COMPARATIVE STUDY OF MORPHO-PHYSICO-CHEMICAL TRAITS OF 27 F_6 LINES OF BORO RICE (*Oryza Sativa* L.) AGAINST 2 CHECK VARIETIES

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CERTIFICATE

This is to certify that the thesis titled, " **COMPARATIVE STUDY OF MORPHO-PHYSICO-CHEMICAL TRAITS OF 27 F_6 LINES OF BORO RICE (*Oryza Sativa* L.) AGAINST 2 CHECK VARIETIES*"*** *submitted to the* ***Instititute of Seed Technology, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka*** *in partial fulfilment of the requirements for the degree of* ***MASTER OF SCIENCE (MS)*** *in* ***SEED TECHNOLOGY*** *embodies the result of a piece of bona fide research work carried out by* ***ROUNAK FATIMA , Reg. No. 10-03874*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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Dated:
Place: Dhaka, Bangladesh

DEDICATED

TO

MY BELOVED PARENTS

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Dated: June, 2017 *The author*
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COMPARATIVE STUDY OF MORPHO-PHYSICO CHEMICAL TAITS OF 27 F6 LINES OF BORO RICE (*Oryza sativa* L.) AGAINST TWO CHECH VARIETIES

By
ROUNAK FATIMA

ABSTRACT

The experiment was conducted at the experimental Farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh during December 2014 to May 2015. Twenty seven selected Boro rice lines and two check varieties were evaluated. Highly significant variations were found among the advanced lines for all the characters studied. The genotypes G7, G4 and G12 taken lower days to 50% flowering than the two check varieties. The highest total tillers per plant and effective tillers per plant were recorded from G25. The highest panicle length, yield per plant, yield per hectare were recorded from G8. The highest secondary branches per panicle, total number of spikelets and number of filled grains were found from G14. Maximum thousand seed weight was recorded from G6. The highest length of rough rice was found from G24. The genotype G5 has shown the highest value in breadth of rough and uncooked rice. The highest value in L/B ratio of rough and uncooked rice was found in G27. Maximum hulling (%), milling outturn (%) and head rice recovery (%) were recorded from G13, G2 and G10 respectively. In this study, ten lines are classified as long slender grains, twelve lines and two check varieties (BRRI dhan-28, BRRI dhan-29) are classified as medium slender, three lines are long bold and two lines are short bold grains. Maximum volume expansion (%) and water absorption (%) were recorded from G8 and G20, respectively. The genotype G3 has shown the highest kernel elongation ratio and alkali spreading value, which was in the range

of ASV (7.00) that was high alkali digestion and low gelatinization temperature. The genotype G15 has shown the maximum amylose content. Maximum protein content was found in the genotypes G20, G22 and one check variety (BRRI dhan-29).

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LIST OF ABBREVIATED TERMS

ABBREVIATION	FULL NAME
AEZ	Agro-Ecological Zone
BRRI	Bangladesh Rice Research Institute
BBS	Bangladesh Bureau of Statistics
Cm	Centimeter
°C	Degree Celsius
DAS	Date After Sowing
et al.	and others
F6	The fourth generation of a cross between two dissimilar homozygous parents
GEPB	
	Department of Genetics and Plant Breeding
ha	Hectare
hr	Hour
kg	Kilogram
m	Meter
Mm	Millimeter
Mo	Month
MP	Muriate of Potash
no.	Number
%	Percent
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University

m^2	Square meter
TSP	Triple Super Phosphate

CHAPTER I

INTRODUCTION

Bangladesh is an agro-based country. About 75% of her population depends directly on agriculture. Rice is comprehensively grown all over the year in Aus, Aman and Boro seasons. Rice is a self pollinated cereal crop belong to genus *Oryza* of family Poaceae under the order Cyperales and class Monocotyledon having chromosome number 2n = 24 (Hooker, 1979). The genus *Oryza* has twenty three wild and two cultivated species viz., *Oryza sativa* and *Oryza glaberrima* (Brar and Khush, 2003).

Rice is one of the most important food crops of the world. Universally rice is cultured in 150 million hectares, which is more than 10% of the earth's arable land. In April 2017 the United States Department of Agriculture (USDA) estimates that the world rice production 2016-2017 will be 481.14 million metric tons, around 0.8 million tons more than the previous months projection. Rice production last year (2015) was 472.25 million metric tons. This year 481.14 estimated million tons could represent an increase of 8.89 million tons in rice production around the globe.

It is also the staple food crops of nearly half of the total population of the world and is the main source of calories of almost 40% of the world population. It is the most important crop in Asia as a whole comprises to about 92% of the world rice harvest (IRRI, 2016). The world‟s annual rice production must be increased to 760 million tons by the year 2020 (Kundu and Ladha, 1995).

In Bangladesh, majority of food grains come from rice (*Oryza sativa* L.). About 80% of the cropped area of this country is used for rice cultivation with annual production of 25.18 million tons from 10.19 million ha of land (IRRI, 2006). The average yield of rice in Bangladesh is 2.45 t ha^{-1} (BRRI, 2014). The average yield is almost less than 50% of the world average rice grain yield. The increased rice production is needed if possible by the adoption of modern rice varieties on around 70.24% of the rice land which contributes to about 83.39% of the country's total rice production. Rice plays a dominant role in the Bangladesh agriculture of which *Boro* season is the prominent producer. Hossain *et al*. (2003) reported that hybrid rice has the potentiality to increase 15-20% yield but it costs about 19% higher.

In the major rice-consuming countries, grain quality characteristics dictate the market value of the commodity and play an important role in the development and adoption of new varieties (Dingkuhn *et al.,* 1991). Economic product of rice is the paddy yield, which exhibits complex genetics as it is influenced by various yield contributing characters and the environment. In general, increased panicle number is the single most important yield component associated with rice yield, number of spikelet per panicle and percent filled grains per panicle being of secondary and tertiary importance (Jiang *et al.,* 2000).

Another trait directly related to yield is panicle density which chiefly affects the yield potential. Therefore, information about the yield contributing traits is of immense importance to the plant breeders for the development of improved varieties of rice with increased yield potential. Grain quality includes such traits as physical appearance, cooking and sensory properties, as well as nutritional value (Jackson and Lettington, 2003). The relative importance of each characteristic depends on local preferences and the kind of dish to be prepared from the rice.

Grain quality should be acceptable to farmers. Greater emphasis is being given for improving eating quality of rice during development or imported from other countries. Julfiquar *et al.,* (2003) concluded that grain quality is second after yield as the major breeding objective for crop improvement. Consumers base their concept of quality on the grain appearance, size and shape of the grain behavior upon cooking, taste, tendemess and favor of cooked rice. The cooking quality preferences vary within the country within ethnic groups and from one country to another within different geographical regions (Juliano *et.al.*, 1997). Quality of rice may be considered from the view point of size, shape and appearance of grain, milling quality and cooking properties (Dela Cruz and Khush, 2000). The breeders and nutritionists seek rice grain with higher content of protein, vitamins and minerals.

The cooking quality and amylose content in short grain rice are similar to those of rice in the medium grain category. Grain shape has attracted significant attention in rice breeding programs due to its contributions to rice yield and quality. The rice millers prefer varieties with high milling whereas consumers consider physicochemical characteristics (Merca and Juliano, l98l). The consumers judge the quality of rice on the basis of size and shape of rice grain. The preference for grain size and shape can vary from one group of consumer to another group of consumers (Khush *et al.,* 1979).

In Bangladesh consumer's demand for rice, as reflected by price, is mostly influenced by grain size and shape (Choudhury *et al.*, 1991). Boro rice is the most important rice for Bangladesh as the production of this rice covers 55-60% of the total rice production of the country. Boro rice requires huge amount of underground water for its production. Moreover, the duration of the present boro rice varieties ranges 140-160 days. It is important to develop short duration varieties without declining its yield potential. A number of advanced lines of boro has been developed and advanced to select short duration high yielding lines.Thus it has become important to compare among the lines and to study their physico chemical aspect.

OBJECTIVES

Therefore the present study was undertaken with the following objectives:

- To select short duration Boro rice genotypes with higher yield.
- To study the physico-chemical properties of grains of advanced lines of Boro rice.

