considering different yield contributing and quality contributing traits. Considering the traits days to 50% flowering and days to maturity the genotype G11 (BRRI dhan 28 x BRRI dhan 29 F6 S2 P4 P3G9) was earliest which was followed by the genotype G15 (BRRI dhan 28). The highest number of effective tillers per plant was recorded in G12 (BRRI dhan 28 X BRRI dhan 36 F6 S7 P8 P5),highest number of primary branches per panicle was recorded from G4 (BR 21× BRRI dhan 28 F6 S5 P3 P4),the number of filled grains per panicle was recorded highest in G7 (BR 24 × BR 26 F6 S6 P4 P8) and Thousand seed weight was found maximum in G4 (BR 21× BRRI Dhan 28 F6 S5 P3 P4).In the experiment G4(BR 21× BRRI dhan 28 F6 S5 P3 P4)showed maximum length, breadth and L/B ratio of milled rice and maximum protein percent. Except G4(BR 21× BRRI dhan 28 F6 S5 P3 P4) and G10(BR 26 x BRRI dhan 29 F6 S6 P3 P3) all lines showed high amount of amylase percent as like check varieties. The maximum milling and hulling percent were found from G3(BR 21 x BRRI dhan 28 F6 S5 P1 P2).The maximum kernel elongation ratio, kernel elongation index and also maximum cooked rice length and cooked rice L/B ratio and also maximum amount of alkaline spreading value showed by G1(BR 21 x BR 26 F6 S6 P7 P7). Among these 13 F6 lines, G11 (BRRI dhan 28 x BRRI dhan 29 F6 S2 P4 P3) exhibited the early maturity, highest total number of spikelet, higher filled grains than checks, third highest yield per plant which was higher than check varieties and most earliest maturity and had higher hulling (%), milling outturn and higher HRR (%), lowest water absorption (%),GT types intermediate, moderate protein (%) and had high amylose content and G5 was shown moderate maturity, higher number of primary branches, highest number of secondary branches, had maximum yield per plant and also had high amylase content.

CHAPTER I

INTRODUCTION

Rice is one of the most essential world food crops, serving as the staple food for over one-third of the world's population (Reddy *et al.*, 2013). There are two individual types of cultivated rice, *Oryza sativa* otherwise Asian rice and *Oryza glaberrima* otherwise African rice. The genus *Oryza* contains 21 wild relatives of the domesticated rice. The genus is divided into four species complexes such as: *O. sativa, O. officialis, O. ridelyi* and *O. granulata* species complexes. All members of the *Oryza* genus have n = 12 chromosomes.

Among the most cultivated cereals in the world, rice ranks as second to wheat (Abodolereza and Racionzer, 2009). Rice is grown in more than a hundred countries with a total harvested area of about 160 million hectares, producing more than 700 million tons every year. In Bangladesh, this covers about 75% of the total cropped area (BBS, 2015). In respect of area and production of rice, Bangladesh ranks fourth following China, India and Indonesia (FAO, 2014). The population of Bangladesh is still growing by two million every year and may increase by another 30 million over the next 20 years. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020. But the average yield of rice is poor (4.34 t ha^{-1}) in Bangladesh (BRRI, 2011). On the other hand, rice production area is decreasing day by day due to high population pressure.

Rice occupies a unique position in many nations because for its importance in traditional diets and the main source of income of many peoples in the whole 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 in 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, 2015) and the production for *Aus*, T. *Aman* and *Boro* season is 2328 m.tons, 13190 m.tons and 19192 m.tons, respectively (BBS, 2015). The area, production and yield of rice in the country in 2010 were 11.58 million ha, 33.90 million tons and 2.92 t ha-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 tons, respectively (AIS, 2011) .

Boro covers the largest production area and produces the highest amount of rice in Bangladesh but it takes long duration for its cultivation which ultimately affects the cropping system. Alternatively, early rice variety in Boro season might also help to create a gap between Boro and Aus, which can be utilized to grow minor crops in between to promote crop diversification. The continuous growing of rice in the same land decreases soil fertility and soil health. Therefore, the land can be kept fallow or grown with green manuring crops in the gap period before the Aus starts, which might be also helpful for improving soil health and nutrition status. BRRI dhan 28 and BRRI dhan 29 are the two popular rice variety. The duration of BRRI dhan 28 is 140 days and BRRI dhan 29 is 160 days. Moreover, there is lack of short duration Boro rice variety in Bangladesh. So we have to give more attention for the improvement of early Boro rice varieties to increase rice production in order to satisfy our population's need of food.

Boro rice has a major contribution to the percentage share of total rice production in the state. Considering the vast potential of boro rice in Bangladesh, it is imperative that rice scientists develop suitable rice varieties and management practices that are ideally suited to diverse boro rice-growing situations. Inter varietal crosses and evaluation of generations need to be performed to select high yielding materials for using them in generating boro rice varieties. Characterization and comparative study of 13 F6 lines of boro rice is to facilitate modern rice. It will pave the ways for further breeding programs.

Therefore the present study was undertaken with the following objectives:

1. To compare the yield and other yield contributing traits among the 13 F6 lines.
2. To characterize the F6 lines in respect of both yield and quality traits.
3. To select the best lines for further breeding program.

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 13 F6 lines of Boro rice

2.1.1. Days to 50% flowering

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 grains/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.

Sathya *et al.* (1999); studied of eight quantitative traits in rice *(Oryza sativa).* Days to 50% flowering was the principal character responsible for grain yield per plant followed by 1000-grain weight, plant height and harvest index as they had positive and significant association with yield.

Vijayakumar *et al.* (1997) found that hybrids out yielded than their parents when their days to 50% flowering were similar or more than their respective restorers. They concluded that superior hybrids could he identified early by comparing their tiller number, plant height and days to 50% flowering with those of their respective restores.

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

Wang *et al.* (1991) reported 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.

2.1.2. Days to maturity

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

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.

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

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.

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) observed 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.

Oka and Saito (1999) reported that among F1 there were relationships between plant heights; panicle length and number of grains/panicle were higher in the hybrid MH 2005.

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

Xu and Li (1998) observed that the maintainer lines were generally shorter than restorer line.

He *et al.* (1998) studied that plant height is 102.1 cm and it is directly resistant to rice bacterial leaf blight (*Xanthomonas oryzae).*

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

Padmavathi *et al.* (1996) said that high positive direct effects of plant height, number of panicles/plant and panicle length on grain yield.

Saravanan and Senthil (1997) reported that high heritability estimates were observed for plant height (99.15%) followed by days to 50% flowering (98.2%) and productive tillers/plant (98.19%).

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

Yu *et al.* (1995) concluded that hybrid where it reaches a height of 90 cm and proved resistant to *Magnaporthe grisea* and *Nilaparvata lugens*.

Qiu *et al.* (1994) suggested that enhancing biological yields by increasing plant height would be effective in improving hybrid rice yields.

BINA (1993) evaluated the performance of four rice varieties (IRAATOM 24, BR14, BINA13 and BINA19). It was found that varieties differed significantly in respect of plant height.

Haque *et al.* (1991) reported positive association of plant height with yield per plant but negative association with panicle per plant in modern varieties.

BRRI (1991) observed the plant height differed significantly among BR3, BR11, BR14, Pajam and Zagali varieties in the *Boro* season.

Patnaik *et al*. (1990) found that hybrids with intermediate to tall plant height having non-lodging habit could be developed gave more than 20% grain yield than the standard checks.

Shamsuddin *et al*. (1988) conducted a field trial with nine different rice varieties and observed that plant height differed significantly among the varieties tested.

Futsuhara and Kikuchi (1984) suggested that Dwarfness may be one of the most important physical characters, because it is often accompanied by lodging resistance and there by adapts well to heavy fertilizer application. Plant height is negatively correlated with lodging resistance; positive for plant height in hybrids would not be desirable, particularly with high nitrogen fertilizer.

Amirthadevarathinam (1983) reported that Grain yield is negatively correlated with plant height.

2.1.4. Number of effective tillers per plant

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.

Paramasivam *et al*. (1995); 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) concluded that the early vigor of hybrid rice (*Oryza sativa*) developed in temperate areas has been mainly attributed to its higher tillering rate. However, the tillering rate of hybrids was significantly lower than or equal to that of conventional varieties.

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.

Thakur *et al.* (1999) studied genetic variability and correlations among grain yield and its attributing traits, in an F2 population in hybrid rice. Correlation studies suggested that tillers per plant, had a positive association with grain yield, plant height, panicle weight, biological yield and harvest index.

Sathya *et al.* (1999) studied of eight quantitative traits in rice *(Oryza sativa),* productive tillers per plant was the principal character responsible for grain yield per plant followed by 100-grain weight, days to 50% flowering, plant height and harvest index as they had positive and significant association with yield.

Ashvani *et al.* (1997) studied twenty two genotypically diverse strains of hybrid rice were to correlate yield contributing characters. Number of effective tillers/plant showed significant and positive correlation at genotypic and phenotypic levels with, grain yield/panicle, 1000-grain weight and total biological yield/plant.

Saravanan and Senthil (1997) studied that information on heritability. High heritability estimates were observed for productive tillers/plant (98.19%), plant height (99.15%) followed by days to 50% flowering (98.2%).

Mishra *et al.* (1996) concluded that number of tillers per hill and number of grains per panicle exhibited positively high significant correlation with yield.
Reddy and Kumar (1996) reported that Productive tillers/hill showed significant positive correlations with grain yield.

Ganapathy *et al.* (1994) studied that the number of productive tillers per hill, panicle length and grains/panicle had a significant and positive association with grain yield.

Miller *et al*. (1991) reported that Rice tillering is a major determinant for panicle production.

Effective tillers/plant, number of grains/panicle and grain weight as the major contributing characters for grain yield were reported by Ghosh and Hossain (1988).

Ghose and Ghatge (1960) stated that tiller number, panicle length contributed to yield.

2.1.5. Panicle length (cm)

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

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

Sharma (2002) worked 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) showed 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) observed 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.

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

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

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

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

Ganapathy *et al.* (1994) reported that panicle length, the number of productive tillers per hill, and grains/panicle had a significant and positive association with grain yield.

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

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

2.1.6. Filled grain per panicle

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

Yuan *et al.* (2005) 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.

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

Ramana *et al.* (1998) observed that hybrids produced more panicles m-2 and filled grains per panicle than conventional cultivars.

Dhananjaya *et al.* (1998) evaluated some 121 elite homozygous rice genotypes. Most variation was observed for filled grain/panicle, number of fertile spikelets and grain yield/plant. Grain yield was positively correlated with number of filled grain/panicle, harvest index, panicle density, 1000-grain weight, number of productive tillers and plant height.

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

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

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

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

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

Ramalingam *et al.* (1994) examined the varieties with long panicles, a greater number of filled grains/panicle and more primary rachis would be suitable for selection because these characters have high positive association with grain yield.

Yang and Song (1994) observed that heterosis was highest for number of effective panicles (59.06%) and high for total filled grain number/main panicle

(42.44%). Number of effective grains/ panicles was correlated with 100-grain weight and 10-grain length.

Ganapathy *et al.* (1994); said that the number of filled grains/panicle, productive tillers per hill, panicle length had a significant and positive association with grain yield.

Mahajan (1993) indicated that filled grains/panicle, grain yield/plant was positively and significantly correlated with straw yield/plant.
Geetha (1993) indicated that number of ear-bearing tillers, filled grain/per panicle, percentage filled grain, and test weight, straw yield and harvest index were all correlated positively with grain yield.

Gravois and Helms (1992) reported the importance of number of filled grains per panicle in determination of rice yield.

Patnaik *et al. (*1990) reported that the heterosis for grain yield was due to the significant heterosis for the number of spikelets/panicle, test weight and total dry matter accumulation.

2.1.7. Total grains per panicle

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

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

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

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.

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

Wey and Traore (1998) analysed of yield components. The most important components were the number of panicles per plant and the number of grains per panicle.

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

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

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

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

Yang and Song (1994) reported that in a hybrid from crosses heterosis was highest for number of effective panicles (59.06%) and high for total grain /main panicle (42.44%).

Ganapathy *et al.* (1994) concluded that the number of productive tillers per hill, panicle length and grains/panicle had a significant and positive association with grain yield.

Positive association between grain number per panicle and grain yield has been reported by number of workers (Chauhan *et al*., 1986; Janagle *et al*., 1987; Kalaimani and Kadambavanaundaram, 1988).

Choi (1985) reported that grain yield was positively correlated with spikelet numbers/panicle.

2.1.8. 1000-grain weight (g)

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

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

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

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

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

Sitaramaiah *et al*. (1998) showed negative and significant standard heterosis for 1000 grain weight because the check had bold grains.

Mishra and Pandey (1998) evaluated standard heterosis for seed yield in the range of 44.7 to 230.9% and 42.4 to 81.4%, respectively. Heterosis for seed yield was due to the positive and significant heterosis for components like panicle length and 1000 grain weight.

Li and Yuan (1998) reported that parental genotype divergence had a relatively low impact on heterosis for panicle number and 1000 grain weight.

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

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

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

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

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

Kumar *et al.* (1994) stated that grain weight was highly correlated to grain size, which is product of grain length and width that are inherited independently and this independent inheritance lead to variation in F1 grain weights.

Saha Ray *et al*. (1993) reported that Plant height, panicle per plant, grain per panicle and 1000 grain weight increase the yield in modern varieties

Haque *et al*. (1991) reported negative association of 1000 grain weight and yield per plant in traditional varieties.

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

Kaneda (1985) evaluated standard heterosis for seed yield in the range of 44.7 to 230.9% and 42.4 to 81.4%, respectively. Heterosis for grain yield was due to the positive and significant heterosis for components like panicle length and 1000 grain weight.

2.1.9. 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 m2, 1000-grain weight and yield percentages. Yields were generally lower mainly due to unfavorably high temperatures.

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

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 (Mao, 2001).

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

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

Chauhan *et al.* (1999) grain yield was positively associated with dry matter at 50% flowering, biological yield and harvest index. Leaf area index, dry matter accumulation of 50% flowering, biological yield and harvest index seemed to be important in improving grain yield.

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

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

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

Paul and Kand (1997) said that yield was negatively correlated with false grains/panicle days to maturity, plant height and filled grains/panicle.

Ganapathy *et al.* (1994) concluded that the number of productive tillers per hill, panicle length and grains/panicle had a significant and positive association with grain yield.

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

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

Bai *et al*. (1992) reported that grain yield per plant positively correlated with numbers of productive tillers and number of grains per/panicle.

Improvement of rice grain yield is the main target of breeding program to develop rice varieties for diverse ecosystems. However, grain yield is a complex trait, controlled by many genes and highly affected by environment (Jennings *et al*., 1979).

2.2. Study of milling quality and grain appearance

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 (Singh *et al*., 2005; Izawa 2008).

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.

Khush *et al.* (1997) studied milling outturn varied from 68 to 72% and most of the varieties had more than 70% milling outturn.

Milling yield of rough rice is an estimation of the quantity of head rice and total milled rice that can be produced from a unit of rough rice. It is generally expressed as percentage (Khush *et al.*, 1979).

Webb (1985) reported that a variety should possess a high turnout of whole grain (head) rice and total milled rice.

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.

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.

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.

Ahmed *et al.* (1998) reported that derived from the cross jaya × Mahsuri, Jaymati is recommended for summer cropping, milling recovery is 66.5%.

Gravois (1994) reported that the value of rough rice is often determined by the percentage of head rice and total milled rice produced after milling.

Biswas *et al.* (1992) studied milling outturn varied from 68 to 72% and most of the varieties had more than 70% milling outturn.

Zhu (1992) showed that milling-quality characters are controlled by both seed genotype and maternal genotype.

Webb *et al.* (1985) reported that milling recovery is one of the most important criteria of rice quality especially from the standpoint of marketing. A variety should possess a high turnout of whole grain (head) rice and total milled rice.

Srinivas and Bhashyam (1985) reported that the substantially improved the milling properties of rice by eliminating white belly and reducing grove depth on the kernel surface.

Lanignelet and Marie (1983) reported that milling quality was slightly affected by locality, moderately affected by year and mostly affected by grain type.

Islam (1983) reported that chalky grains are not as hard as the translucent one and more prone to breakage during milling.

Chauhan and Singh (1982) found that the objective of milling is to improve appearance and palatability of rice grain with minimum loss in weight and nutritive value. Factors like grain moisture at harvest, postharvest operations such as threshing, winnowing, drying, storage, efficiency of the mill used and degree of polishing also contribute for the major part of loss during milling.