CHAPTER II

REVIEW OF LITERATURE

Rice is the staple food for most of the planet inhabitants. 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 yield and quality of short durated Boro rice, so far been done at home and abroad, have been reviewed in this chapter.

2.1 Evaluation of yield performance of different selected lines of Boro rice

2.1.1 Days of 50% flowering

Verma *et al*., (2002) observed 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.

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 accomplished that better-quality hybrid could he acknowledged untimely through compare their tiller number, plant height and days to 50% flowering among individuals of their relevant restore.

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.

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.

2.1.2 Days of maturity

Valarmathi and Leenakumary (1998) carried out a field experiment in Kerala, India to evaluate the suitability of aman rice cultivars under direct sown conditions because of scarcity of labor for transplanting. Shorter duration in time to maturity was observed in all the cultivars under direct sowing, upland situation than under lowland transplanted conditions.

Bo and Min (1995) noticed that transplanted rice was most costly and it delayed flowering by 20days and yielded lower than the direct wet-seeded rice.

Sattar and Khan (1992) reported that direct wet-seeded rice was harvested 16 days earlier than transplanted rice.

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.

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

Hosain and Alam (1991) found that the plant height in modern rice varieties BR3, BR11, BR14 and Pajam were 90.4, 94.5, 81.3 and 100.7 cm, respectively.

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.

Masum *et al*. (2008) found that plant height of rice affected by varieties in Aman season where Nizershail produced the taller plant height than BRRI dhan 44 at different days after transplanting (DAT).

2.1.4 Number of tiller

Karmakar et al., 2004) found that Number of tiller/hill was varied significantly among the different plant spacing of rice. Number of tillers and penicles per unit area were higher in closer spacing.

(Balasubramaniyan and Palaniappan, 1991) found that higher tiller numbers/plant was found to greater space due increased levels of soil fertility, less competition among the plants also larger row spacing will promote production of healthier and more panicle bearing tillers. In contrast, with limited soil fertility, crowded plant population will produce lest panicle fertile tillers.

Rice tillering is a major determinant for panicle production (Miller *et al.*, 1991) and as a consequence affects total yield (Gallagher and Biscoe. 1978). The high tillering capacity is considered as a desirable trait in rice production, since number of tillers per plant is closely related to number of panicles per plant. To some extent, yield potential of a rice variety may be characterized by tillering capacity. On the other hand, it was reported that the plants with more tillers showed a greater inconsistency in mobilizing assimilates and nutrients among tillers. Moreover, grain quality could be also affected by tillering ability due to different grain development characteristics. It has been well documented that either excessive or insufficient tillering is unfavorable for high yield. Ghose and Ghatge (1960) stated that tiller number, panicle length contributed to yield.

2.1.5 Number of effective tiller

Miah et al. (1990) found that in wider spacing plants absorbed more nutrient, moisture and light which resulted on more number of effective tillers per hill.

Tohiduzzaman, (2011) observed that Significant difference was found for number of effective tillers among sixteen varieties due to the variation of plant height in SRI system in Boro season.

Ghosh and Hossain (1988) reported that effective tillers/plant, number of grains/panicle and grain weight as the major contributory characters for grain yield it had positive correlations with number of productive tillers/plant.

Jiang *et al.,* (2000) observed the importance of number of tillers/plant influencing yield.

Productive tillers/bill showed significant positive correlations with grain yield (Reddy and Kumar, 1996).

2.1.6 Panicle length

Associations of various yield components in rice (Padmavathi *et al.,* 1996) indicate that the plants with large panicles tend to have a high number of fertile grains. Similarly, a positive correlation was observed between number of panicle/plant and panicle length.

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

2.1.7 Number of primary branchs/panicle

Sinha et al(1999) observed that Panicle yield was significantly and positively correlated with number of primary branches panicle-1, number of spikelets on secondary branches panicle-1, number of grains on primary branches panicle-1, grain length, grain breadth, grain thickness, kernel length, kernel breadth, kernel thickness both at genotypic and phenotypic level.

2.1.8 Number of secondary branches/panicle

Sinha *et al.,* (1999) found that High significant and positive genotypic and phenotypic association revealed between number of secondary branches panicle^{-1}, number of spikelets panicle^{-1}, number of spikelets on secondary branches panicle^{-1}, number of grains on secondary branches panicle^{-1}.

2.1.9 Total number of spikelets/panicle

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.

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.

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

2.1.10 Number of filled spikelet/panicle

Spikelets/panicle had positive direct effect on yield. Filled spikelets/panicle had high direct effect on single plant yield was reported by Janardhanam *et al*., (2001) ; Cheema *et al*., (1998).It had positive indirect effect on yield through plant height, days to 50% flowering, unfilled spikelets/panicle and negative indirect effect through ineffective tillers/plant, panicle length and 1000 seed weight. The cumulative effects of these characters produced a significant positive genotypic correlation on yield. Since the direct effect and correlation coefficient between total spikelets per panicle and grain yield are positive, so it is an indication of true relationship among these traits. It suggests that the direct selection for total spikelets per panicle would likely to be effective in improving the grain yield.

Choudhury and Das (1997) and Kim *et al*., (1999) reported positive contribution of total spikelets towards grain yield, which supports the present finding.

Sarker *et al*., (2001) showed filled spikelets/panicle is the most important character for rice because of grain yield is highly influenced by it directly as well as indirectly.

Pathak *et al*., (1998) reported that grains per panicle was the main component which affected yield directly.

2.1.11 Yield/plant (dry)

Anon. (2005) summarized the speech of a workshop on drum seeding held at Bangladesh Rice Research Institute (BRRI) in Gazipur on June 20, that it was possible to produce 10-20 percent higher yield than the traditional transplanting method.

Latif et al. (2005) reported that in comparison of short- and long-duration varieties, the long-duration variety BRRI dhan29 yielded highest.

Anon.,(2004e) reported that in an experiment in Boro season with the planting methods of transplanting, seedling throwing/broadcasting with normal seedlings, direct seeding and seedling throwing with young seedling, the highest grain yield (5.4 t ha-1) of BRRI dhan 29 was obtained from transplanting method and direct seeding method gave the lowest grain yield (4.73 t/ha^{-1}). Seedling throwing method gave little bit lower yield than transplanting method but higher than direct seeding method.

Bari (2004) reported the grain yield from direct wet seeded line sowing method was significantly higher than those from transplanted method.

2.1.12 Thousand seed weight

Awan *et al.*, 2011 reported that When there are more spacing there will be more air, light and inputs availability and that may responsible for maximum 1000 grain weight. Increase in grain weight at higher nitrogen rates might be primarily due to increase in chlorophyll content of leaves which led to higher photosynthetic rate and ultimately plenty of photosynthates available during grain.

Haque *et al*., (1991) reported negative association of 1000 grain weight and yield per plant in traditional varieties. Li and Yuan (1998) reported that parental genotype divergence had a relatively low impact on heterosis for panicle number and 1000 grain weight. Plant height, panicle per plant, grain per panicle and 1000 grain weight increase the yield in modern varieties (Saha Ray *et al*., 1993). Kumar *et al*., (1994), noted that grain weight was highly correlated to grain size, which is the product of grain length and width.

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

2.1.13 Yield/ha

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).

Yield per hectare is the most important consideration in rice breeding program, but yield is a complex character in inheritance and may involve several related components. To get better rice (*Oryza saliva* L.) grain yield per unit land area is the only way to achieve increased rice production because of the reduction in area devoted to rice production.

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). In addition, grain yield also related with other characters such as plant type, growth duration, and yield components (Yoshida, 1981). Yield per hectare is the most important consideration in rice breeding program, but yield is a complex character in inheritance and may involve several related components. Rice yield is a product of number of panicles per unit area, number of spikelets per panicle, percentage of filled grains and weight of 1000 grains (Yoshida, 1981; De Datta, 1981). It is therefore important to know the factors or traits that influence grain yield directly or indirectly or both, and to determine heritability and genetic advance under selection of those traits so that response to selection can be predicted. Improving rice (*Oryza sativa* L.) grain yield per unit land area is the only way to achieve increased rice production because of the reduction in area devoted to rice production. Bai *et al*., (1992) reported that grain yield per plant positively correlated with numbers of productive tillers and number of grains per/panicle.

2.2 Study of milling quality and grain appearance

The milling quality of rice variety is said to be better if gives more whole kernel and less of broken when subjected to milling. Milling outturn depends on grain shape and appearance, which has direct effect on the percentage of milling. Milling yield is one of the most important criteria of rice quality, especially from a marketing standpoint. A variety should possess a high turnout of whole grain (head) rice and total milled rice (Webb, 1985). 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). Thus, the milling quality of rice may be defined as the ability of rice grain to stand milling and polishing without undue breakage so as to yield the greatest amount of total recovery and the highest proportion of head rice to broken. 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. He *et al.* (2001) reported that the inheritance of grain quality is more complicated than that of other agronomic traits in cereals due to epitasis, maternal and cytoplasmic effects, and the triploid nature of endosperm. A study of the genetic effects of parents showed that parents with high amylose content were unfavorable for eating and cooking quality improvement (Bao *et al.*, 2003). Adu-Kwarteng *etal.* (2003) found good grain size and shape (L/W-3.12), good endosperm appearance, milling quality (TMR-67.2%) and higher amylose content(22.87-30.78%) in the breeding lines. A brief review of literature available on various quality traits is given below:

2.2.1 Milling outturn (%)

Milling recovery is one of the most important criteria of rice quality especially from the standpoint of marketing. A variety should posses a high turnout of whole grain (head) rice and total milled rice (Webb *et al*., 1985). 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 (Khush *et al.*, 1979).

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% (Khush *et al*., 1979).

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, post harvest 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 (Chauhan and Singh, 1882).

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. 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.

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

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

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%.

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

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

Lanignelet and Marie (1983) 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 prone to breakage during milling (Islam, 1983). The substantially improved the milling properties of rice by eliminating white belly and reducing grove depth on the kernel surface (Srinivas and Bhashyam, 1985).

2.2.2 Head rice recovery (%)

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 (Arf *et al*., 2002). Head rice recoverability is an inherited trait, although environmental factors such as temperature and humidity during ripening and post harvest 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 (Bhattacharya, 1980). In general, varieties with long 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.

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.

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. 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.

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.

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. 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 (Shobha Rani *et al*., 2002).

2.2.3 Kernel elongation ratio

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 (Juliano, 1979).

Some rice show extreme elongation on cooking particularly in presoaked grain while in most varieties the expansion is relatively more breadth wise (Azeez and Shafi, 1986; Juliano, 1972 and Sadhukhan and Chattopadhay, 2001).

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

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

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

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

Tomar and Nanda (1982) reported that water uptake at 77°C showed significant positive correlation with kernel elongation. They also reported that alkali value much more important than amylose content in determining kernel elongation, which was contradictory to the report of Kongseree and Juliano (1972).

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.

Significant association of L/B ratio with kernel elongation was reported by Deosarker and Nerker (1994).

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 (Gua *et al.*, 2003). 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.

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.

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.

Chauhan *et al.* (1995) point out significant positive correlation between kernel elongation and cooked kernel length.

Singh (1988) 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).

Different type of Indian and Pakistani Basmati, Afghanistan's Sadri and Myanmar's D25-4 (Nga Kyee) posses this extreme elongation property. Later on, it becomes more popular for its high cooked kernel elongation ratio (Hadjim *et al*., 1994; Faruq *et al*., 2003

2.2.4 Water absorption (uptake) percentage and volume expansion

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

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

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

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

The traits of elongation water absorption are very important in determining the quality of cooked rice grains (Ge *et al*., 2005). Lower VER is preferred than higher VER.

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

2.2.5 Gelatinization temperature (GT) and Alkali spreading value (ASV)

The GT is correlated with the extent of disintegration of milled rice in dilute alkali solution and hence an indirect estimate of the GT. The gelatinization temperature is positively co-related with the cooking time (Juliano, 1967), but GT does not show a relationship with the texture of 25 cooked rice (IRRI, 1968).

Mostly the rice varieties with higher GT may have low amylose content (AC). No varieties have been found with higher GT and higher AC (Jennings *et al*., 1979).

Gelatinization temperature may be classified as low (Below 70º), intermediate (70º to 74º) or high (above 74º) (Little *et al*.,1958).

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 (Zaman, 1981).

At high GT, rice becomes extensively soft when overcooked, elongates less and remains 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).

Indian consumers like rice with intermediate GT (Bhattacharya, 1978).

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 (Yang *et al.*, 2003).

An estimate of the gelatinization temperature is indexed by the alkali digestion test (Little *et al.,* 1958). It is measured by the alkali spreading value. The degree of spreading value of individual milled rice kernels in a weak alkali solution (1.7% KOH) is very closely correlated with GT. Rice with a low GT disintegrates completely, whereas rice with an intermediate GT shows only partial disintegration. Rice with a high GT remains largely unaffected in alkali solution.

Although the gelatinization temperature and cooking time of milled rice positively correlated (Juliano, 1967), GT does not correlate with the texture of cooked rice (IRRI 1968).

Gelatinization temperature is not associated with other important plant or grain traits except for certain useful correlations with amylose content (Jennings *et al.*, 1979).

Varieties with a high GT generally have low amylase content. No varieties are known with a high GT and high amylase content. The varietal difference in gelatinization temperature is due to the micellar structure of molecules in the starch granules and the gelatinization temperature effects the orderly arrangements of molecules in the granules and perhaps of the whole endosperm. Rices that have low gelatinization temperature such as, *japonica* varieties start to swell at low temperature during cooking than rice varieties that have intermediate or high gelatinization temperature (Nagato and Kishi,1966).

2.2.6 Amylose content

Amylose content is important because firmness and stickiness are two properties of cooked rice that influence consumer preference and use of different classes of rice.

Juliano, 1979a, 1979b; Webb, 1985; Carreres, 1988 reported that amylose content is considered to be the single most important characteristic for predicting rice cooking and processing behaviors.

Juliano, 1972 stated that amylose content influences the properties of cooked rice, sticky if the quantity is low.

amylose content of rice endosperm was influenced by the temperature during the ripening period (Okuno 1985).

Classification of amylose content identified classes as waxy (0-5%), very low (5-12%), low (12-20%), intermediate (20-25%) and high (25-33%), even considering that commercially rice is classified by amylose content as either low (less than 20% amylose), medium (21-25%) and high (26-33%) (Juliano, 1992; Suwannaporn *et al.*, 2007).

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 of the grains of a rice plant can be seen as the result of interaction between environmental forces and genetic properties of the individual variety (Gomez, 1979).

Based on the amylose content, the gelatinization temperature varies and the tenderness of rice grain depends upon the amylose content (Juliano, 1985). Amylose content can play a significant role in determining the overall cooking, eating and pasting properties of a rice variety(Adu-kwarteng *et al.,* 2003).Apart from the amylose content, the cooking quality of rice can also be influenced by components such as proteins, lipids or amylopectin (Cai *et al.*, 2011). Most of these traditional rice varieties are found mainly in Tiruchirappalli region and cultivated in small patches. Out of 14 rice varieties collected, some of the varieties becoming rare but their amylose content is appreciable. So there is a need to preserve these varieties. The amylose content of a rice variety can vary by as much as 6 percentage points (Juliano, 1972). Temperature during grain ripening has been shown to affect amylose content (Stansel, 1965; Suzuki and Murayama, 1967; Kihara and Kajikawa, 1960; Murayama *et al.,* 1963; Nikuni *et al,,* 1969). Amylose content generally decreased as the mean temperature increased. However, response to temperature may differ, depending on whether the variety is japonica or indica (Resurreccion *et al.,* 1977) and depending upon the inherent level of amylose content of the varieties (Paule. 1977). Waxy rice flour is chosen for its unique soft and sticky texture in many Asian desserts. Snacks, many puffed breakfast cereals are produced using low amylose rice; intermediate amylose rice is used in canned soups and higher amylose rice is chosen for products requiring an intact cooked product, such as extruded pasta, noodles, and retort boiled rice (Juliano and Hicks 1996).