Barbar and Barbar (1980) stated that morphological characters of grains such as shape, size and topography markedly influenced rice milling outturn.

Khush *et al*. (1979) reported that milling recovery of rough rice is an estimation of the quantity of head rice and total milled rice that can be produced from a unit of rough rice. It is generally expressed as percentage. They also stated that the proportions of the various components vary according to the method of milling used and the variety of rice. Generally, the hulls vary from 20% to 22% of the rough rice although variation of 18% to 26% has been recorded. Barn and embryos constitute another 8% to 10%. Thus, from a given sample of rough rice, about 70% milled rice is obtained. The proportion of whole rice is known as head rice recovery and is expressed as percentage of rough rice. Thus, if from a sample of 100g of rough rice, 70g of milled rice is obtained and 20g of this is broken, head rice recovery is 50%. The head rice recovery may very form as low as 25% to as high as 65%.

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.

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, 2003).

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.

Jodari and Linscombe (1996) studied the influence of environmental condition on grain fissuring and milling yields of rice cultivars and reported that milling was influenced by both genotype and environmental conditions prior to harvest. Grain fissuring was highly related with relative humidity and average temperature during crop maturity and grain moisture content at harvest and they proposed to maintain optimum harvest moisture of 15-17% for high HRR.

Sarkar *et al*. (1994) observed that percentage of high density grains was significantly and positively associated with 1000-grain weight, hulling, milling and head rice recovery.

Gravois (1994) reported that the value of rough rice is often determined by the percentage of head rice and total milled rice produced after milling.

Ali *et al*. (1993a) reported that threshing on the day of harvest gave highest HRR and lowest broken rice, and delay will lead to reduction in milling recovery.

Ali *et al*. (1993b) 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.

Viraktamat (1987) and Yadav and Singh (1989) reported an inverse relationship between HRR% and grain L/B ratio.

Tomar (1985) 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.

Bhattacharya (1980) reported that 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. Grain size and shape, hardness, presence or absence of abdominal white, moisture content, harvest precision, storage conditions, processing and type of mills employed have direct bearing on head rice recovery .

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.

Anonymous (1997), reported that in Bangladesh, high income people prefer long slender grains whereas the low income group prefer the short bold grains because of its high volume expansion.

Biswas *et al.* (1992) found that length of the grain is more variable and important than width and thickness or shape. The grain size and shape of most modern rice varieties is short to medium bold with translucent appearance.

A length breadth ratio from 2.5 to 3.0 has been considered widely acceptable as long as the length is more than 6mm (Kaul, 1970).

Thus, grain size and shape are among the first criteria of rice quality that breeders consider in developing new varieties for release for commercial production (Adair *et al.*, 1966).

2.3. Cooking and eating characteristics of the grain

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

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 (Rui *et al.*, 2005).

Cooking and eating qualities of rice are largely depends upon the properties of starch that makes up 90% of milled rice. Cooking quality preferences vary in different countries of the world (Azeez and Shall, 1986).

Cooking and eating characteristics included the grain elongation, amylose content, gel consistency, gelatinization temperature and aroma (Khush *et al*., 1979).

Julino (1972) reported that additionally, amylose content as well as gelatinization temperature and gel consistency can highly influence cooking and eating qualities of rice, which can vary based on the varieties.

Rice is one cereal that is consumed mainly as whole milled and boiled grain. The desired properties may vary from country to country (Juliano *et al.*, 1964).

Quality in rice may therefore be considered from the viewpoint of milling quality; grain size, shape and appearance and cooking characteristics. Several component traits collectively determined cooking and eating qualities of rice are reviewed below:

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.

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

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.

Ahuja *et al*. (1995) reported that during storage, grain hardness and gelatinization temperature increase which allows more swelling and elongation during cooling.

Chauhan *et al*. (1995) pointed out significant positive correlation between kernel elongation and cooked kernel length. Kernel elongation was primarily influenced by kernel shape and size.

Biswas *et al.* (1992) found that elongation ratio and volume expansion ratio varied from 1.3 to 1.9 and from 3.4 to 3.9 respectively.

Singh (1989) established that long duration varieties (145-150 days) have more L/B ratio after cooking.

Kumar (1989) concluded that proportionate change and elongation index which involve both length-wise and breadth-wise component are reliable measure of kernel elongation.

Lengthwise expansion (grain elongation) upon cooking without increase in girth is considered a high desirable trait in high quality rice such as Basmati, which elongate almost 100 per cent upon cooking (Khush *et al*., 1979; Sidhu, 1989).

Pilaiyar (1988) proposed elongation ratio to be best index of quality compared to elongation index and proportionate change.

Sood and Siddiq (1986) concluded that the characters such as volume expansion, kernel length and breadth which were positively related to water uptake did not show significant association with kernel elongation, so all such characters were independent of each other as far their contribution to kernel elongation was concerned and only those kernel types were capable of absorbing more water during cooking were considered to possess better kernel elongation property.

Tomar and Nanda (1982) reported that water uptake at 77°C showed significant positive correlation with kernel elongation.

Juliano (1979) reported that kernel elongation, in general, is given as kernel elongation ratio, which is the ratio of mean length of cooked kernel to the original length. Kernel elongation is the result of swelling of starch granules by uptake of water upon cooking.

Grain elongation of rice is one of the major characteristic of good rice (Sood and Sadiq, 1979).

Kongseree and Juliano (1972) reported that kernel elongation has significant positive correlation with amylose content but not with gelatinization temperature.

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.

Correlation co-efficient of grain physical characters were correlated with uptake and volume expansion (Choi *et al.*, 1999; and Chauhan, 2000).

Chauhan *et al.* (1992) found wide range of variability for grain length, shape, water uptake and head rice recovery.

Marzempi and Edi (1990) concluded that expansion volumes also affected by the change of amylase content.

Sood and Siddiq (1986) reported that water uptake showed a positive and significant influence on grain elongation, while volume expansion did not influence grain elongation.

Zaman (1981) reported that the good cooking rice varieties have water absorption value ranging between 174% and 275%, whereas majority of those showing pasty appearance have value as high as from 300 to 570%. He concluded that high water absorption is relatively less desirable characteristics and it would be desirable to select a variety or hybrid with moderate water absorption. Volume expansion by and large is determined by water uptake, however, subject to the influence of kernel texture. 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.

Sood and Siddiq (1980) have reported still wider range (74-439%) of variation for this character.

The volume ratio of raw milled rice and cooked rice was determined by water displacement method using a measuring cylinder. The volume expansion was calculated with the method by Sidhu et al., (1975).

Hogan and Planck (1958) observed that shot and medium grain varieties of the USA have high water absorption as compared to long grain types. Working with a larger number of scented basmati varieties.

2.3.3 Gelatinization temperature (GT)

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.

Bhattacharya (1980) reported that Indian consumers like rice with intermediate GT.

At high GT, rice becomes extensively soil when overcooked, elongates less and remain under cooked under standard cooking procedures, Rice varieties with a high GT require more water and more time to cook than those with low or intermediate GT. Rice with intermediate GT is most preferred (Khush *et al.,* 1979).

Zaman (1981) reported that Gelatinization temperature is estimated by extent of spreading and clearing of milled rice kept in alkali (1.7% KOH) solution for 16 hours at 30 ±1 °C.

The GT is correlated with the extent of disintegration of milled rice in dilute alkali solution and hence an indirect estimate of the GT. Gelatinization temperature may be classified as low (Below 70°), intermediate (70° to 740) or high (above 74°) (Little *et al.,* 1958)

Jennings *et al.* (1979) reported that mostly the rice varieties with higher GT may have low amylase content (AC). No varieties have been found with higher GT and higher AC.

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%.

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

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

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.

Champagne (1996) reported that starch from rice is non-allergenic, because of the hypoallergenicity of the associated protein. Rice starch granule being very small in size provides a texture perception similar to that of fat.

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.

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, 2008).

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

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.

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

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 (Frei and Becker, 2003).

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 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 central farm, Sher-e-Bangla Agricultural University (SAU), Dhaka during December, 2014- May, 2015. 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.

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%. The record of air temperature, humidity, rainfall and sunshine (hr) during the period of experiment were noted from the SAU Weather Station, Sher-e-Bangla Nagar Dhaka-1207.

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 May to October, winter or dry season from November to February and the pre-monsoon period or hot season from March to April. Information regarding monthly maximum and minimum temperature, rainfall, relative humidity, soil temperature and sunshine as recorded by Bangladesh Meterological Department, Agargaon, during the period of study.

3.2. Planting materials used

Fifteen rice genotypes were used for the present study. Among fifteen rice genotypes, thirteen genotypes were F5 materials and two were check materials. The physically healthy seeds of these genotypes were obtained from the Department of Genetics and Plant Breeding (SAU), Dhaka. The name and origin of these genotypes are presented in Table 1.

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

Sl. No.	Genotypes	Pedgree	Source
1	(G1)	BR 21 x BR 26 F6 S6 P7 P7	GEPB , SAU
2	(G2)	BR 21 X BR 26 F6 S6 P3 P5	
3	(G3)	BR 21 X BRRI dhan 28 F6 S5 P1 P2	
4	(G4)	BR 21 X BRRI dhan 28 F6 S5 P3 P4	
5	(G5)	BR 21 X BRRI dhan 29 F6 S6 P6 P1	
6	(G6)	BR 21 X BRRI dhan 29 F6 S6 P2 P3	
7	(G7)	BR 24 X BR 26 F6 S6 P4 P8	
8	(G8)	BR 24 X BRRI dhan 28 F6 S10 P6 P10	
9	(G9)	BR 26 X BRRI dhan 28 F6 S1 P9 P5	
10	(G10)	BR 26 X BRRI dhan 29 F6 S6 P3 P3	
11	(G11)	BRRI dhan 28 X BRRI dhan 29 F6 S2 P4 P3	
12	(G12)	BRRI dhan 28 X BRRI dhan 36 F6 S7 P8 P5	
13	(G13)	BRRI dhan 29 X BRRI dhan 36 F6 S5 P10	
14	(G14)	BRRI dhan 29	BRRI, Gazipur
15	(G15)	BRRI dhan 28	

Note: GPB= Department of Genetics and Plant Breeding, SAU= Sher-e-Bangla Agricultural University, BRRI= Bangladesh Rice Research Institute

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. Fifteen separate strips were made and sprouted seeds were sown in 1st December of 2014. 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 power tiller 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	Doses **(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 30m x 3.4m, and the distance between replication to replication was 50 cm. The individual plot size was 3.25m×3m (9.75 m2.). Total number of plots was 15 × 3 = 45.

3.3.5. Transplanting

One seedling per hill was transplanted to the main plot on the 30th December, 2015 when they were 30 days old. Row to row and plant to plant distance were 25 cm and 20 cm, respectively. Fifteen 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 upto 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 mechanical 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 liter of water for 5 decimal lands. Crop was protected from birds and rats during the grain-filling period. Field trap and phostoxin poisonous bait was used to control the rat. For controlling the birds, watching was done properly, especially during morning and afternoon.

3.3.7. Crop harvesting

Different genotypes matured at different times from 2nd April to 13th May, 2015. 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 F6 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

The data were recorded under the following heads:

• Evaluation of the yield performance of different F6 line of Boro rice

• Study of the milling and grain appearance of these lines

. Determination of cooking and eating characteristics of the grain

3.3.8.1. Evaluation of the yield performance of different F6 line of Boro rice

3.3.8.1.1. Days to flowering

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

3.3.8.1.2. 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.

Plate 1. A field view of the experiment

3.3.8.1.3. 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.

3.3.8.1.4. Number of total tillers per plant

The total 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 tiller per plant was counted as the number of panicle 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. Total number of spikelet 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. Yield per plant (g)

Grains obtained from each plant were sun dried and weighted carefully. The dry weight of gains per plant was then recorded.

3.3.8.1.13. Thousand Seeds weight (g)

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

3.3.8.2. Study of the milling and grain appearance of these 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:

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.

$$\text{Elongation ratio (ER)} = \frac{(L_1)}{(L_0)}$$

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.

$$\text{Elongation index (EI)} = \frac{L_1/B_1}{L_0/B_0}$$

3.3.8.3.4. Water absorption (uptake) percentage

It is measured as the volume of water needed to cook 1 gm of rice in a definite period of time and temperature. Sample comprising one gram milled rice kernels was used of the study of this character. Weight of the samples was recorded before and after cooking. Water absorption was calculated in percentage as,

$$\text{Water absorption \%} = \frac{W_2 - W_1}{W_1} \times 100$$

Care was taken to remove excess of water from the cooked samples with the help of blotting papers before weight. For cooking, the rice samples were taken in long test tube and pre-soaked in slightly excess but uniform quantity of water (10 ml) for five minutes and were placed over a water bath maintained at boiling temperature (100˚C) for 6 to 7 minutes. The sample tubes were then out and cooled under room temperature for 10 minutes.

3.3.8.3.5. 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-

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

3.3.8.3.6. 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 30^0c 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 (^oC)	Alkali Spreading Value
Low	55-69	6-7
Intermediate	70-74	4-5
High	75-79	2-3

3.3.8.3.7. Protein (%)

Protein content was determined by micro Kjeldahl method (AOAC 1970).50 mg powdered samples 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 todissolve 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_2 S_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,

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

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

3.3.8.3.8. Amylose (%)

Amylose content was determined according to Juliano (1979).100mg of rice powder was taken into a 100ml volumetric flasks and 1ml of 95% ethanol and 9ml 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 1N 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 expected on a dry basis. The moisture content of the samples was essentially constant and need not 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

(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 Statistical Package for the Social Sciences (SPSS) Software version 20.0 (SPSS Inc., Chicago, IL, USA). Comparisons of the mean and standard errors were determined by Duncan's multiple range tests at $p \leq 0.05$ level of significance.

CHAPTER IV

RESULT AND DISCUSSION

The present study was conducted to evaluate the performance of different yield and quality attributes of 13 F6 lines and two check varieties.

4.1. Characterization and comparison of the 13 F6 lines

In the present study, 13 F6 lines collected from GEPB, SAU and two check varieties of rice collected from BRRI have been evaluated for their performance of yield and yield contributing traits, quality contributing traits, interrelationships of these traits and comparison for commercial cultivation.

4.1.1. Evaluation of the yield performance of different F6 lines of Boro rice

4.1.1.1. Days to 50% flowering

Days to 50% flowering of different F6 lines of rice varied significantly (Table 9). The maximum days to 50% flowering (129.66 days) was recorded from G14 (BRRI dhan 29) which was check variety and the another check variety is BRRI dhan 28(121.33 days), whereas the minimum days (117.33 days) was recorded from G11 (28 x 29 F6S2P4P3), which was statistically similar with the genotype G3, G4, G5, G6, G10, G12.Maturity of G11 was also earlier than other and third in higher yield per plant which was statistically similar with BRRI dhan 29. A comparative performance of F6 lines and check variety for days to 50% flowering and days to maturity is presented in (Table 9). A pictorial view of variation of in flowering among different lines is presented in Plate 2.