2.2.7 Protein content

Rosniyana *et al.,* (2011) that protein content in rice range from 8.85 to 9.91% for white rice and brown rice respectively. In addition, Banerjee *et al.,* (2011) reported the protein content range from 4.91 to 12.08% in 258 diverse rice landraces maintained in the Germplasm Section of Indira Gandhi Agricultural University at Raipur, Chhattisgarh. Srisawas and Jindal (2007), found the protein content in 14 rice varieties ranged from 6.38 to 8.99%.

Juliano *et al.,* (1964) stated that We measure protein in brown rice in all screening trials rather than in milled are highly rice since the protein contents of brown rice and of milled rice remove correlated Furthermore, it is difficult to bran For example, in a 1968 variety-fertilizer experiment uniformly in milling rice protein content of four improved plant type (IRRI, 1968), the brown 7.3 percent. High varieties averaged 8.2 percent and that of the milled rice, protein rice tends to have a lower percentage loss in protein in milling than low protein rice (IRRI, 1970a).

CHAPTER III

MATERIALS AND METHODS

3.1 Site of the experiment

The experiment was conducted at Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from December 2014 to 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.

3.2 Climate and Soil

The experimental site was situated in the sub-tropical zone. The soil of the experimental site lies in Agro ecological region of "Madhupur Tract" (AEZ No. 28). 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.

3.3 Planting materials used

Twenty nine rice genotypes were used for the present study. Among twenty nine rice genotypes, twenty seven 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.

3.4 Methods

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

3.4.1 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.

3.4.2 Seedbed preparation and seedling rising

The irrigated land was prepared thoroughly by three times ploughing and cross ploughing followed by laddering. Weeds and stubbles were removed. Twenty nine separate strips were made and sprouted seeds were sown in 5 December of 2013. The seedlings were raised by maintaining irrigation with regular intervals and protecting from birds and insects and infestation of pest and diseases.

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

Sl. No.	Genotypes	Prdigree	Source
1	G1	BR 21 × BR 26 F6 S6 P1P6	GEPB, SAU
2	G2	BR 21 × BR 26 F6 S6 P3 P1	GEPB, SAU
3	G3	BR 21 × BR 26 F6 S6 P9 P7	GEPB, SAU
4	G4	BR 21 × BRRI Dhan- 28 F6 S5 P2 P1	GEPB, SAU
5	G5	BR 21 × BRRI Dhan- 28 F6 S5 P4 P1	GEPB, SAU
6	G6	BR 21 × BRRI Dhan -28 F6 S5 P4 P2	GEPB, SAU
7	G7	BR 21 × BRRI Dhan -28 F6 S5 P6 P3	GEPB, SAU
8	G8	BR 21 × BRRI Dhan -28 F6 S5 P7 P6	GEPB,SAU
9	G9	BR 21 × BRRI Dhan -29 F6 S6 P1 P1	GEPB, SAU
10	G10	BR 21 × BRRI Dhan -29 F6 S6 P2 P4	GEPB, SAU
11	G11	BR 21 × BRRI Dhan -29 F6 S6 P6 P2	GEPB, SAU
12	G12	BR 21 × BRRI Dhan -36 F6 S1 P4 P1	GEPB, SAU
13	G13	BR 24 × BR 26 F6 S5 P1 P3	GEPB, SAU
14	G14	BR 24 × BR 26 F6 S5 P3 P2	GEPB, SAU
15	G15	BR 24 × BR 26 F6 S5 P4 P4	GEPB, SAU
16	G16	BR 24 × BRRI Dhan- 36 F6 S8 P1 P1	GEPB, SAU
17	G17	BR 26 × BRRI Dhan- 28 F6 S1 P7 P2	GEPB, SAU
18	G18	BR 26 × BRRI Dhan- 28 F6 S1 P9 P3	GEPB, SAU
19	G19	BR 26 × BRRI Dhan 28 F6 S1 P9 P4	GEPB, SAU
20	G20	BR 26 × BRRI Dhan 29 F6 S6 P3 P1	GEPB, SAU
21	G21	BR 26 × BRRI Dhan 29 F6 S6 P3 P2	GEPB, SAU
22	G22	BRRI Dhan- 28 × BRRI Dhan- 29 F6 S2 P2 P1	GEPB, SAU
23	G23	BRRI Dhan- 28 × BRRI Dhan- 29 F6 S2 P3 P3	GEPB, SAU
24	G24	BRRI Dhan- 28 × BRRI Dhan- 29 F6 S2 P4 P3	GEPB, SAU
25	G25	BRRI Dhan- 29 × BRRI Dhan- 36 F6 S5 P2 P4	GEPB, SAU
26	G26	BRRI Dhan- 29 × BRRI Dhan- 36 F6 S5 P2 P7	GEPB, SAU
27	G27	BRRI Dhan- 29 × BRRI Dhan- 36 F6 S5 P3 P1	GEPB, SAU
28	G28	BRRI Dhan 29	BRRI
29	G29	BRRI Dhan 28	BRRI

3.4.3 Preparation of main land and application of manure and fertilizer

Cow dung was applied to the experimental field and the plot was ploughed thoroughly by two ploughing and cross ploughing followed by harrowing with a tractor drawn disc plough to attain a good puddle. Four days later the final ploughing and cross ploughing were done and weeds and stubbles were removed. First split of urea and full portion of all other fertilizers recommended by BRRI were added to the main land before final ploughing. Urea, TSP, MP, Gypsum and Zinc Sulphate were applied at the rate 261.45, 97.11, 119.52, 112.05, and 11.205 kg/ha, respectively. The second, third and fourth splits of urea was applied at 15, 30 and 45 days after transplanting (DAT), respectively (BRRI, 2011).

3.4.4 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total area of the experiment was 30 m× 12.2 m = 366 m2. The experimental field was divided into three blocks, representing three replications. Each replication size was 30m× 3.4m, and the distance between replication to replication was 50 cm.

3.4.5 Transplanting

Thirty days old and healthy seedlings were transplanted to the main field on January 6, 2014 followed by proper irrigation. One seedling per hill was transplanted maintaining 25 cm × 20 cm spacing from row to row and plant to plant, respectively. Twenty nine rice genotypes were distributed in each of the block through randomization process.

3.4.6 Intercultural operations

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

3.4.6.1 Irrigation and drainage

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

3.4.6.1Gap filling

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

3.4.6.2Weeding

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.

3.4.6.3Top 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.

Plate 1: A field view of experiment

3.4.6.4Plant Protection

Diazinon 57 EC was applied at the time of final land preparation and later on other insecticides were applied as and when necessary.

3.4.7 Crop harvesting

Harvesting was done from 25th April to 6th May, 2016 depending upon the maturity. When 80% of the plants showed symptoms of 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 F5 progenies in each replication. The plants were harvested by uprooting and then they were tagged properly. Data were recorded on different parameters from these plants.

3.4.8 Data collection

For studying different genetic parameters and inter-relationships, fourteen characters were taken into consideration. The data were recorded on ten selected plants for each cross and ten selected plants for each parent on the following traits.

3.4.8.1 Days to flowering

Difference between the dates of transplanting to the date of 50% flowering of a plot was counted and was recorded when 50% plant of a plot were at the flowering stage.

3.4.8.2 Days to maturity

Maturities of the crops of different combination were recorded considering the symptom such as moisture content of rice, color changing of the plant from greenish to straw colored appearance.

3.4.8.3Plant height (cm)

The height of plant was recorded in centimeter (cm) at the time of harvesting. The height was measured from the ground level to the tip of the panicle.

3.4.8.4 Number of total effective tiller

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

3.4.8.5 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.

3.4.8.6 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.

3.4.8.7 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.

3.4.8.8 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.

3.4.8.9 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.

3.4.8.10 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.

3.4.8.11 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.

3.4.8.12 Yield per plant (gm)

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

3.4.8.13 Thousand seed weight (gm)

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

3.4.8.14 Yield per hectare (t/ha)

Grains obtained from each unit plot were sun dried and weighted carefully and converted to ton per hectare.