4.1.1.2. Days to maturity

Days to maturity of different F6 lines of Boro rice varied significantly (Fig. 1).Among the genotypes days to maturity ranged from 155 to 138 days with a mean value of 144.17 days. The maximum days to maturity was found in genotype G14 (BRRI dhan 29). The genotype G11(BRRI dhan 28 x BRRI dhan 29 F6 S2 P4 P3) had the shortest maturity period 138 days, representing earliness, which is lower than their check BRRI dhan 29 but similar to check

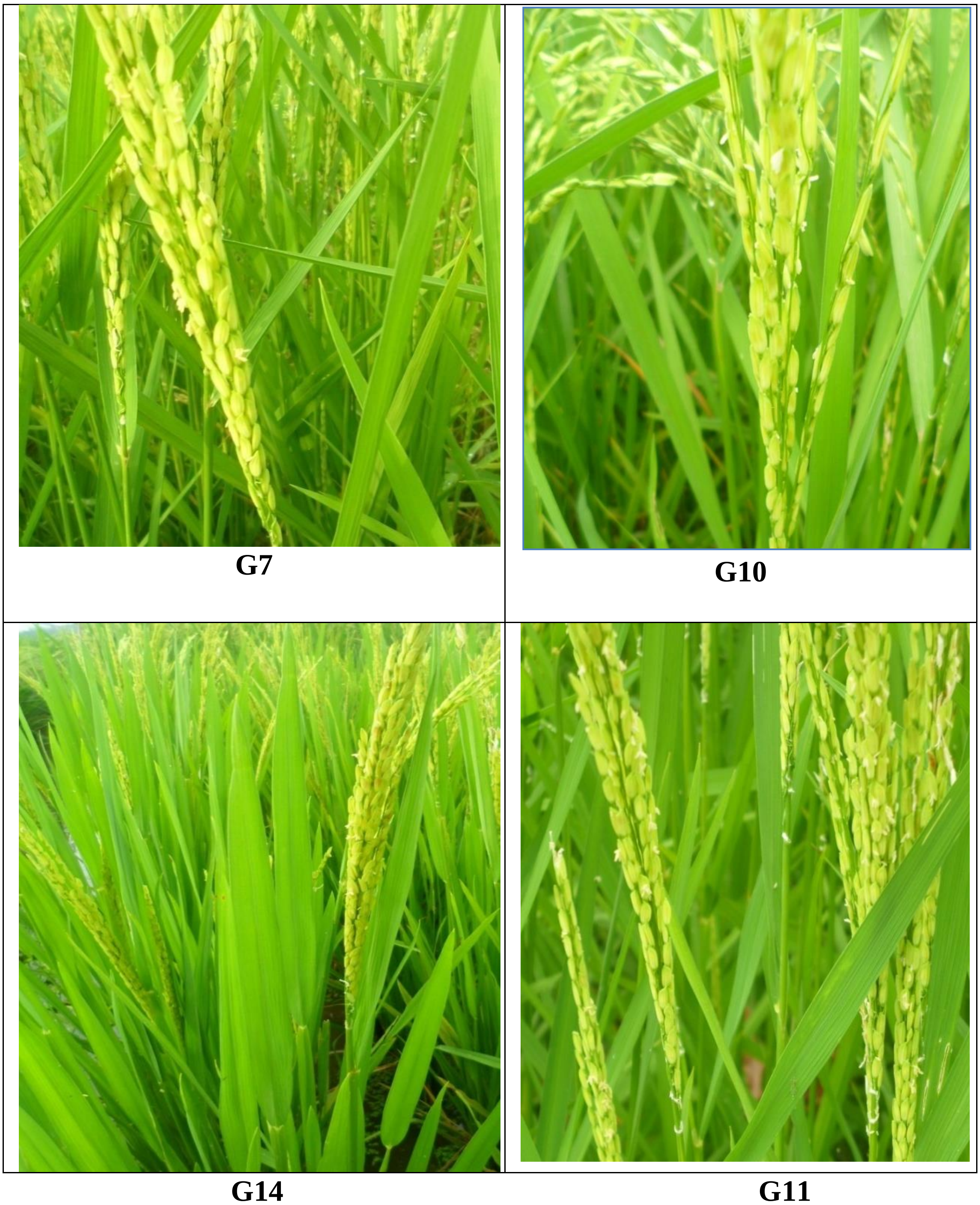


Plate 2. Photograph showing variation in flowering among different lines

Table 9: Performance of growth and yield contributing characters of different F6 lines of Boro rice

Genotype	Days to 50% flowering	Plant height (cm)	Number of total tillers/Plant	Number of effective tillers/Plant
G1	123.00 ±0.57^{c}	108.57 ± 0.40^{de}	16.60 ±0.84^{abc}	16.16 ± 0.74^{ab}
G2	121.33 ±0.33^{d}	111.54 ± 0.43^{c-e}	17.83 ± 0.28^{a}	16.86 ± 0.82^{a}
G3	118.66 ± 0.33^{e}	124.88 ± 3.25^{b}	14.57 ± 0.12^{de}	13.80 ± 0.39^{c-e}
G4	119.33 ± 0.67^{e}	142.20 ± 1.52^{a}	12.53 ± 0.03^{f}	12.07 ± 0.08^{e}
G5	119.33 ± 0.66^{e}	113.44 ± 1.37^{cd}	15.23 ± 0.41^{cd}	14.40 ± 0.78^{b-d}
G6	119.00 ± 0.57^{e}	105.45 ± 2.50^{e-g}	12.97 ± 0.58^{ef}	12.63 ± 0.46^{de}
G7	126.33 ± 0.33^{b}	115.44 ± 5.07^{c}	15.13 ± 0.26^{cd}	14.76 ± 0.27^{bc}
G8	121.00 ± 0.57^{d}	107.02 ± 1.48^{d-f}	12.97 ± 0.52^{ef}	12.63 ± 0.61^{de}
G9	121.00 ± 0.57^{d}	100.18 ± 0.58^{g}	16.80 ± 0.46^{a-c}	16.26 ± 0.54^{ab}
G10	118.33 ± 0.33^{ef}	116.70 ± 1.27^{c}	16.80 ± 1.08^{a-c}	16.16 ± 1.24^{ab}
G11	117.33 ± 0.33^{f}	100.84 ± 0.62^{fg}	16.13 ± 0.19^{a-d}	15.66 ± 0.27^{a-c}
G12	118.66 ± 0.33^{e}	107.29 ± 3.92^{d-f}	17.40 ± 0.68^{ab}	17.20 ± 0.17^{a}
G13	121.33 ± 0.67^{d}	99.95 ± 0.39^{g}	15.90 ± 0.87^{b-d}	15.73 ± 0.81^{a-c}
G14	129.66 ± 0.33^{a}	93.54 ± 0.68^{h}	14.47 ± 0.48^{de}	13.86 ± 0.51^{c-e}
G15	121.33 ± 0.33^{d}	100.52 ± 0.57^{fg}	17.67 ± 0.37^{a}	16.93 ± 0.28^{a}

The data represent the mean values ± standard error. Different letter (s) corresponds to significant differences at $p \leq 0.05$ by Duncan's Multiple Range Test (DMRT).

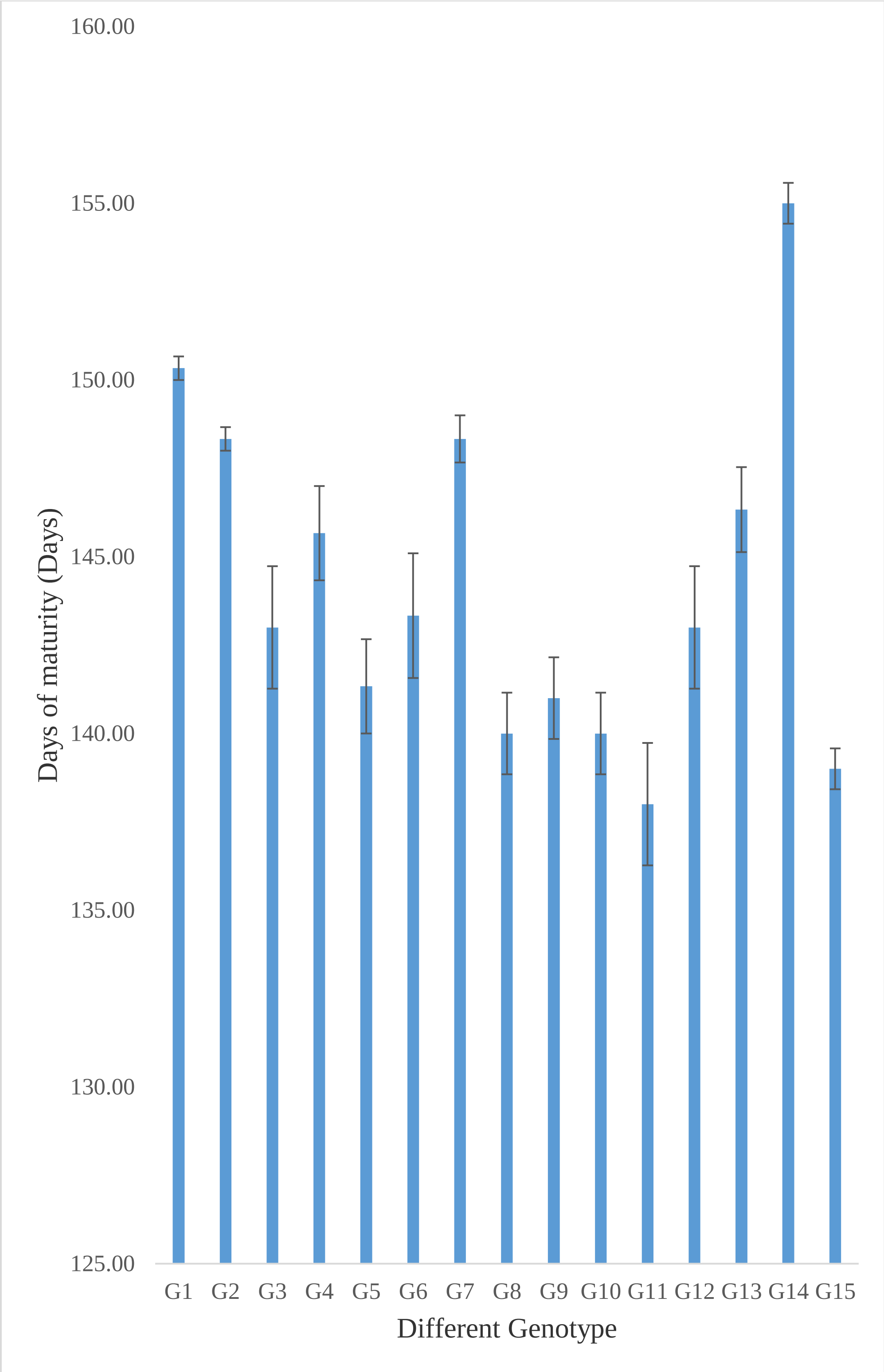


Fig. 1: Days of maturity on different F6 lines of Boro rice

G10

G14

G11

G5

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

BRRI dhan 28 and G5, G8, G9, G10 were more or less close to every other. The G11 line also showed minimum 50% flowering and third higher yield per plant. These short duration lines can a good source for future trial. Variations in duration of crop could be utilized directly under varied agro-ecological situation as well as breeding program. Plate 4 showing variation in plant height in different lines.

4.1.1.3. Plant height (cm)

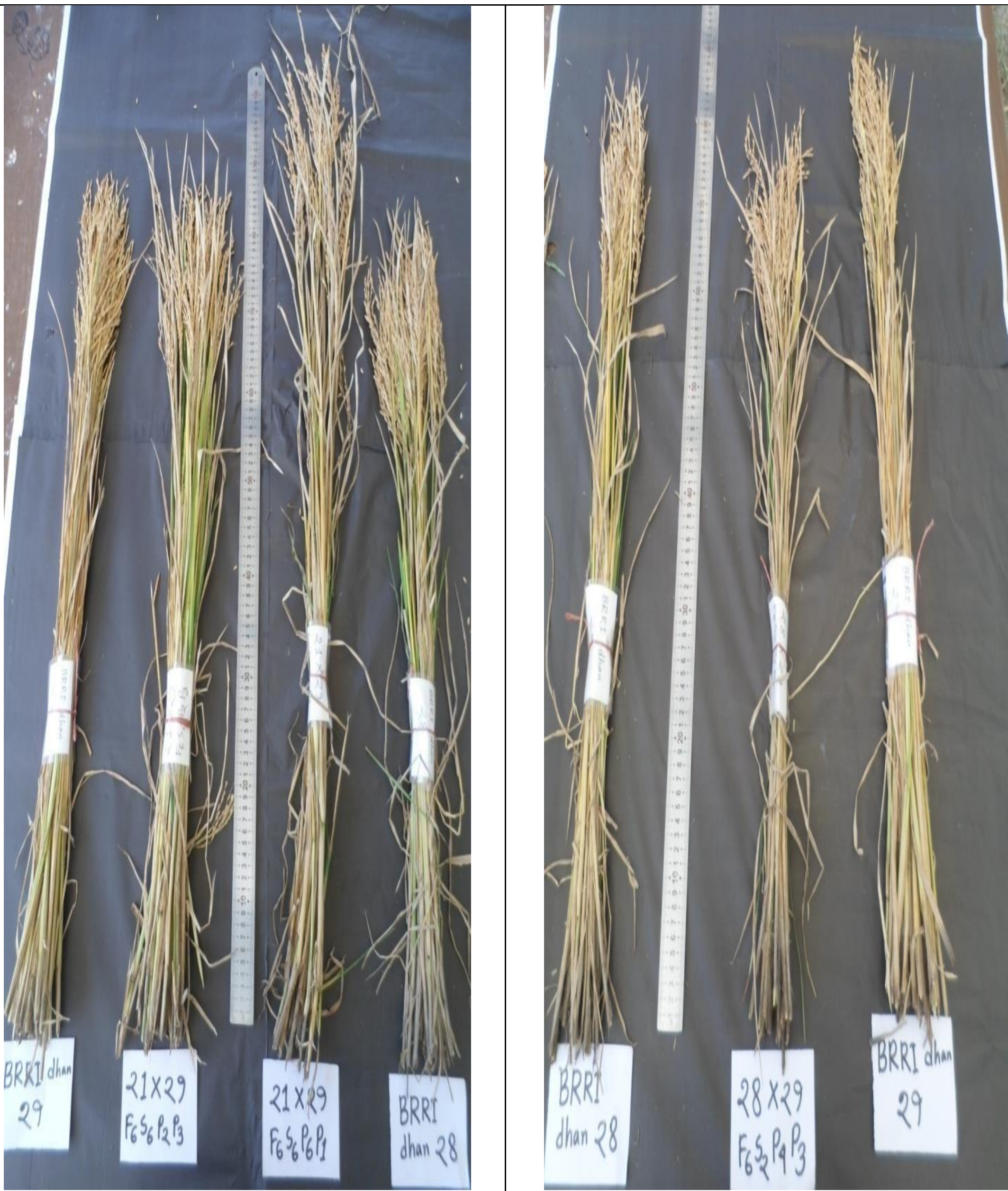
In this study the highest plant height (142.20cm) was recorded in G4 (BR 21 x BRRI dhan28 F6S5P3P4) which was taller than their checks, as their checks BRRI dhan 29 (93.54cm) and BRRI dhan 28 (100.52cm) respectively and G4 showed lower yield than checks. G1, G2, G3, G6, G7, G8, G10, G12 were also took taller in plant height than checks. The minimum plant height showed G14 (93.54) which was one check. The rest of the populations showed different plant height (Table 9). Plate 4 showing variation in plant height.

4.1.1.4. Number of total tillers per plant:

Number of total tillers per plant of different lines of rice varied significantly (Table 9). The maximum number of total per plant (17.83) was recorded G2 (BR 21 x BR 26 F6S6P3P5), which was similar to G12 (17.40) and check BRRI dhan 28(17.67) whereas G12 showed second highest yield.The minimum number (12.53) was recorded from G4 (BR 21 x BRRI dhan 28 F6S5P3P4). Similar trend is also observed in case of effective tillers per plant. Plate 5 showing variation in number of total tillers per plant.

4.1.1.5. Number of effective tillers per plant

The performance of F6 lines and check variety for number of effective tillers per plant is presented in (Table 9). Number of effective tillers per plant of different F6 line of boro rice varied significantly (Table 9). The maximum number of effective tillers per plant (17.20) was recorded from G12 (BRRI dhan 28 X BRRI dhan 36 F6 S7 P8 P5) which was higher than check BRRI



G14 G6 G5 G15 G15 G11 G14

Plate 4. Photograph showing variation in plant height in different lines and comparison with their checks.

G10

G8

G11

G15

Plate 5. Photograph showing variation in number of total tiller per plant in different lines

dhan 28 (16.93) & BRRI dhan 29 (13.86) and these line showed second higher yield per plant. The minimum number (12.07) recorded from G4 (BR 21 x BRRI dhan 28 F6 S5 P3 P4).The genotypes G1, G2, G5, G7, G9 and G10 were statistically similar. The rest of population showed different number of effective 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)

4.1.1.6. Panicle length (cm)

Panicle length was significantly varied on different F6 lines of Boro rice (Table 10). The highest panicle length (27.90 cm) was recorded from G4 (BR 21 x BRRI dhan 28 F6S5P3P4), which was higher than checks BRRI dhan 28 (24.07 cm) &BRRI dhan 29 (23.17 cm) and the minimum panicle length (20.91 cm) was recorded from G6 (BR 21 x BRRI dhan 29 F6S6P2P3). G3, G7, G11& G12 were close to BRRI dhan 28. Again G1, G8, G9, G13 were similar. The rest of lines showed different panicle length. Plate 6 showing variation in penicle length in different lines.