3.5 Determination of the milling and grain appearance

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

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

3.5.2 Milling outturn: The brown rice obtained after 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 outturn was calculated as,

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

3.5.2 Head Rice Recovery (HRR %): The milled samples were sieved to separate whole kernels from the broken ones. Small proportion of whole kernels which passed along with broken grains was hand separated. Head rice recovery was calculated in percentage as,

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

3.6 Determination of the grain appearance

3.6.1 Grain length and breadth of uncooked rice: Ten rough kernels, ten brown kernels and five polished kernels from the bulk sample of each entry were measured for their length by slide calipers. Ten rough kernels, ten brown kernels and five polished kernels from the bulk sample of each entry were measured for their breadth slide calipers.

3.6.1 L/B ratio of uncooked rice: L/B ratio was computed according to following formula:

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

3.6.3 Grain type: Grain types (polished rice) were classified by using the following classification proposed by Robin Graham, IRRI in 2002 in a discussion paper of "A proposal for IRRI to Establish a Grain Quality and Nutrition Research Center" is presented below.

Table 2: Classification of rice on the basis of average length

Scale	Size category	Length in mm
1	Very long	More than 7.50
3	Long	6.61 to 7.50
5	Medium or intermediate	5.51 to 6.60
7	Short	Less than 5.50

(Robin Graham, 2002)

Table 3: Classification of rice on the basis of length/breadth ratio

Scale	Shape category	Length/breadth ratio
1	Slender	More than 3.0
5	Medium	2.1 to 3.0
7	Bold	2.0 or less than 2.0

(Robin Graham, 2002)

Grain types were classified by using the following classification proposed by Ramaiah committee in 1965:

Table 4. Systematic classification of grain types of rice proposed by Ramaiah Committee in 1965

Class	Designatio-n	Description	
		Length	Length/Breadth ratio
Long Slender	LS	Length 6 mm and above	Length/Breadth ratio 3 and above
Short Slender	SS	Length less than 6 mm	Length/Breadth ratio 3 and above
Medium Slender	MS	Length less than 6 mm	Length/Breadth ratio 2.5 to 3
Long Bold	LB	Length 6 mm and above	Length/Breadth ratio less than 3
Short Bold	SB	Length less than 6 mm	Length/Breadth ratio less than 2.5

(Source: Shobha Rani, 2003)

3.7 Determination of cooking and eating characteristics of the grain

3.7.1 Grain 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.

3.7.2 Grain Length/ Breadth ratio of cooked rice: L/B ratio of cooked kernel was computed according to following formula:

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

3.7.3 Kernel elongation ratio: Elongation ratio was calculated by dividing the length of cooked kernel by its original length.

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

Where, L_0 and L_1 are kernel length before and after cooking, respectively

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

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

Where, L_1/B_1 and L_0/B_0 represent length/breadth ratio before and after cooking, respectively.

3.7.5 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,

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

Where, W_1 and W_2 represent weight of the sample before and after cooking, respectively.

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.

3.7.5 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 as,

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

Where, V_1 and V_2 represent volume before and after cooking, respectively.

3.8 Determination of grain quality characteristics

3.8.1 Alkali spreading value: Alkali spreading value was determined according to procedure of Little et al. (1958). A sample of eight whole milled rice kernel 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±1°C for 16 hours as suggested by Zaman (1981). After 16 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 proposed by Jennings et al. (1979) and IRRI (1980).

Gelatinization temperature (GT) can be measured from alkali spreading value. ASV and GT are inversely related.

Table 5 : 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	Center cottony; Collar clearing	Intermediate	Intermediate
6	Kerneldispersed merging with collar	Center Cloudy; Collar clear	High	Low
7	Center and collar clear	Center and collar clear	High	Low

According to Alkali spreading score the GT. Types were classified as follows

Table 6: Classification of GT types according to the Alkali spreading score

Alkali spreading value/code	**G.T. Types**
1-3	High
4-5	Intermediate
6-7	Low

3.8.2 Estimation of Amylose: This value was determined according to Juliano (1979). 100mg of rice powder was taken into a 100 ml volumetric flask and 1ml of 95% ethanol and 9ml of 1M sodium hydroxide were added. The contents were heated in a boiling water bath for 10 minutes to gelatinize the starch. After cooking for 1 hour, distilled water was added and the contents were mixed well.

Five ml of starch solution was put in a 100ml volumetric flask with a pipette. One ml of 1M acetic acid and 2ml 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 620mm 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.

3.8.3 Protein content: Protein content was calculated from nitrogen and it was determined by micro-kjeldahl method. 50mg powdered samples were weighed and introduced into 30ml kjeldahl flasks. 1.95g catalyst (a mixture of K_2SO_4 and HgO) and 2.3ml concentrated H_2SO_4 were added. The mixture was digested in Labconco digester with 200 watt chromalux heaters until the mixture became clear (20 minutes). The digested mixture was cooled and a minimum amount of water was added to dissolve the solid. 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 the solution was placed. About 9.0ml of NaOH-$Na_2S_2O_3$ solution was slowly added to the digest. The flask was connected to the steam source and distilled until about 30ml 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 immediatedly with standard HCl solution to the first appearance of the violet or reddish colour. A blank determination was made and simultaneously percent N was calculated with the following formula,

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

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

CHAPTER IV

RESULTS AND DISCUSSION

Mean performance for yield along with yield components of special preferred lines of Boro rice are obtainable now to identify with the general scenarios of the research. A total of twenty seven chosen lines of Boro rice plus two check variety were evaluate for yield and some yield causative characters.

4.1 Assessment of the yield presentation of special lines of Boro rice

Generally a breeder aims on accumulate constructive genes from various possessions within a meticulous genotype, which would fundamentally depend leading the accessibility of hereditary changeability in the germplasm in value of several meticulous quality and hereditary likely of a crop set is probable on the source of yield of profitable part. In case of rice, it is grain yield. This grain yield have been define by Podhi and Singh (1991) as a meaning of number of panicles per plant, number of grains per panicle, percentage of filled grains and weight of kernels. Venkateswarlu *et al.,* (1986) have anticipated enrichment of grain yield probable in rice by ever-increasing the proportion of high compactness grains. Many unlike morphological and yield mechanism causative to yield have been projected by a range of worker, but the the largest part acknowledged mechanism are days to flowering, number of effective tillers per plant, number of filled grains per panicle, grain size as viewed by Talwar and Guad (1974), Reddy and Ramchandraiah (1990), Basak and Ganguli (1996) and Peng *et al.*, (2000).

A total of twenty seven chosen lines of Boro rice plus two checks were evaluate on behalf of yield and some yield causative characters. The outcome of mean performance on behalf of different yield causative characters are existing below the subsequent numbers:

Plate 2. Photograph showing variation in flowering among different genotypes and parents