4.1.1.7. Number of primary branches per panicle

From the mean table value it was found that highest number of primary branches per panicle was recorded for G4 (14.26) while the minimum number of primary branches per panicle was recorded for G2 (9.26) (Table 10) which was very close to G1 (9.60), G7 (9.43), G9 (9.50) and G15 (9.46). The genotypes G3, G4, G5 , G8 ,G10,G11 and G12 were shown higher number of

G15 G11 G14

G15 G10 G14

G15 G2 G14

Plate 6. Photograph showing variation in panicle length in different lines and comparison with their checks (BRRI dhan 29 and BRRI dhan 28)

primary branches per panicle than two checks the G14 (BRRI Dhan29) (10.16) and G15 (BRRI Dhan28) (9.46).Here G4, G9, G10 were shown moderate yield but G5 was shown highest number of secondary branches , moderate filled grain , highest yield per plant & moderate maturity; G12 showed third higher secondary branches, second highest total spikelet ,higher filled grain than checks & second highest yield,G11 was shown higher total spikelet, higher filled grains than checks, third highest yield per plant and most earliest maturity. The rest lines showed different primary branches per panicle.

4.1.1.8. Number of secondary branches per panicle

Among 15 genotypes, the highest number of secondary branches per panicle was recorded in G5 (40.10) whereas the minimum number of secondary branches per panicle was observed in G2 (26.50) which was very close to G1 (26.76) (Table 10). G4, G5, G6, G7, G12 were shown higher number of secondary branches per panicle than their checks BRRI dhan 29 (32.20) and BRRI dhan 28(30.23).The genotypes G3, G8, G11, G13 were found similar number of secondary branches per panicle to checks.

4.1.1.9. Total number of spikelets/panicle

Number of total spikelet per panicle of different F6 lines of rice varied significantly (Figure 2). The maximum number of total spikelets per panicle (214.66) was recorded from G7 while the minimum number (152.93) recorded from G1. G4, G7, G10, G11, G12 were shown higher total number of spikelet per plant than checks G14 (176.56) and G15 (187.93). 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). Here G7, G10 were shown moderate yield and G11, G12 were shown higher yield per plant than both checks.

Table 10: Performance of yield contributing characters and yield of F6 lines of Boro rice

Genotype	Panicle length (cm)	Number of primary Branches/ Panicle	Number of secondary Branches/ Panicle	Number of unfilled grains/ Panicle
G1	23.17 ± 0.74^{d-f}	9.60 ± 0.11^{fg}	26.76 ± 0.82^{g}	90.06 ±4.89^{a}
G2	22.48 ± 0.14^{f}	9.26 ± 0.12 ^{g}	26.50± 0.36^{g}	25.03 ± 2.35^{cd}
G3	24.77 ± 0.38^{b}	11.33 ± 0.35^{bc}	30.76 ± 1.17^{d-f}	48.76 ± 0.21^{b}
G4	27.90 ± 0.08^{a}	14.26 ± 0.23^{a}	37.46 ± 0.49^{ab}	41.86 ± 2.33^{b}
G5	22.99 ± 0.04^{ef}	12.06 ± 0.48^{b}	40.10 ± 2.16 ^{a}	22.83 ± 5.80^{d}
G6	20.91 ± 0.39^{g}	10.00 ± 0.17^{e-g}	34.66 ± 1.49^{b-d}	16.03 ± 0.19^{de}
G7	24.06 ± 0.15^{b-d}	9.43 ± 0.18^{fg}	33.60 ± 1.94^{c-e}	18.90 ± 2.51^{de}
G8	23.22 ± 0.57^{d-f}	10.43 ± 0.15^{de}	30.93 ± 0.21^{d-f}	22.83 ± 0.44^{d}
G9	23.57 ± 0.22^{c-e}	9.50 ± 0.32^{fg}	29.60 ± 1.18^{fg}	16.26 ± 1.50^{de}
G10	22.54 ± 0.07^{f}	10.86 ± 0.28^{cd}	28.56 ± 1.62^{fg}	16.73 ± 0.58^{de}
G11	24.35 ± 0.09^{bc}	11.40 ± 0.12^{bc}	30.96 ± 1.12^{d-f}	21.66 ± 2.11^{de}
G12	24.32 ± 0.37^{bc}	11.6 ± 0.12^{b}	36.10 ± 0.44^{bc}	33.06 ± 5.04^{c}
G13	23.36 ± 0.39^{d-f}	10.03 ± 0.29^{e-g}	30.86 ± 0.19^{d-f}	15.13 ± 4.29^{de}
G14	23.17 ± 0.17^{d-f}	10.16 ± 0.18^{d-f}	32.20 ± 0.49^{d-f}	17.06 ± 2.57^{de}
G15	24.07 ± 0.05^{b-d}	9.46 ± 0.09^{fg}	30.23 ± 1.65^{e-g}	12.76 ± 0.27^{e}

The data represent the mean values ± standard error. Different letter (s) corresponds to significant differences at $p \leq 0.05$ by Duncan's Multiple Range Test (DMRT).

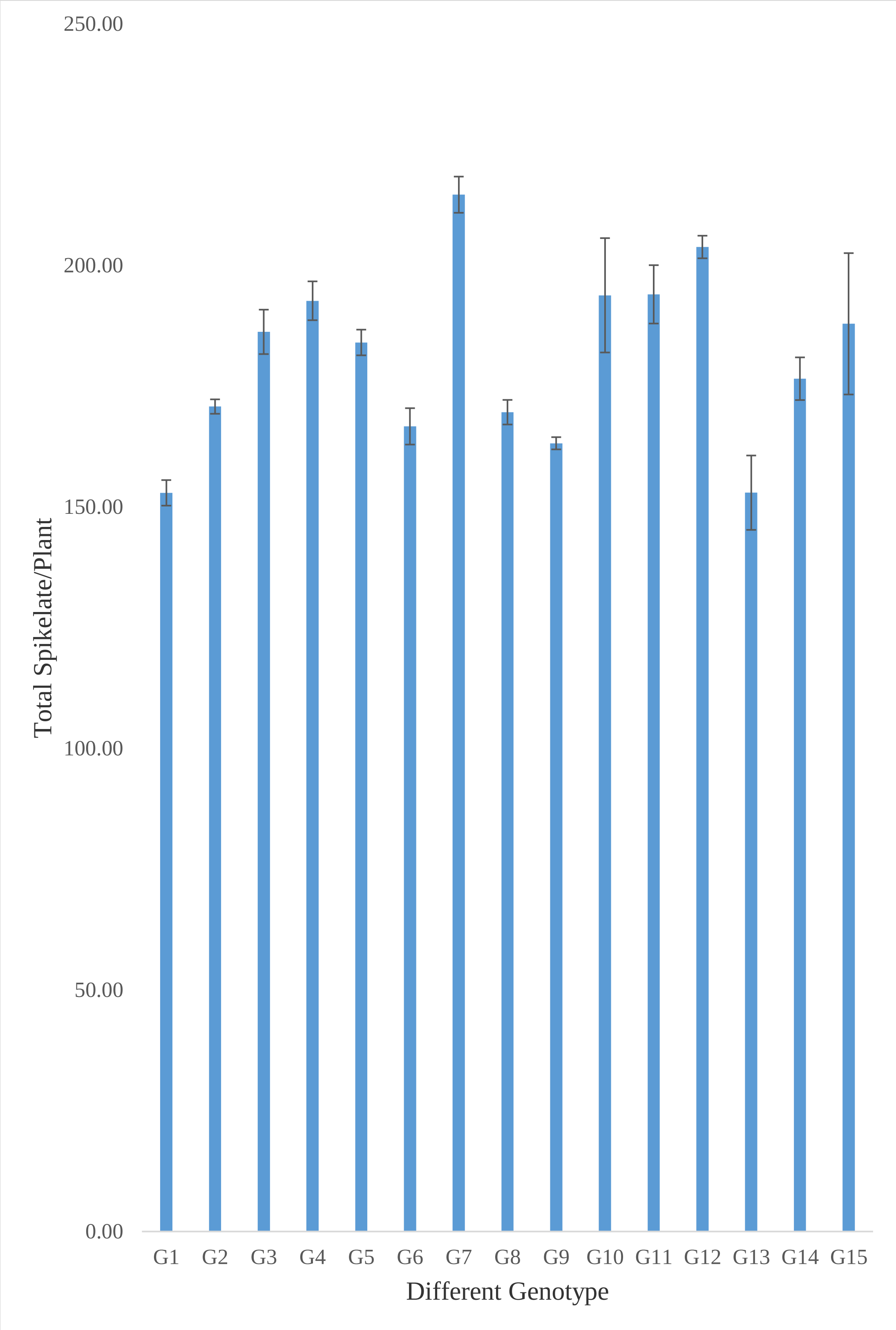


Fig. 2: Total spikelates/plant on different F6 lines of Boro rice

4.1.1.10.Number of filled grains/panicle

The highest number filled grains per panicle was recorded in G7 (195.96) which was higher than their checks, as their checks G14 (BRRI dhan29) (176.56) and G15 (BRRI dhan 28) (187.93) respectively (Figure 3). G10 also had higher number of filled grains per panicle.G5, G10, G11, G12 had higher filled grain per panicle than check G14 (BRRI dhan 29) but similar to check (BRRI dhan 28). G11 & G12 had higher yield per plant than both checks and G11was shown earliest maturity and G12 was shown moderate maturity. Rest of the population showed different number of filled grains per panicle.

4.1.1.11. Number of unfilled grains per panicle

The highest number unfilled grains per panicle was recorded in G1 (90.06) while minimum number of unfilled grains per panicle was recorded in G15 (12.76) which was one check, BRRI dhan 28 and another check) showed (17.06), G14 (BRRI dhan29). G6, G7, G9, G10, G13 were similar to check BRRI dhan 29.Rest of populations showed different number of unfilled grains per panicle (Table 10).

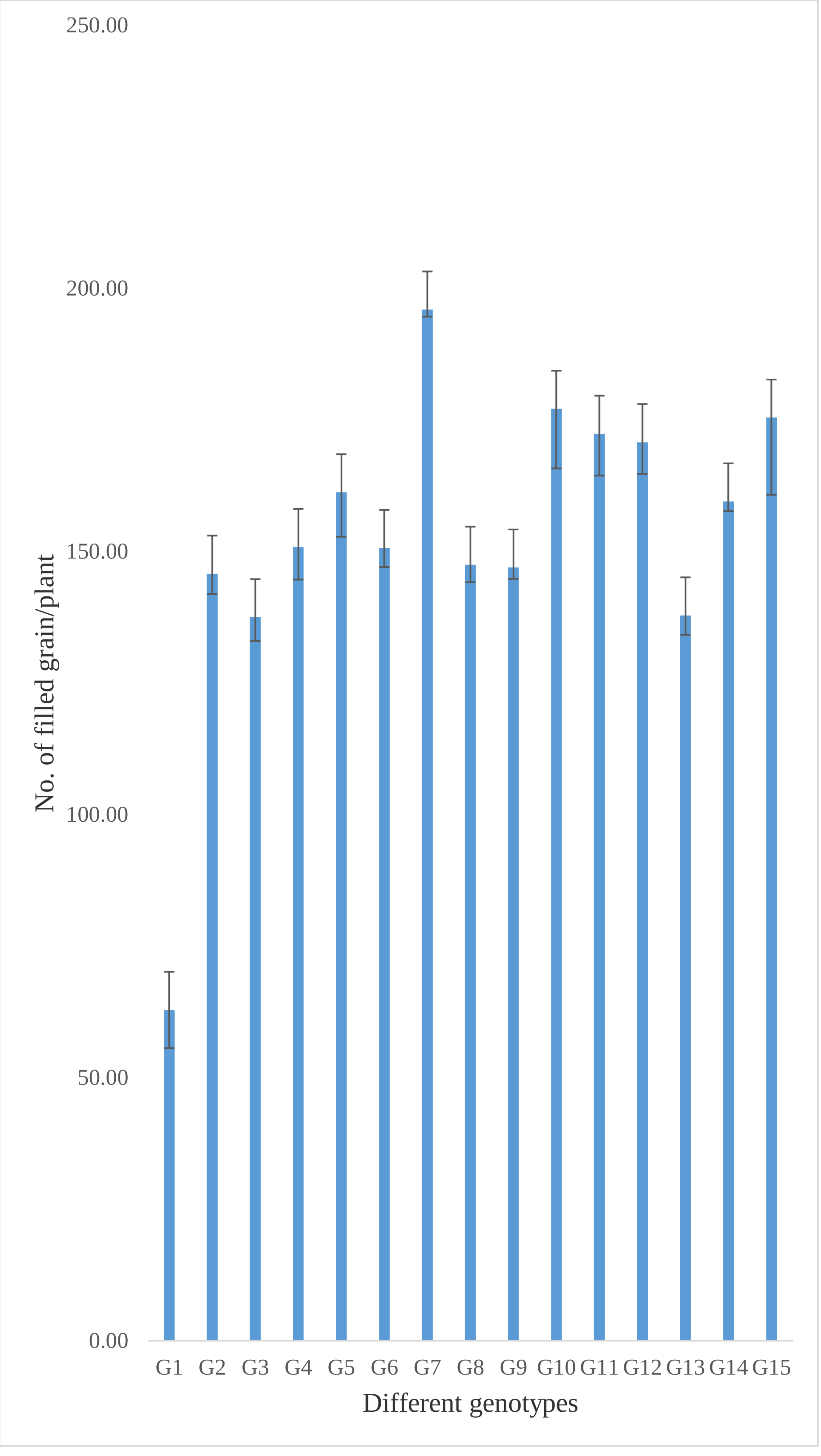


Fig.3: Number of filled grain/plant on different F6 lines of Boro rice

4.1.1.12. Yield per plant (gm)

The maximum yield per plant (54.86 g) was recorded from G5 which was higher than their checks, as their checks BRRI dhan 29 and BRRI dhan 28 had 40.06g and 46.26g yield per plant respectively whereas the minimum (20.53 g) was recorded from G1 (Figure 4). It is very important that G5 showed higher number of primary branches, highest number of secondary branches and higher number of total spikelet. G11and G12 were also showed higher yield per plant than checks whereas G11 showed most earliest maturity and G12 showed moderate maturity.G4,G6,G9,G10,G13 were statistically similar with BRRI dhan 29. Rest of population showed different yield per plant.

4.1.1.13. Thousand Seed weight (gm)

The highest 1000-seed weight (26.41) was recorded from G4 wheras the minimum 1000-seed weight (21.25) which was statistically similar with G1 (21.90), G2 (21.63), G14 (BRRI dhan 9) (21.40). The genotypes G3, G5, G6, G9, G11, G12, G13 were higher 1000 seed weight than their checks, as their checks BRRI dhan 29(21.40), BRRI dhan 28(22.52). The genotype G8 was statistically similar with BRRI dhan 28 (Table 11).

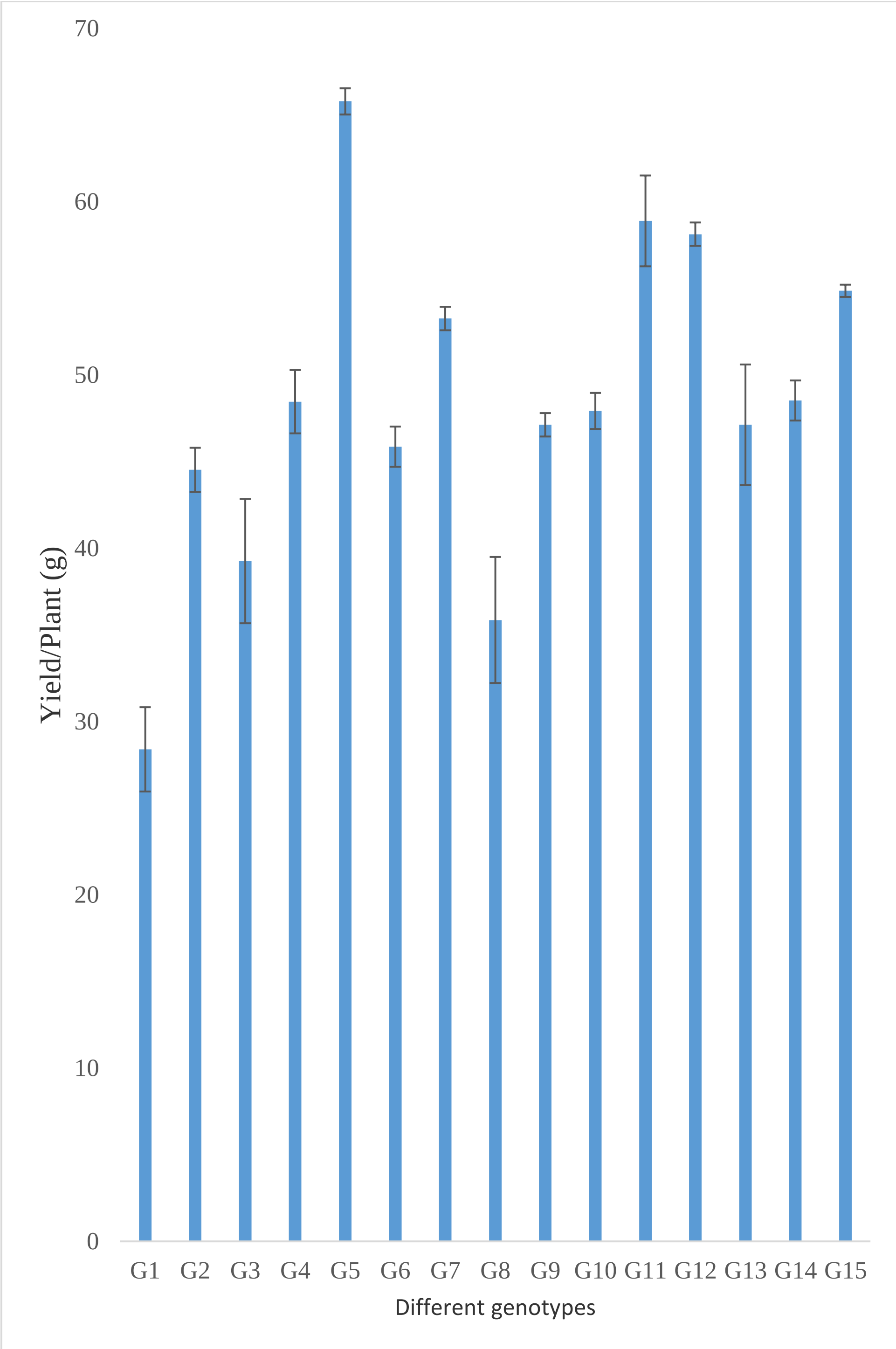


Fig. 4: Yield /plant on different F6 lines of Boro rice

4.1.2. Milling and grain appearance/quality characters of F6 lines of boro 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.

4.1.2.1. Hulling (%)

Hulling percentage of rice for different F6 lines of boro rice varied significantly (Table 11). The maximum hulling (73.75 %) was recorded from G3 which was higher than their checks, as their checks BRRI dhan 29 and BRRI dhan 28 had 70.32 and 70.74 hulling % respectively and the lowest hulling (68.37%) recorded from G2. G1, G5, G6, G7, G9, G10, G11, G13 were also shown higher hulling % than both checks and G4 was statistically similar with both checks. Rest of the line showed different hulling %.

4.1.2.2. 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 outtturn of rice for different F6 lines of rice varied significantly (Figure 5). The maximum milling return (65.84%) was recorded from G3 which was statistically similar with check BRRI dhan 28 but higher than check BRRI dhan 29(62.75%) and

Table 11: Performance of Milling and Grain quality of F6 lines of Boro rice

Genotype	1000 seeds weight (gm)	Hulling (%)	Kernel length of rough rice	Kernel breadth of rough rice
G1	21.90 ± 0.44^{f}	70.95 ± 0.25^{de}	$8.48 \pm 0.04^{d\text{-}f}$	$2.61 \pm 0.05^{b\text{-}e}$
G2	21.63 ± 0.22^{f}	68.37 ± 0.79^{f}	$8.29 \pm 0.09^{e\text{-}g}$	$2.53 \pm 0.07^{c\text{-}g}$
G3	25.03 ± 0.27^{bc}	73.75 ± 0.15^{a}	8.97 ± 0.14^{bc}	2.70 ± 0.04^{bc}
G4	26.41 ± 0.69^{a}	70.73 ± 0.30^{e}	9.92 ± 0.29^{a}	$2.68 \pm 0.05^{b\text{-}d}$
G5	24.14 ± 0.35^{cd}	71.04 ± 0.70^{de}	$8.37 \pm 0.12^{d\text{-}f}$	2.95 ± 0.06^{a}
G6	23.60 ± 0.48^{de}	72.53 ± 0.37^{b}	7.72 ± 0.11^{h}	2.75 ± 0.17^{b}
G7	21.25 ± 0.12^{f}	$71.59 \pm 0.32^{b\text{-}e}$	$8.72 \pm 0.11^{c\text{-}e}$	2.36 ± 0.01^{g}
G8	22.44 ± 0.09^{ef}	67.97 ± 0.16^{f}	7.91 ± 0.13^{gh}	$2.56 \pm 0.02^{c\text{-}f}$
G9	23.86 ± 0.73^{cd}	$71.12 \pm 0.58^{c\text{-}e}$	9.13 ± 0.09^{bc}	$2.51 \pm 0.03^{d\text{-}g}$
G10	21.99 ± 0.21^{f}	$72.16 \pm 0.13^{b\text{-}d}$	8.28 ± 0.04^{fg}	2.72 ± 0.02^{bc}
G11	23.90 ± 0.29^{cd}	$71.36 \pm 0.38^{b\text{-}e}$	8.74 ± 0.26^{cd}	$2.59 \pm 0.03^{b\text{-}f}$
G12	$24.30 \pm 0.02^{b\text{-}d}$	70.23 ± 0.01^{e}	9.05 ± 0.08^{bc}	$2.60 \pm 0.02^{b\text{-}f}$
G13	25.47 ± 0.57^{ab}	72.41 ± 0.23^{bc}	9.28 ± 0.05^{b}	$2.51 \pm 0.05^{d\text{-}g}$
G14	21.40 ± 0.50^{f}	70.32 ± 0.68^{e}	$8.46 \pm 0.04^{d\text{-}f}$	2.42 ± 0.04^{fg}
G15	22.52 ± 0.16^{ef}	70.74 ± 0.13^{e}	9.04 ± 0.11^{bc}	$2.47 \pm 0.11^{e\text{-}g}$

The data represent the mean values ± standard error. Different letter (s) corresponds to significant differences at $p \leq 0.05$ by Duncan's Multiple Range Test (DMRT).

the lowest recorded from G8 (61.05%). G1, G4, G5, G6, G7, G9, G10, G11 and G13 also had higher hulling % than BRRI dhan 29 but lower than BRRI dhan 28.

4.1.2.3. Head rice recovery (%)

Head rice is the proportion of the whole grain in the milled rice. Head rice recovery (HRR) of rice for different F6 line of boro rice varied significantly (Figure 6). The maximum head rice recovery was recorded from G9 (61.63%) which was higher than checks, as their checks BRRI dhan 29(59.33%) and BRRI dhan 28(56.66%), while the lowest recorded from G3 (44.63%). G11 also had higher HRR% than checks. G5, G10, G12 and G13 had higher HRR% than BRRI dhan 28 but they were statistically similar with BRRI dhan 29 and G7 was statistically similar with BRRI dhan 28. For the commercial success of a rice variety it must possess high total milled rice and whole kernel (HRR) turnout. G11 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.

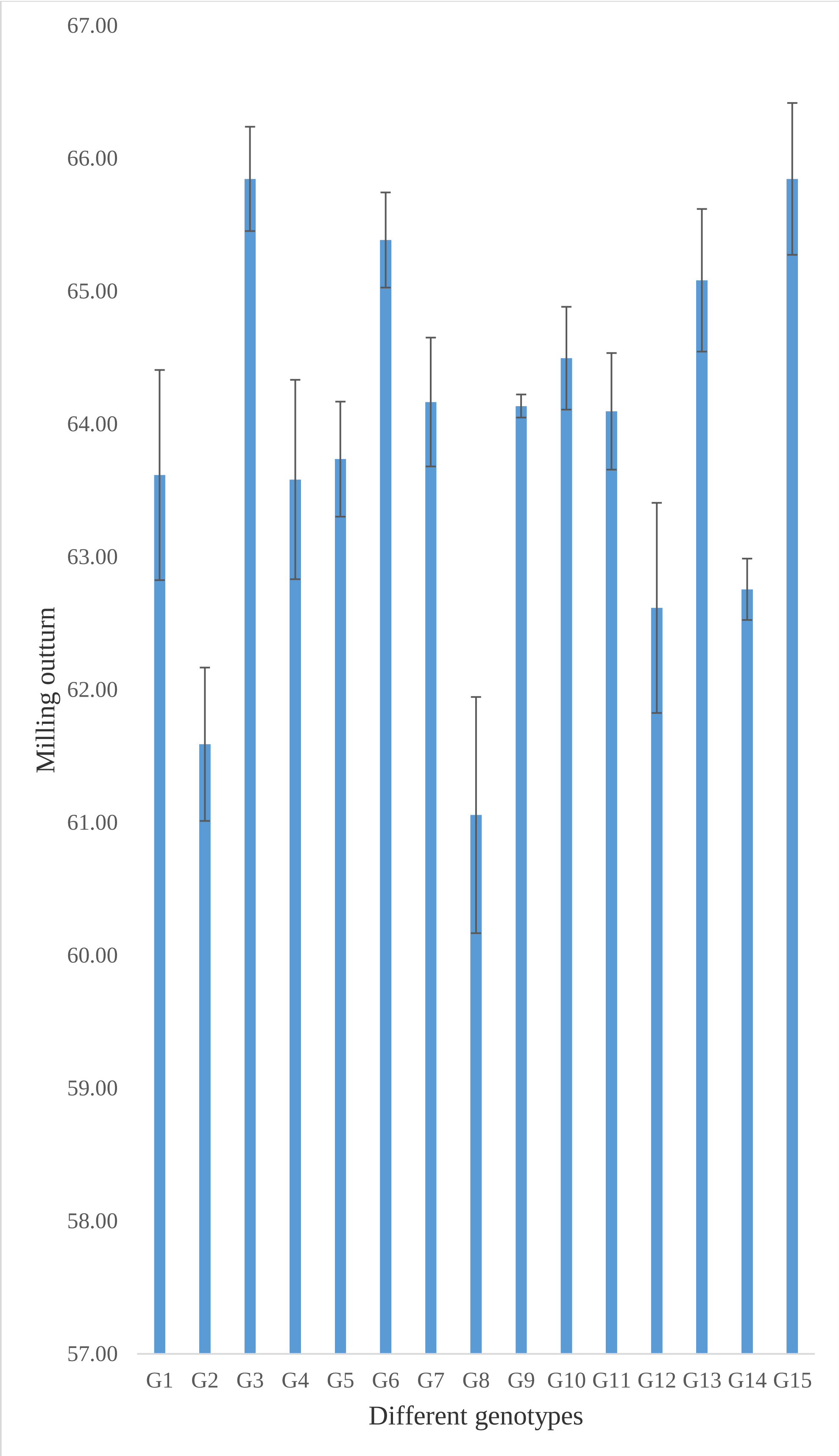


Fig. 5: Milling outturn on different F6 lines of Boro rice

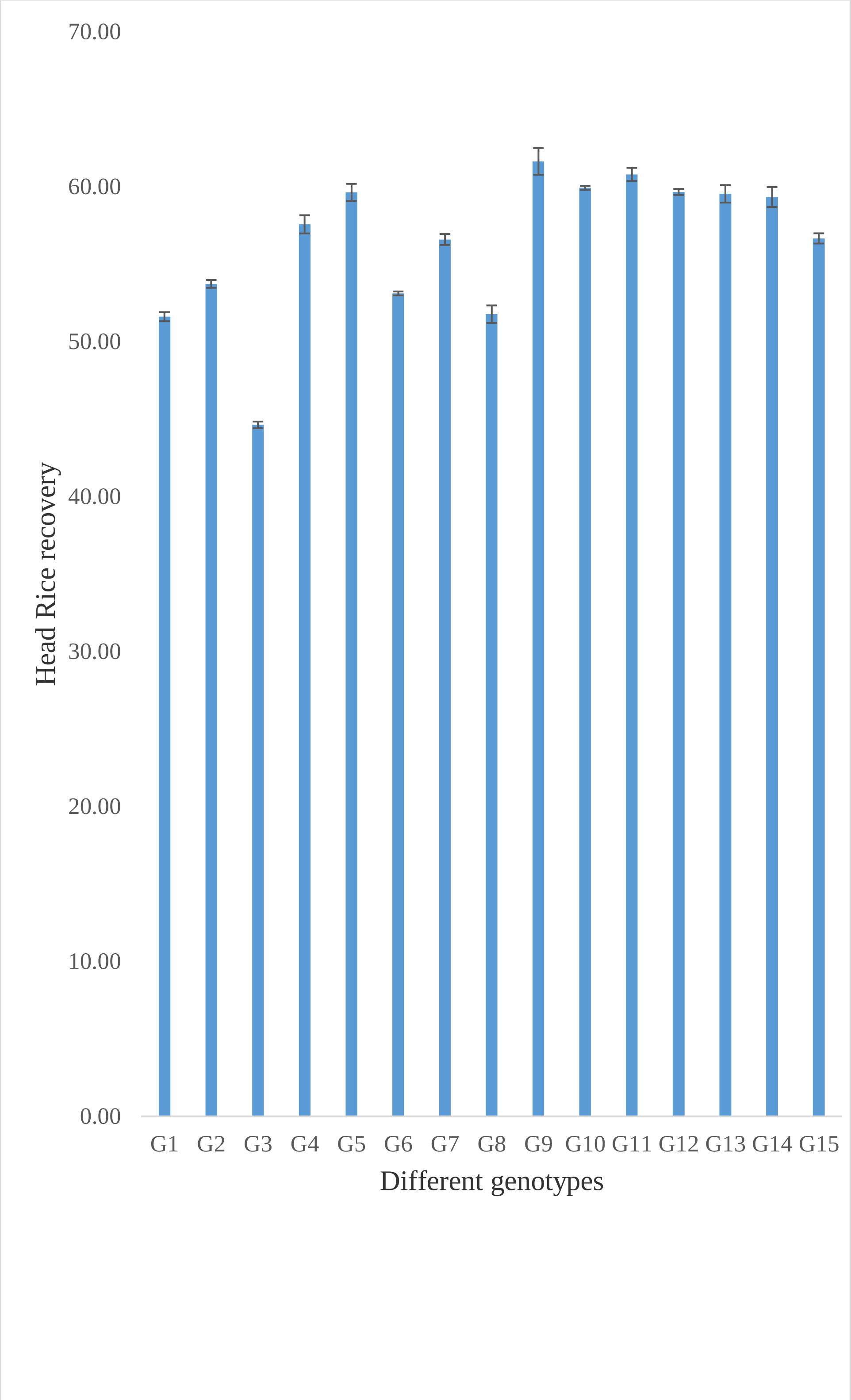
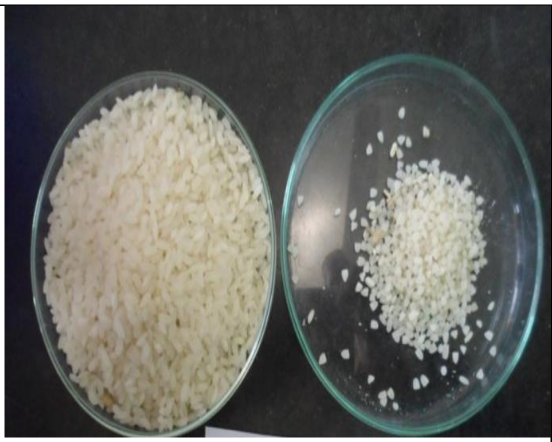


Fig. 6: Head rice recovery on F6 lines of Boro rice



G5

G3

G6

G9

G15

G14

Plate 7. Photograph showing variation in head rice recovery in different lines and comparison with their checks (BRRI dhan 29(G14) and BRRI dhan 28(G15))

4.1.2.4. Kernel length, breadth and length/breadth of rough rice

Kernel length breadth (Table 11)and their ratio (Table 12)of rough rice for different F6 lines of boro rice varied significantly . The longest rough rice was observed in G4(9.92 mm) , which was longer than both checks , as their checks BRRI dhan 29 (8.46 mm) and BRRI dhan 28 (9.04 mm) whereas the shortest rough length (5.84 mm) was found in G6(7.72). G9, G12 and G13 also were longer than checks.G3, G7 and G11 were longer than BRRI dhan 29 but shorter than BRRI dhan 28.G1 and G5 were statistically identical with BRRI dhan 29. The highest breadth of rough rice (2.95mm) was observed in G5, which was higher than both checks, as their checks BRRI dhan 29 and BRRI dhan 28 had 2.42mm and 2.47 mm respectively, whereas the lowest breadth (2.36 mm) was recorded in G7. Except G7 all lines showed higher breadth than checks. The highest (5.08) ratio of length and breadth of rough rice was recorded from G4 (3.70) which was higher than both checks BRRI dhan 29 and BRRI dhan 28 had 3.50 and 3.65 respectively and the lowest ratio (2.68) from G6. G7, G9 and G13 were statistically similar with BRRI dhan 28 and G11 and G12 was statistically similar with BRRI dhan 29.Rest populations showed different L/B ratio of rough rice (table 12).