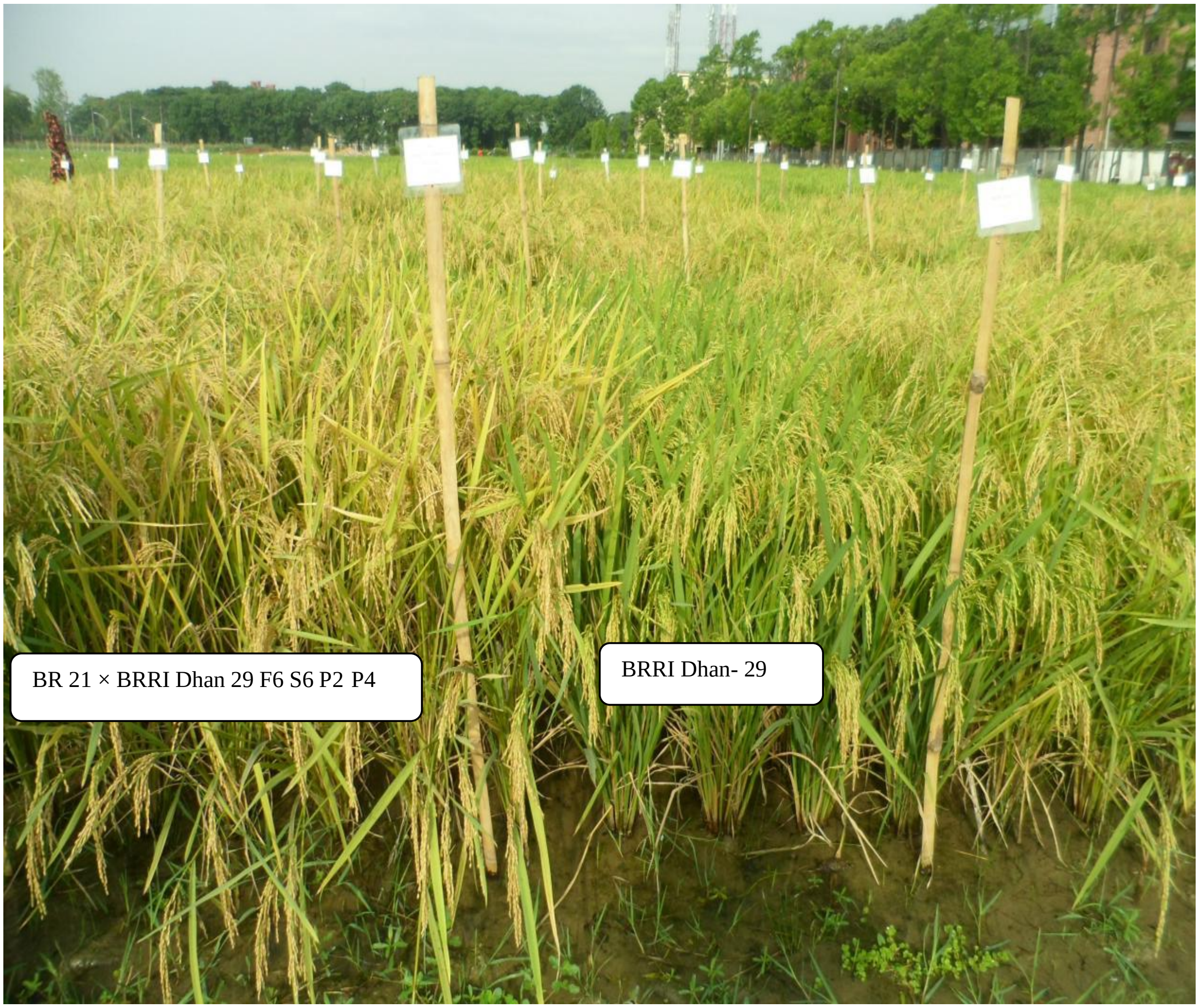

Plate 3. Photograph showing variation in days to maturity in different genotypes

Plate 4. Photograph showing variation in plant height in different genotypes with parents

4.1.1 Days to flowering

Significant variations were observed among the genotypes (25.62**) for days to flowering. (Table 7a) were recorded with days to 50% flowering 129 days and 122.00 days respectively. The G7, G4 and G12 were shown lower days to 50% flowering than the two checks varieties. A few crosses show heterobeltiosis for days to 50% flowering. The correlation between heterosis over better parent). Among 29 genotypes, the lowest days to 50% flowering were observed in G7 (118 days) which is very closed to G4 (118.3 days) , G12 (118.3 days) and highest (129 days) was observed in G28 (Table 8a). Whereas the G28 (BRRI Dhan29) and G29 (BRRI Dhan 28)and inbreeding depression showed that yield can be improved by direct selection for days to 50% flowering and number of productive tillers per plant (Wang *et al.*, 1991).

4.1.2 Days to maturity

Significant variations were observed among the genotypes (48.28**)for days to maturity (Table 7a).The highest days to maturity was taken in G28 (155.30 days) and the minimum days to maturity was taken in G19 (141.3 days), G29 (141.3 days) and G10 (141.7 days) among 29 genotypes (Table 8a). The G19, G29 and G10 were shown lower days to maturity than checks the G28 (BRRI Dhan29) (155.30 days) but similar to G29 (BRRI Dhan28) (141.30 days).

Khush (1999) reported that the optimal growth period designed for highest rice yields in the tropics is consideration to be 120 days from seed to seed. Growth period of in relation to 120 days allow the plant to develop additional soil nitrogen plus solar radiation and consequential in elevated yield. However, for variation of a variety of cropping system, varieties with varying growth period of 100-130 days are required. Karim *et al.*, (2007) studied that dissimilarity for days to maturity was certified by hereditary element slightly than environment. Short

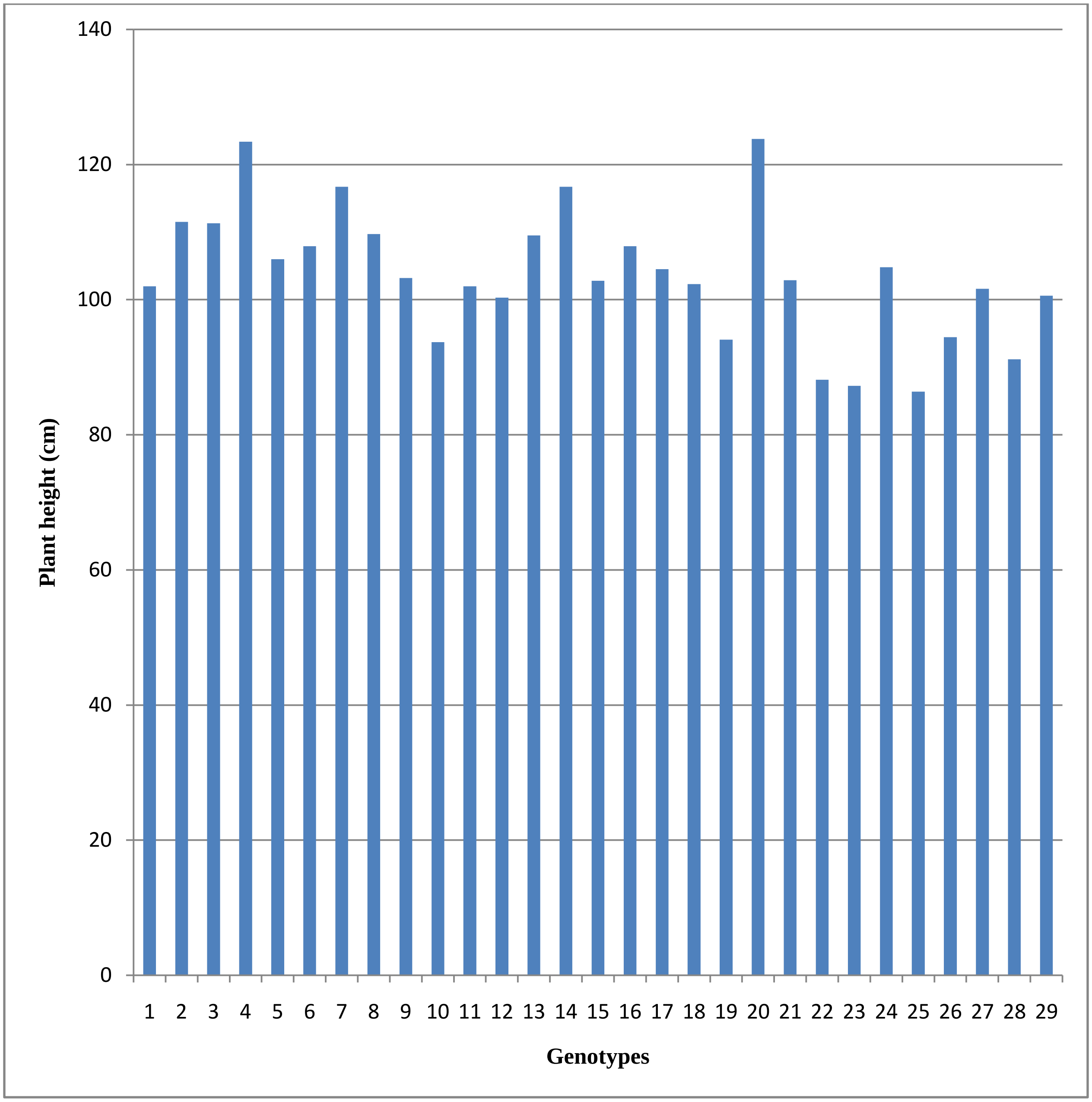

Figure 1. Mean performance of twenty nine genotypes in respect of plant height

period lines be capable of a high-quality foundation for breeder toward make use of as parents.