4.1.2.5. Kernel length, breadth and length/breadth ratio of uncooked (milled) rice

Statistically significant variation was recorded for different F6 lines of boro rice and check in terms of length, breadth and ratio of milled rice (Table 12). The highest length of milled grain (7.13 mm) was observed in G4 (also had highest L/B ratio of rough rice) which was higher than their checks,as their checks BRRI dhan 29 and BRRI dhan 28 had 6.46mm and 6.72mm respectively. The lowest length (5.47 mm) was found in G6. Statistically similar G9, G12 with BRRI dhan 28 and G3, G7, G11 with BRRI dhan 28. The highest breadth of milled grain (2.47 mm) was observed in G6 which was statistically identical with G5(2.45mm), while the lowest breadth (2.06 mm) was recorded in BRRI dhan 29 (check varity). Another check BRRI dhan 28

Table 12: Performance of Milling and Grain quality of F6 lines of Boro rice

Genotype	Kernel Length, breadth ratio of rough rice	Kernel length of uncooked rice	Kernel breadth of uncooked rice	Kernel Length, breadth ratio of uncooked rice
G1	3.25 ± 0.05^{cd}	6.22 ± 0.01^{de}	$2.25 \pm 0.01^{a-d}$	$2.72 \pm 0.06^{e-g}$
G2	3.22 ± 0.04^{cd}	6.22 ± 0.10^{de}	$2.10 \pm 0.16^{b-d}$	$2.74 \pm 0.04^{e-g}$
G3	3.31 ± 0.02^{cd}	6.48 ± 0.04^{cd}	$2.34 \pm 0.02^{a-c}$	2.77 ± 0.04^{df}
G4	3.70 ± 0.05^{a}	7.13 ± 0.15^{a}	$2.22 \pm 0.02^{a-d}$	$3.21 \pm 0.05^{a-c}$
G5	2.86 ± 0.04^{ef}	6.02 ± 0.14^{ef}	2.45 ± 0.06^{a}	2.45 ± 0.01^{gh}
G6	2.68 ± 0.06^{f}	5.47 ± 0.02^{g}	2.47 ± 0.02^{a}	2.21 ± 0.03^{h}
G7	3.63 ± 0.10^{ab}	6.47 ± 0.01^{cd}	$2.13 \pm 0.06^{b-d}$	$3.04 \pm 0.08^{b-d}$
G8	2.88 ± 0.23^{ef}	5.79 ± 0.01^{fg}	2.37 ± 0.01^{ab}	2.45 ± 0.02^{gh}
G9	3.64 ± 0.08^{ab}	6.63 ± 0.03^{bc}	$2.15 \pm 0.02^{b-d}$	$3.14 \pm 0.03^{a-c}$
G10	3.05 ± 0.02^{de}	6.19 ± 0.01^{de}	$2.26 \pm 0.01^{a-d}$	2.54 ± 0.17^{fg}
G11	3.37 ± 0.06^{bc}	6.41 ± 0.24^{cd}	$2.33 \pm 0.03^{a-c}$	$2.73 \pm 0.05^{e-g}$
G12	$3.49 \pm 0.06^{a-c}$	6.61 ± 0.13^{bc}	$2.25 \pm 0.01^{a-d}$	$2.93 \pm 0.07^{c-e}$
G13	3.60 ± 0.16^{ab}	6.89 ± 0.12^{ab}	2.08 ± 0.02^{cd}	3.31 ± 0.09^{ab}
G14	$3.50 \pm 0.03^{a-c}$	6.46 ± 0.16^{cd}	2.06 ± 0.23^{d}	$2.93 \pm 0.05^{c-e}$
G15	3.65 ± 0.02^{ab}	6.72 ± 0.12^{bc}	$2.15 \pm 0.02^{b-d}$	3.33 ± 0.23^{a}

The data represent the mean values ± standard error. Different letter (s) corresponds to significant differences at $p \leq 0.05$ by Duncan's Multiple Range Test (DMRT).

had 2.15mm which was statistically similar with G2, G7 and G9. G1, G3, G4, G5, G8, G10, G11 and G12 showed higher breadth than checks. The highest ratio of length and breadth of brown rice was recorded from BRRI dhan 28 (3.33) and the lowest ratio from G6 (2.21). G7, G9 and G13 showed higher ratio than BRRI dhan 29 but lower than BRRI dhan 28. G12 was statistically similar with BRRI dhan 29.

4.1.2.6. 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).

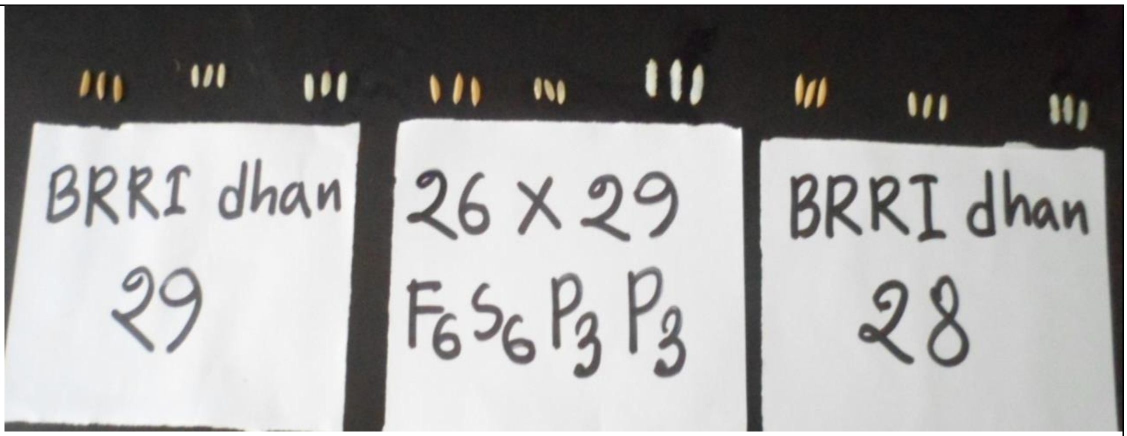
Table 13: Classification of grain types of 13 F6 lines and 2 check varieties on the basis of systematic classification of rice proposed by Ramaiah Committee (1965).

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)**
-	-	G1	-	-
-	-	G2	-	-
-	-	G3	-	-
G4	-	-	-	-
-	-	-	G5	-
-	-	-	-	G6
G7	-	-	-	-
-	-	-	-	G8
G9	-	-	-	-
-	-	G10	-	-
-	-	G11	-	-
-	-	G12	-	-
G13	-	-	-	-
-	-	G14(BRRI dhan 29)	-	-
G15(BRRI dhan 28)	-		-	-

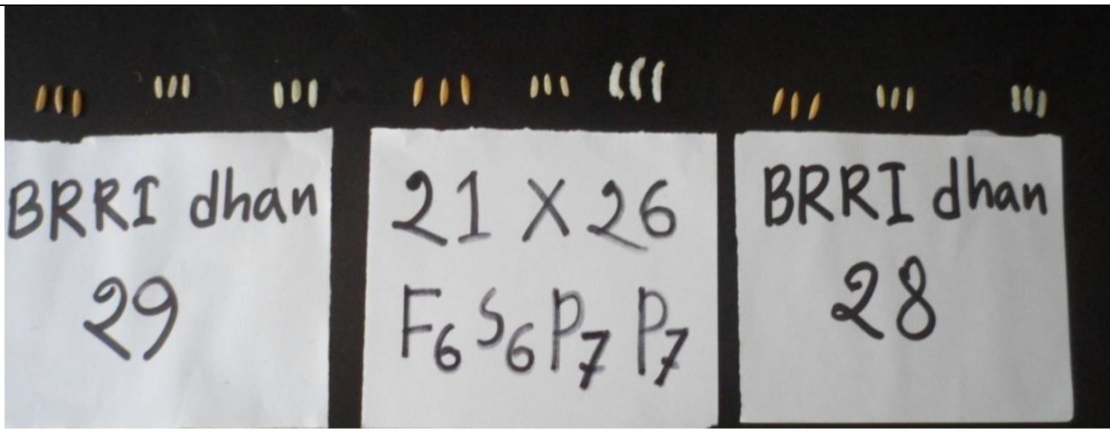
4.1.3. Determination of cooking and eating characteristics of the grain

4.1.3.1. Kernel length, breadth and ratio of cooked rice

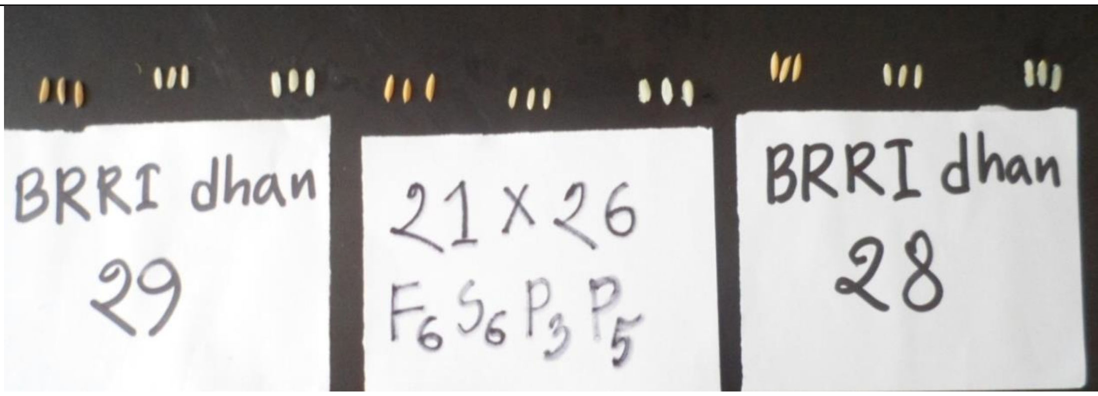
Kernel length, breadth and their ratio of cooked rice for different F6 lines varied significantly (Table 14). The longest kernel of cooked rice (11.05 mm) was recorded from G1 which was statistically similar with G10(10.70) and the shortest (7.27 mm) from G6 which was statistically similar with G2 (7.55mm), G12 (7.54mm) and BRRI dhan 29 (7.36mm) .G3, G4, G5, G7, G8, G11 and G13 showed higher length than both checks, as their checks BRRI dhan 29 (7.36mm) and BRRI dhan 28 (7.77 mm) which was similar to G9. 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 G 10(3.74mm) and lowest breadth was recorded from G12 (2.41mm). Expect G12 all lines showed higher breadth than checked as their checks BRRI dhan 29(2.57mm) and BRRI dhan 28(2.56mm). The highest ratio of kernel length and breadth (3.50) was recorded from G1 and the lowest ratio (2.09) from G6, as their checks BRRI dhan 29 and BRRI dhan 28 had 2.85 and 3.04 respectively.G12 also showed higher ratio than checked; G4, G9 and G10 were similar to BRRI dhan 29 and G3, G5, G7, G8 and G11 were showed moderate ratio.Plate 8 showing variation in rough rice, uncooked rice and cooked rice.



G14 G10 G15



G14 G1 G15



G14 G2 G15

Plate 8. Photograph showing variation in rough rice, uncooked rice and cooked rice in different lines and comparison with their checks (BRRI dhan 29(G14) and BRRI dhan 28(G15))

Table 14: Performance of Grain quality of F6 lines of Boro rice

Genotype	Kernel length of cooked rice	Kernel breadth of cooked rice	Kernel Length, breadth ratio of cooked rice	Kernel elongation ratio
G1	11.05 ± 0.02^{a}	3.18 ± 0.03^{bc}	3.50 ± 0.03^{a}	1.77 ± 0.01^{a}
G2	7.55 ± 0.01^{f}	3.23 ± 0.07^{bc}	2.35 ± 0.05^{ef}	1.21 ± 0.02^{fg}
G3	$9.07 \pm 0.03^{b-d}$	$3.38 \pm 0.09^{a-c}$	2.67 ± 0.07^{de}	$1.40 \pm 0.01^{c-e}$
G4	9.53 ± 0.01^{bc}	$3.31 \pm 0.08^{a-c}$	$2.94 \pm 0.07^{b-d}$	$1.33 \pm 0.02^{c-f}$
G5	9.74 ± 0.10^{b}	3.65 ± 0.11^{ab}	2.68 ± 0.04^{de}	1.62 ± 0.05^{b}
G6	7.27 ± 0.06^{f}	$3.29 \pm 0.04^{a-c}$	2.09 ± 0.17^{f}	$1.32 \pm 0.01^{d-f}$
G7	8.75 ± 0.09^{cd}	3.18 ± 0.03^{bc}	2.75 ± 0.01^{cd}	$1.35 \pm 0.01^{c-e}$
G8	8.54 ± 0.68^{de}	3.12 ± 0.12^{c}	2.78 ± 0.32^{cd}	1.47 ± 0.11^{c}
G9	7.65 ± 0.02^{ef}	2.65 ± 0.02^{d}	$2.89 \pm 0.03^{b-d}$	1.15 ± 0.01^{g}
G10	10.70 ± 0.17^{a}	3.74 ± 0.3^{a}	$2.89 \pm 0.02^{b-d}$	1.74 ± 0.01^{a}
G11	$9.24 \pm 0.93^{b-d}$	$3.40 \pm 0.18^{a-c}$	2.72 ± 0.13^{cd}	1.43 ± 0.09^{cd}
G12	7.54 ± 0.03^{f}	2.41 ± 0.01^{d}	3.14 ± 0.02^{b}	1.14 ± 0.01^{g}
G13	8.75 ± 0.05^{cd}	3.21 ± 0.52^{bc}	2.36 ± 0.02^{ef}	$1.26 \pm 0.01^{e-g}$
G14	7.36 ± 0.04^{f}	2.57 ± 0.02^{d}	$2.85 \pm 0.01^{b-d}$	1.13 ± 0.02^{g}
G15	7.77 ± 0.02^{ef}	2.56 ± 0.01^{d}	3.04 ± 0.02^{bc}	1.15 ± 0.02^{g}

The data represent the mean values ± standard error. Different letter (s) corresponds to significant differences at $p \leq 0.05$ by Duncan's Multiple Range Test (DMRT).

4.1.3.2. Kernel elongation ratio

Kernel elongation ratio for different F6 lines of rice varied significantly (Table 14). The highest kernel elongation ratio (1.77) was recorded from G1 which was statistically similar with G10 (1.74) and the lowest ratio (1.13) recorded from BRRI dhan 29 which was statistically similar with G9 (1.15), G12 (1.14) and BRRI dhan 28(1.15). The maximum lines showed higher ratio than checked. Elongation ratio (L1 /L0) 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 (L1/Lo) which indicates length wise elongation will be a better measure of cooking quality than elongation index which indicates both length and breadth wise elongation.

4.1.3.3. Kernel elongation index

Kernel elongation index for different F6 lines of rice varied significantly (Table 14). The highest kernel elongation index (1.28) was recorded from G1 and the lowest ratio (0.85) recorded from G2. Two checks BRRI dhan 29 and BRRI dhan 28 had 0.97 and 0.89 respectively.G5, G8 and G12 were showed higher elongation index like G1.Rest of the populations showed different elongation index.

4.1.3.4. Volume expansion (%)

Volume expansion of kernels on cooking is considered another important measure of consumer preference. Volume expansion for different new F6 lines of boro rice varied significantly (Table 14). The maximum volume expansion (83.50 %) was recorded from G7 and the minimum (16.35 %) recorded from G13 and two checks BRRI dhan 29 and BRRI dhan 28 had 20.07% and 20.93%

Table 15: Performance of Grain quality of F6 lines of Boro rice

Genotype	Kernel elongation Index	Volume expansion (%)	Water Absorption (%)
G1	1.28 ±0.02 ^{a}	40.54 ± 0.57^{e}	315.81 ± 34.02^{b}
G2	0.85 ± 0.03^{ef}	29.62 ± 0.25^{h}	230.87 ± 3.25^{cd}
G3	0.96 ± 0.01^{c-e}	28.31 ± 0.21^{i}	243.33 ± 19.15^{c}
G4	0.91 ± 0.03^{de}	34.68 ± 0.05^{f}	171.33 ± 3.55^{ef}
G5	1.09 ± 0.02^{b-d}	54.01 ± 0.08^{d}	353.75 ± 0.91^{b}
G6	0.94 ± 0.08^{c-e}	55.63 ± 0.32^{c}	223.50 ± 1.45^{cd}
G7	0.90 ± 0.03^{de}	83.50 ± 0.28^{a}	470.33 ± 32.13^{a}
G8	1.13 ± 0.12^{a-c}	33.78 ± 0.51^{g}	188.68 ± 2.40^{de}
G9	0.91 ± 0.01^{de}	16.84 ± 0.10^{l}	155.79 ± 6.02^{f}
G10	1.21 ± 0.08^{ab}	57.66 ± 0.38^{b}	321.00 ± 9.81^{b}
G11	0.99 ± 0.03^{c-e}	20.91 ± 0.05^{j}	140.11 ± 2.80^{f}
G12	1.18 ± 0.11^{ab}	20.81 ± 0.11^{jk}	167.66 ± 10.96^{ef}
G13	0.72 ± 0.03^{f}	16.35 ± 0.21^{l}	253.49 ± 7.26^{c}
G14	0.97 ± 0.02^{c-e}	20.07 ± 0.04^{k}	179.84 ± 4.68 ^{ef}
G15	0.89 ± 0.05^{e}	20.93 ± 0.06^{j}	155.99 ± 3.54^{ef}

The data represent the mean values ± standard error. Different letter (s) corresponds to significant differences at $p \leq 0.05$ by Duncan's Multiple Range Test (DMRT).

respectively. 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.

4.1.3.5. Water absorption (%)

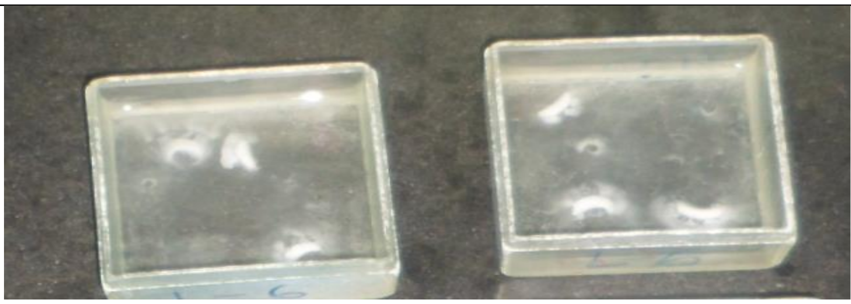
Water absorption for different F6 lines of rice varied significantly (Table 14). The highest water absorption (470.33 %) was recorded from G7 and the lowest (140.11 %) was recorded from G11. The two checks BRRI dhan 29 and BRRI dhan 28 had 179.84% and 155.99%.G4, G9, G12 were similar to BRRI dhan 28. Rest of the populations showed different water absorption%. Low water absorption is more desirable for suitable line selection.

4.1.3.6. Alkali spreading value (ASV)

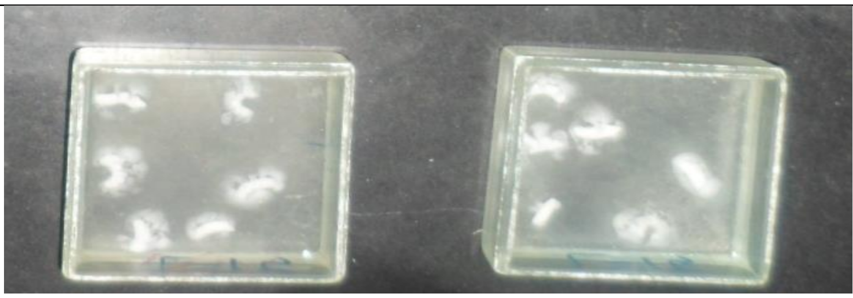
The gelatinization temperature (GT) is considered to be yet another major index of cooking quality of rice. The time required for cooking is determined by the gelatinization temperature. Alkali spreading value is inversely related to gelatinization temperature (Table 15). It is the range of temperature 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 F6 line of rice (Table 16). The highest alkaline spreading value (7.03) was recorded from

G1

G8



G15



G14

Plate 9. Photograph showing variation in alkali spreading value (GT) in different lines and comparison with their checks(BRRI dhan 29(G14) and BRRI dhan 28(G15))

Table 16: Classification of 13 lines and 2 check varieties on the basis of alkali spreading score, alkali spreading value and GT types

Sl. No.	Lines/check	Alkali spreading value	Alkali digestion	GT types
1.	G1	7.03	High	Low
2.	G2	7.00	High	Low
3.	G3	7.03	High	Low
4.	G4	5.06	Intermediate	Intermediate
5	G5	5.33	Intermediate	Intermediate
6	G6	7.03	High	Low
7	G7	5.13	Intermediate	Intermediate
8	G8	5.93	Intermediate	Intermediate
9	G9	4.83	Intermediate	Intermediate
10	G10	7.00	High	Low
11	G11	5.00	Intermediate	Intermediate
12	G12	4.63	Intermediate	Intermediate
13	G13	5.13	Intermediate	Intermediate
14	G14	3.33	Low or Intermediate	High or Intermediate
15	G15	4.93	Intermediate	Intermediate

G1,G3 and G6 which were statistically similar to G2(7.00) and G10(7.00) and the lowest (3.33) was recorded from BRRI dhan 29 ,these was one check and another check was BRRI dhan 28(4.93) which was statistically similar with G7,G9,G11,G12 and G13.comparative view of alkali spreading value of 15 F6 lines is presented in Table 16. Plate 9 showing variation in alkali spreading value in different lines.

4.1.3.7. Protein (%)

Protein content of rice is important from nutritional point of view. Protein content of the varieties ranges from 7.03 to 9.53%. Protein% for different F6 lines of rice varied significantly (Figure 7). The highest protein (9.63%) was recorded from G4 which was statistically similar with G1 (9.53%) and the lowest (7.03%) recorded from BRRI dhan 29 which was statistically similar with G6 (7.13%) and G9 (7.20%). The two checks BRRI dhan 29 had 7.03% (All were showed higher protein% than BRRI dhan 29) and BRRI dhan 28 had 8.50% which was statistically similar with G2 (8.60%).G5 and G8 also had higher protein % and G3, G7, G10, G11 had moderate protein. Several factors such as variety, environment and cultural practices might influence on the protein content of the grain (Gomez 1979).

4.1.3.8. Amylose (%)

Amylose content of the different F6 lines varied significantly and ranges from 23.53 to 27.5% (Figure 8). The highest amylose (27.5%) was estimated in BRRI dhan 29 and the lowest (23.53%) were in G10 which was statistically similar with G4 (24%). The two checks BRRI dhan 29 and BRRI dhan 28 had 27.50% and 26.80% respectively.

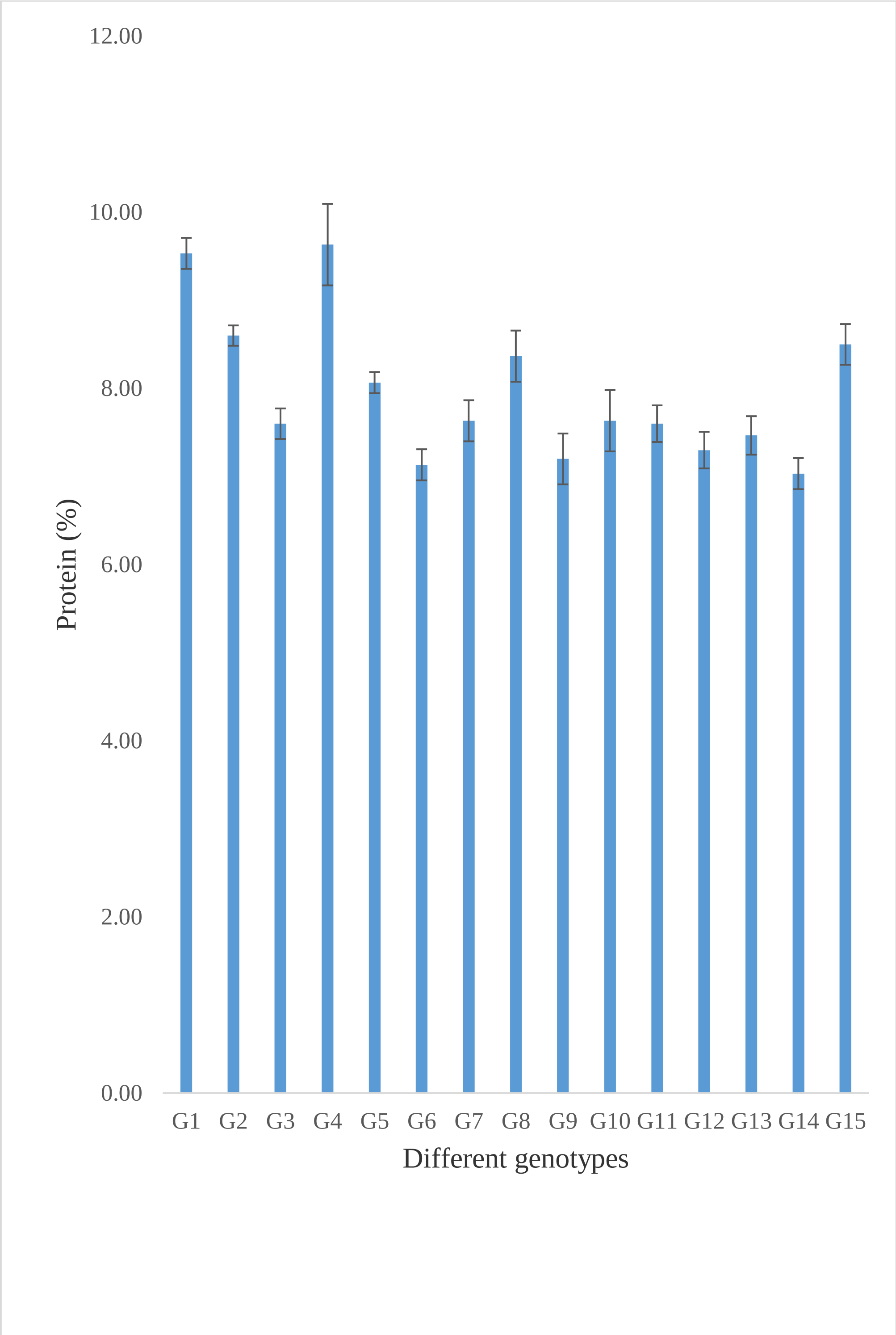


Fig.7: Protein (%) content on different F6 lines of Boro rice

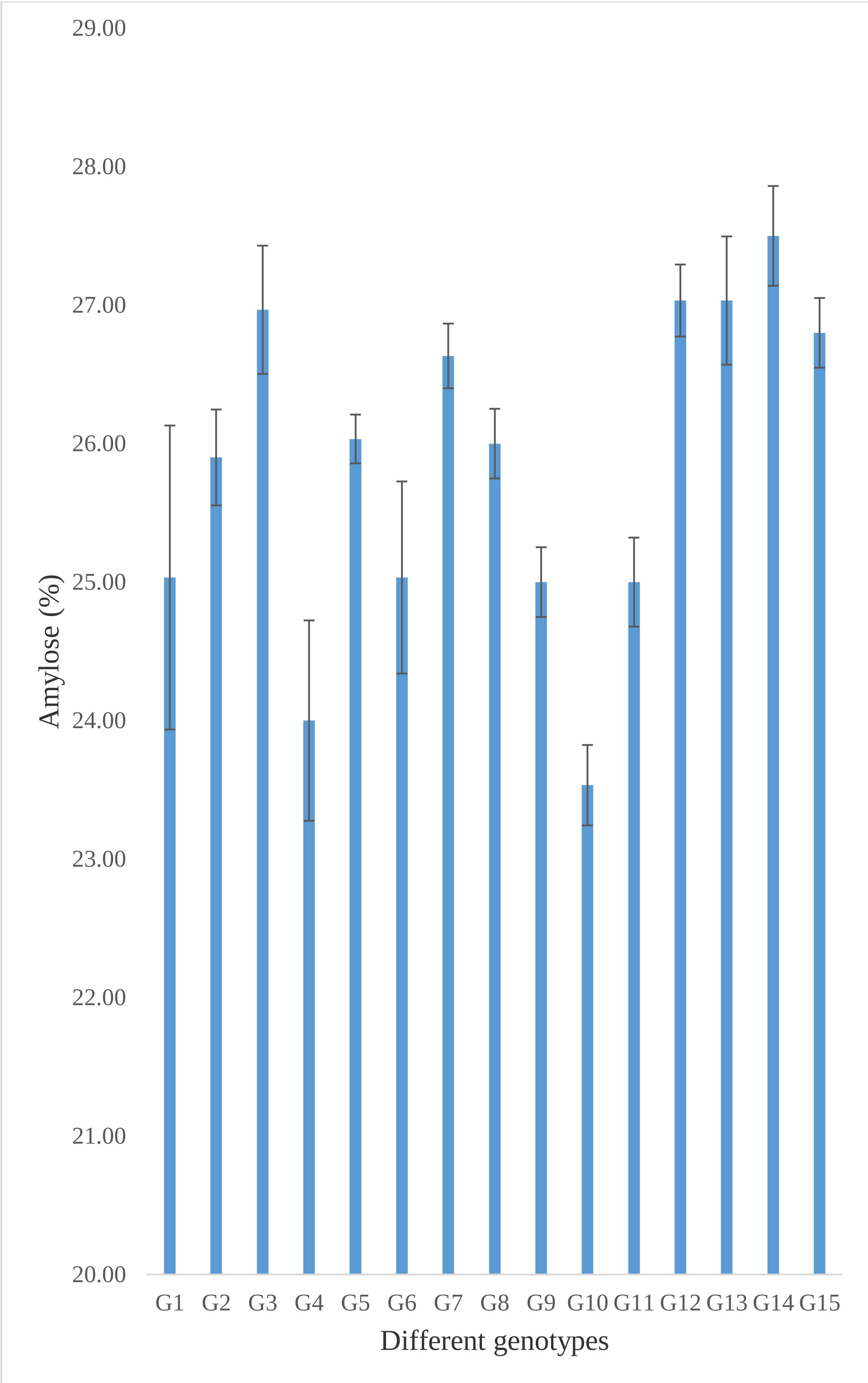


Fig.8: Amylose (%) content on different F6 lines of Boro rice

Table 17: Classification of 13 F6 lines and two check varieties 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)
-	-	-	-	G1
-	-	-	-	G2
-	-	-	-	G3
-	-	-	G4	-
-	-	-	-	G5
-	-	-	-	G6
-	-	-	-	G7
-	-	-	-	G8
-	-	-	-	G9
-	-	-	G10	-
-	-	-	-	G11
-	-	-	-	G12
-	-	-	-	G13
-	-	-	-	G14
-	-	-	-	G15

Amylose content of rice determines the hardness and stickiness of cooked rice. Amylose content higher than 25% gives non sticky soft or hard 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.

CHAPTER V

SUMMARY AND CONCLUSION

Bangladesh has made significant improvement in agriculture sector but the chronic food deficiency has persisted unabated for many years. The growth of population in our country is much faster than rice production. It is not possible to increase the production of rice horizontally due to lack of land. So we can improve the production of rice by cultivation of high yielding variety. Bangladeshi farmers will also prefer to cultivate boro rice to get more returns if we can make available suitable varieties adapted to our agro- climatic zone. However characterization and comparative study of boro rice will be the beginning and a step towards these perspectives.