4.1.3 Plant height (cm)

Significant variations were observed among 29 genotypes (283.15**) for Plant height (Table 7a). The highest plant height was observed in G4 (123.40 cm) and G20 (123.80 cm) where as the minimum plant height was observed in G25 (86.38 cm) which is near to G23 (87.23 cm) and G22 (88.17cm) (Table 8a). The G25 (83.12 cm), G23 (84.82 cm) and G22 (87.53 cm) were shown lower plant height than two checks the G28 (BRRI Dhan29) (91.19 cm) and G29 (BRRI Dhan28) (100.6 cm). Khush (1999) reported that short height reduce the vulnerability of rice crop to accommodation as well as leads headed for superior harvest index. Ponnuthurai *et al., (*1984) reported that taller plants may have better plant canopy for photosynthesis. For optimally managed as well as multiple crop growing circumstances earliness and short height are normally chosen where as in not well drained and deep water circumstances normally late and taller hybrids well better. Hussain *et al.*, (2005) reported that transplantation time, water and soil condition, planting and sowing method affect plant height in rice.

4.1.4 Number of total tillers per plant

Significant variations were observed among 29 genotypes (8.71**) at the level of 1% probability for number of total tillers per plant (Table 7a). The genotype G25 (18.93) have shown higher number of tiller per plant than two checks the G28 (BRRI Dhan29) (14.7) and G29 (BRRI Dhan28) (15.27) and number of total tillers per plant and the minimum one was in G16 (10.97) (Table 8a) which is near to G20 (11.8).On the other hand, Among the 29 genotypes G25 (18.93) showed the maximum the genotypes G10 (10.97) and G20 (11.8) were shown lower number of tiller per plant than two check variety.

4.1.5 Number of effective tillers per plant

Significant variations were observed among 29 genotypes (8.80**) at the level of 1% probability for number of total tillers per plant (Table 7a). The highest number of effective tillers per plant was observed in G25 (18.27) whereas the minimum number of effective tillers per plant was observed in G16 (10.53) (Table 8a). The genotypes G10 (15.70) and G25 (18.27) were shown higher number of effective tiller per plant than two checks the G28 (BRRI Dhan29) (14.33) and G29 (BRRI Dhan28) (14.57). Former several people reported that superior records of productive tillers are liable for higher yield (Pandey *et al*., 1995; Reddy and Ramachandraiah, 1995; Padmavathi *et al*., 1996; Rao *et al*., 1996). According to new plant type concept of Khush (1999) compact tillering habit (6-10 tillers/plant) would provide high yield than the modern varieties having 20-25 tillers. He found that only 14-15 of these tillers generate panicles which are small and rest remaining unproductive. Reduced tillering facilitates synchronous flowering and maturity and more homogeneous panicle size. Genotypes with lesser tliller number are also reported to produce a superior proportion of heavier grains (Padmaja Rao, 1987).

4.1.6 Panicle length (cm)

From ANOVA table (Table 7a) significant difference were observed among 29 genotypes (2.59**) at the level of 1% probability for panicle length. Among the 29 genotypes the highest panicle length was observed in G8 (25.04) which are very close to G14 (24.92) where as the minimum panicle length was observed in G13 (21.42) (Table 8a). The genotypes G4 (24.33),