The study was attempted to identify short duration and high yielding rice genotypes amongst 13 F6 lines of Boro rice by comparing with 2 check varieties. Keeping in view this idea, the performance of studied genotypes, association among various morpho-physiological, yield contributing and quality contributing traits among the genotypes were evaluated under the field condition and lab condition. The experiments were carried out at the Sher-e-Bangla Agricultural University Farm, Bangladesh during December, 2014-May, 2015. Seedlings were transplanted in the main field in Randomized Complete Block Design (RCBD) with three replications. The results of the studies have been summarized as follows:

The performance of 13 F6 lines of Boro rice (comprising of 13 F6 lines and 2 check varieties) for different yield contributing and quality contributing traits were evaluated. Considering the traits days to 50% flowering and days to maturity the genotype G11 (BRRI dhan 28 x BRRI dhan 29 F6 S2 P4 P3G9) was earliest which was followed by the genotype G15 (BRRI dhan 28). Plant height exhibited highest in G4 (BR 21 x BRRI dhan 28 F6S5P3P4), which showed lower yield than checks and lowest height in G14 (BRRI dhan 29) which was check. G2 (BR 21 x BR 26 F6S6P3P5) showed the maximum number of total tillers per plant, which was similar to G12 (17.40) and check BRRI dhan 28(17.67) and the minimum one was recorded from G4 (BR 21 x BRRI dhan 28 F6S5P3P4). The highest number of effective tillers per plant was recorded in G12 (BRRI dhan 28 X BRRI dhan 36 F6 S7 P8 P5), which showed higher yield per plant than check varieties and the minimum number of effective tillers per plant was recorded in G4 (BR 21 x BRRI dhan 28 F6 S5 P3 P4). The highest panicle length was observed in G4 (BR 21 x BRRI dhan 28 F6S5P3P4) and the minimum panicle length was observed in G6 (BR 21 x BRRI dhan 29 F6S6P2P3). Highest number of primary branches per panicle was recorded for G4 (BR 21× BRRI dhan 28 F6 S5 P3 P4) while the minimum number of primary branches per panicle was recorded for G2 (BR 21× BR 26 F6 S6 P3 P5). The highest number of secondary branches per panicle was recorded in G5 (BR 21 x BRRI dhan 29 F6S6P6P1)) which showed highest yield per plant and the minimum number of secondary branches per panicle was observed in G2 (BR 21× BR 26 F6 S6 P3 P5). The total number of spikelet per panicle was maximum in G7 (BR 24 × BR 26 F6 S6 P4 P8) and minimum was observed in G1 (BR 21 x BR 26 F6 S6 P7 P7). The number of filled grains per panicle was recorded highest in G7 (BR 24 × BR 26 F6 S6 P4 P8) and minimum was recorded in G1 (BR 21 x BR 26 F6 S6 P7 P7). The G1 (BR 21 x BR 26 F6 S6 P7 P7) showed the highest number of unfilled grains per panicle and the G15 (BRRI dhan 28) showed the minimum number of unfilled grains per panicle. Yield per plant was recorded highest in G5 (BR 21× BRRI dhan 28 F6 S6 P6 P1) and the lowest was found in G1 (BR 21 x BR 26 F6 S6 P7 P7). Thousand seed weight was found maximum in G4 (BR 21× BRRI dhan 28 F6 S5 P3 P4) where as the minimum thousand seed weight was found in G1 (BR 21 x BR 26 F6 S6 P7 P7).

In the experiment G4 (BR 21 x BRRI dhan 28 F6 S5 P3 P4) showed maximum length (9.92 mm), G5 (BR 21 x BRRI dhan 29 F6S6P6P1) showed maximum breadth (2.95 mm) and G4 (BR 21 x BRRI dhan 28 F6 S5 P3 P4) showed maximum L/B ratio (5.08 mm) of rough rice. For uncooked rice maximum length (7.13 mm), breadth (2.47 mm) and L/B ratio (3.33 mm) showed by G4 (BR 21 x BRRI dhan 28 F6 S5 P3 P4) , G6(BR 21x BRRI dhan 29 F6 S6 P2 P3) and G15(BRRI dhan 28) respectively. For cooked rice maximum length (11.05 mm) showed by G1 (BR 21 x BR 26 F6 S6 P7 P7) which was was statistically similar with G10 (10.70), maximum breadth (3.74) showed by G10 (BR26 x BRRI dhan 29 F6 S6 P3 P3) and L/B ratio (3.50 mm) showed by G1 (BR 21 x BR 26 F6 S6 P7 P7) and G1 had maximum alkaline spreading value. The maximum milling percent (65.84%), hulling percent (73.75%) and were found from G3 (BR 21 x BRRI dhan 28 F6 S5 P1 P2). The maximum head rice recovery percent (61.63%) was found from G9 (BR 26 x BRRI dhan 28 F6 S1 P9 P5) .The maximum volume expansion percent (83.50%) and water absorption percent (470.33%) were found from G7 (BR 24 x BR 26 F6 S6 P4 P8). The highest alkaline spreading value (7.03) was recorded from G1 (BR 21 x BR 26 F6 S6 P7 P7) ,G3(BR 21 x BRRI dhan 28 F6 S5 P1 P2) and G6(BR 21 x BBBI dhan 29 F6S6P6P1).The maximum kernel elongation ratio (1.77)and kernel elongation(1.28) were found from G1(BR 21 x BR 26 F6 S6 P7 P7) which also showed maximum length and L/B ratio of cooked rice. The maximum protein percent(9.63) was found from G4(BR 21 x BRRI dhan 28 F6 S5 P3 P4) which yield was statistically similar with BRRI dhan 29.The maximum amylase percent(27.5%) was found from G14(BRRI dhan 29).

Analysis of variance revealed highly significant variation present among the 13 F6 lines for all the characters studied. Existing of significant level of variation present in the materials indicate the possibility of improving the yield potential. Wide range of mean values for different characters showed presence of wide variability in the experiment. Among these 13 F6 lines, G11 (BRRI dhan 28 x BRRI dhan 29 F6 S2 P4 P3) and G5 (BR 21 x BRRI dhan 29 F6 S6 P6 P1)exhibited best performance. G11 was shown most earliest maturity, higher total spikelet than check varieties, higher filled grains, third highest yield per plant which was higher than check varieties and had higher hulling%, milling outturn and higher HRR%, lowest water absorption%, GT types intermediate, moderate protein% and had high amylase content. And G5 was shown moderate maturity, higher number of primary branches, highest number of secondary branches, had maximum yield per plant and also had high amylase content.

CHAPTER VI

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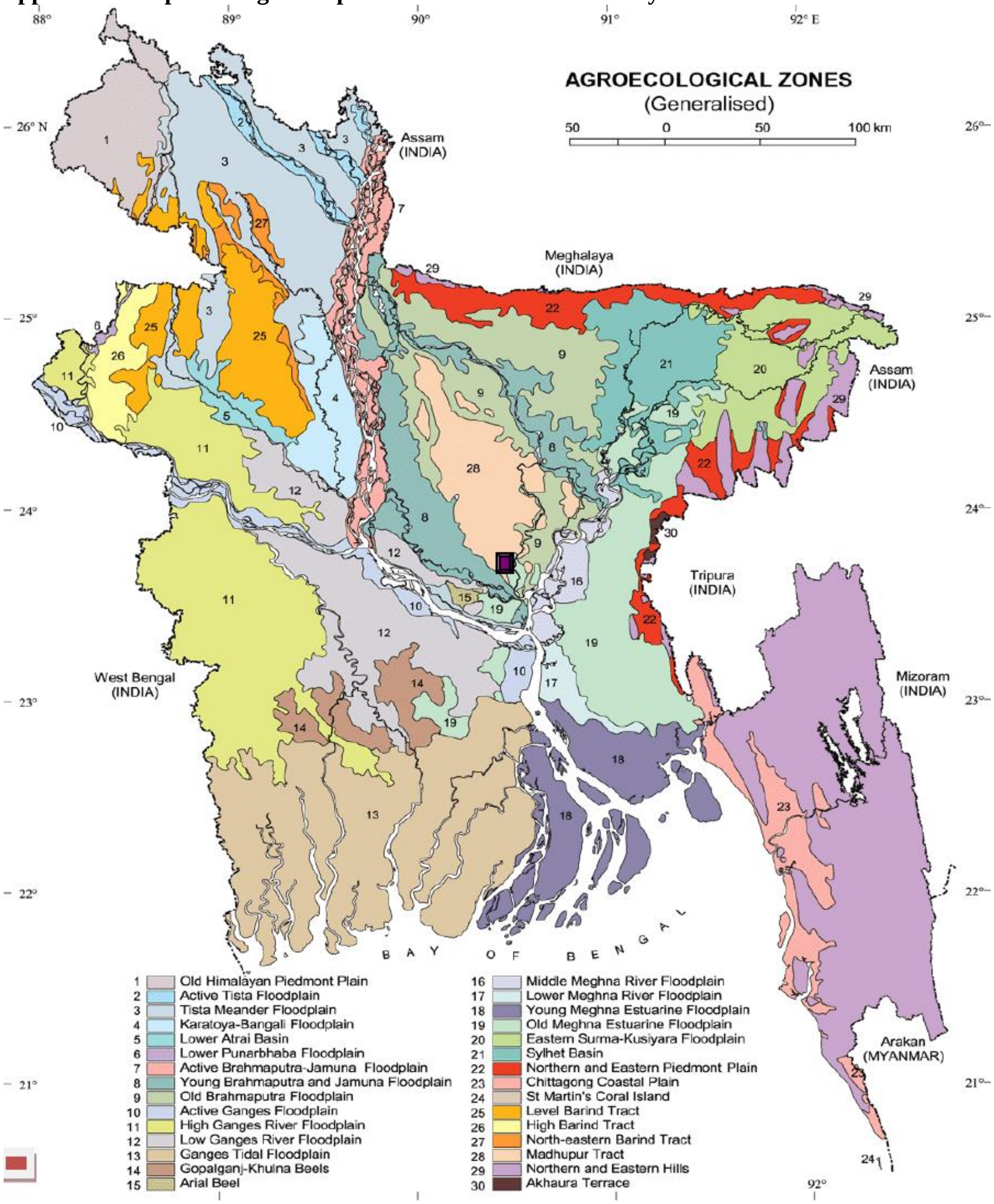
APPENDICES

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	**Horticultural 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	D0
Texture class	Clay loam	Do

C. Chemical composition of the soil

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

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

Appendix III. Monthly average Temperature, Relative Humidity and Total Rainfall and sunshine of the experimental site during the period from November, 2014 to May, 2015

Month	Air temperature (ºc)		Relative humidity (%)	Rainfall (mm) (total)
Minimum	Maximum			
November, 2013	28.10	6.88	58.18	**1.56**
December, 2013	25.36	5.21	54.30	**0.63**
January, 2014	21.17	15.46	64.02	**0.00**
February, 2014	24.30	19.12	53.07	**2.34**
March, 2014	29.78	22.37	48.66	**0.12**
April, 2014	29.80	23.40	47.76	5.90

Appendix IV: Analysis of variance of the data on yield performance of different F6 lines of Boro rice.

Treatments	Sum of Squares		Degrees of freedom (df)	Mean Square	F-value	Significance level
Days to 50% flowering	Between Groups	446.578	14	31.898	44.857	.000
	Within Groups	21.333	30	.711		
	Total	467.911	44			
Days of maturity (days)	Between Groups	953.911	14	68.137	15.179	.000
	Within Groups	134.667	30	4.489		
	Total	1088.578	44			
Plant height (cm)	Between Groups	6082.917	14	434.494	31.977	.000
	Within Groups	407.625	30	13.587		
	Total	6490.542	44			
Number of total tillers/Plant	Between Groups	127.259	14	9.090	9.783	.000
	Within Groups	27.873	30	.929		
	Total	155.132	44			
Number of effective tillers/Plant	Between Groups	123.678	14	8.834	7.891	.000
	Within Groups	33.587	30	1.120		
	Total	157.264	44			
Panicle length (cm)	Between Groups	95.439	14	6.817	21.241	.000
	Within Groups	9.628	30	.321		
	Total	105.067	44			

Appendix V: Analysis of variance of the data on yield performance of different F6 lines of Boro rice.

Treatments	Sum of Squares		Degrees of freedom (df)	Mean Square	F-value	Significance level
Number of primary Branches/Panicle	Between Groups	76.487	14	5.463	31.929	.000
	Within Groups	5.133	30	.171		
	Total	81.620	44			
Number of secondary Branches/Panicle	Between Groups	615.911	14	43.994	10.199	.000
	Within Groups	129.400	30	4.313		
	Total	745.311	44			
Total spiklet/plant	Between Groups	13673.170	14	976.655	8.642	.000
	Within Groups	3390.433	30	113.014		
	Total	17063.603	44			
Number of filled grain/plant	Between Groups	37363.879	14	2668.849	19.428	.000
	Within Groups	4121.160	30	137.372		
	Total	41485.039	44			
Number of unfilled grain/plant	Between Groups	16834.450	14	1202.461	45.325	.000
	Within Groups	795.893	30	26.530		
	Total	17630.343	44			
Yield per plant (gm)	Between Groups	3714.988	14	265.356	21.463	.000
	Within Groups	370.900	30	12.363		
	Total	4085.888	44			
Thousand seed weight (gm)	Between Groups	2987.319	14	213.380	22.597	.000
	Within Groups	283.280	30	9.443		
	Total	3270.599	44			

Appendix VI: Analysis of variance of the data on milling and grain appearance of different F6 lines of Boro rice.

Treatments	Sum of Squares		Degrees of freedom (df)	Mean Square	F-value	Significance level
Hulling (%)	Between Groups	106.315	14	7.594	15.569	.000
	Within Groups	14.633	30	.488		
	Total	120.948	44			
Milling (%)	Between Groups	3.782	14	.270	21.009	.000
	Within Groups	.386	30	.013		
	Total	4.167	44			
Head Rice Recovery	Between Groups	13.369	14	.955	17.538	.000
	Within Groups	1.633	30	.054		
	Total	15.002	44			
Length of rough rice	Between Groups	.913	14	.065	6.985	.000
	Within Groups	.280	30	.009		
	Total	1.194	44			
Breadth of rough rice	Between Groups	4.482	14	.320	13.683	.000
	Within Groups	.702	30	.023		
	Total	5.184	44			

Appendix VII: Analysis of variance of the data on milling and grain appearance of different F6 lines of Boro rice.

Treatments	Sum of Squares		Degrees of freedom (df)	Mean Square	F-value	Significance level
L/B ratio of rough rice	Between Groups	7.390	14	.528	14.244	.000
	Within Groups	1.112	30	.037		
	Total	8.502	44			
Length of milled rice	Between Groups	.711	14	.051	2.778	.009
	Within Groups	.549	30	.018		
	Total	1.260	44			
Breadth of milled rice	Between Groups	4.727	14	.338	14.078	.000
	Within Groups	.720	30	.024		
	Total	5.447	44			
L/B ratio of milled rice	Between Groups	60.705	14	4.336	15.749	.000
	Within Groups	8.260	30	.275		
	Total	68.965	44			

Appendix VIII: Analysis of variance of the data on cooking and eating characteristics of different F6 lines of Boro rice.

Treatments	Sum of Squares		Degrees of freedom (df)	Mean Square	F- value	Significance level
Kernel length/Breadth ratio of cooked rice	Between Groups	6.691	14	.478	6.707	.000
	Within Groups	2.138	30	.071		
	Total	8.829	44			
Kernel elongation ratio	Between Groups	4.884	14	.349	10.528	.000
	Within Groups	.994	30	.033		
	Total	5.879	44			
Kernel elongation index	Between Groups	1.857	14	.133	23.552	.000
	Within Groups	.169	30	.006		
	Total	2.026	44			
Water absorption (%)	Between Groups	.985	14	.070	7.097	.000
	Within Groups	.297	30	.010		
	Total	1.282	44			
Volume expansion (%)	Between Groups	15756.756	14	1125.483	5147.599	.000
	Within Groups	6.559	30	.219		
	Total	15763.315	44			
Alkali Spreading value	Between Groups	357358.647	14	25525.618	43.472	.000
	Within Groups	17615.296	30	587.177		
	Total	374973.943	44			
Protein (%)	Between Groups	93.071	14	6.648	12.944	.000
	Within Groups	15.408	30	.514		
	Total	108.479	44			
Amylose (%)	Between Groups	84.833	14	6.060	6.498	.000
	Within Groups	27.975	30	.932		
	Total	112.808	44			