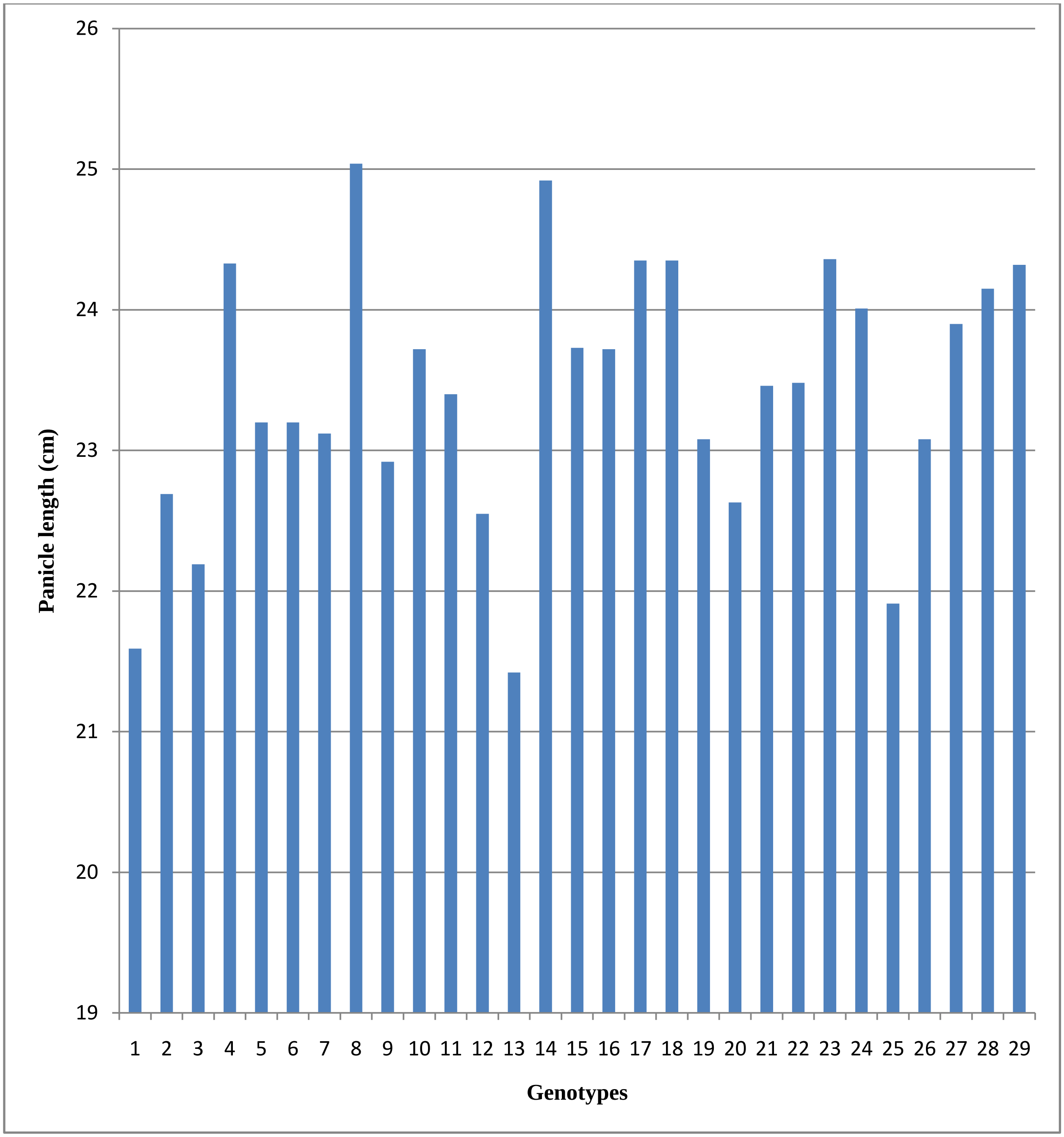

Figure 2. Mean performance of twenty nine genotypes in respect of panicle length

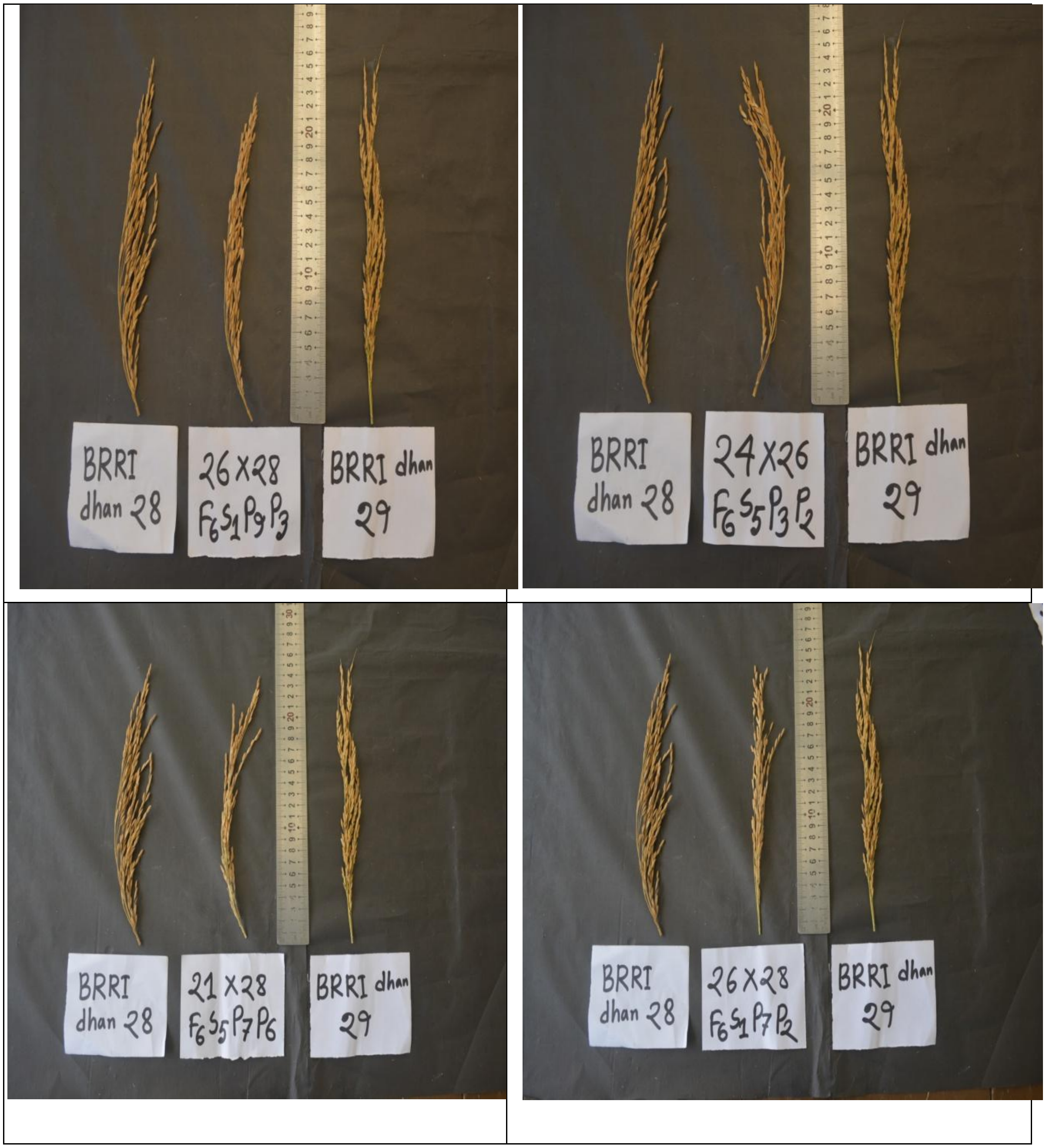

Plate 5. Photograph showing variation in panicle length in different genotypes comparing with parents

G17 (24.35), G18 (24.35), G23 (24.36), G24 (24.01) were shown almost similar panicle length to two checks the G28 (BRRI Dhan29) (24.15) and G29 (BRRI Dhan28) (24.32). Sharma (2002) work with superior grain rice and observed that there had been significant dissimilarity in panicle length. Wang *et al*., (1991) found that the length of panicle varied from 26.30 cm to 27.50 cm among the *indica/japonica* hybrids. But in this experiment, the range of panicle length of lines was from 21.42-25.04 cm. The improved panicle length could be due to the equipment used. Tahir *et al*., (2002) considered hereditary variability for a range of traits. He establishes that these traits are under the genetic organized and could be use in the choice of a wanted trait.

4.1.7 Number of primary branches per panicle

Significant difference were observed among 29 genotypes (3.27**) at the level of 1% probability for number of primary branches per panicle (Table 7a). Highest number of primary branches per panicle was recorded for G11 (12.90) which are very close to G24 (12.20) while the minimum number of primary branches per panicle was recorded for G1 (8.20) (Table 8a). The genotypes G4 (11.03), G6 (10.50), G9 (10.90) and G10 (11.03), G12 (12.07), G16 (11.47), G17 (10.60) were shown higher number of primary branches per panicle than two checks the G28 (BRRI Dhan29) (10.40) and G29 (BRRI Dhan28) (10.27).

4.1.8 Number of secondary branches per panicle

Significant variations were observed among 29 genotypes (27.24**) at the level of 1% probability for number of secondary branches per panicle (Table 7a). Among 29 genotypes, the highest number of secondary branches per panicle was found in G14 (38.03) where as the minimum number of secondary branches per panicle was observed in G25 (23.20) (Table 8b). The genotypes G3 (29.43), G7 (29.27), G21 (29.07), G23 (29.57) were found higher number of secondary branches per panicle to checks the G29 (BRRI Dhan28) (29.00).

Plate 6. Photograph showing variation in number of total tiller per plant in different genotypes with parents

4.1.9 Total number of spikelet per panicle

Significant variations were observed among 29 genotypes (1861.17**) at the level of 1% probability for number of spikelet per panicle. The total number of spikelet per panicle was maximum in G14 (254.60) and minimum was observed in G25 (131.8) (Table 8b) among 29 genotypes. The genotypes G14 (254.60) was found higher number of spikelet per panicle than checks the G28 (BRRI Dhan29) (198.60) and G29 (BRRI Dhan28) (178.9). Affirmative relationship between grain number per panicle and grain yield has been reported by number of human resources (Chauhan *et al*., 1986; Janagle *et al*., 1987' Kalaimani and Kadambavanaundaram, 1988).

4.1.10 Number of filled grains per panicle

From ANOVA table (Table 7b) significant difference were observed among 29 genotypes (2353.18**) at the level of 1% probability for number of filled grains per panicle. In 29 genotypes, the number of filled grains per panicle was recorded highest in G14 (219.2) and minimum was recorded in G12 (99.8) (Table 8b) (Figure 1). The genotypes G14 (219.2) was found higher number of filled grains per panicle than checks the G28 (BRRI Dhan29) (181.10) and G29 (BRRI Dhan28) (161.1). Similarly Tahir *et al*., (2002) observed greatly significant dissimilarity for the grain per panicle for dissimilar genotypes. Other factors i.e. soil fertility, plant nutrients, translocation and weather condition might also responsible.

4.1.11 Number of unfilled grains per panicle

Significant variations were observed among 29 genotypes (530.68**) at the level of 1% probability for number of unfilled grains per panicle. The G1 (61.90) and G4 (61.10) showed the highest number of unfilled grains per panicle among 29 genotypes where as the G24 (9.17) showed the minimum number of unfilled grains per panicle (Table 8b). The genotypes G11 (10.33), G19 (13.53) and G25

(13.90) was found lower number of unfilled grains per panicle than two checks varieties the G28 (BRRI Dhan29) (17.53) and G29 (BRRI Dhan28) (17.77).

4.1.12 Thousand seed weight (gm)

Significant variations were observed among 29 genotypes (10.04**) at the level of 1% probability for thousand seed weight. Among 29 genotypes, thousand seed weight was found maximum in G6 (28.07 gm) where as the minimum thousand seed weight was found in G14 (21.08 gm) (Table 8b).The genotypes G4 (26.40), G5 (25.81), G6 (28.07), G7 (27.24), G8 (27.58), G11 (27.58) and G24 (26.37) were found higher thousand seed weight than two checks the G28 (BRRI Dhan29) (22.40) and G29 (BRRI Dhan28) (24.29). Tahir *et al*., (2002), stated greatly significant dissimilarity among dissimilar character and found that these characters 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. Vijayakumar *et al*., (1997) and Hossain (2004) reported high correspondence between 1000 grain weight and grain yield per plant.

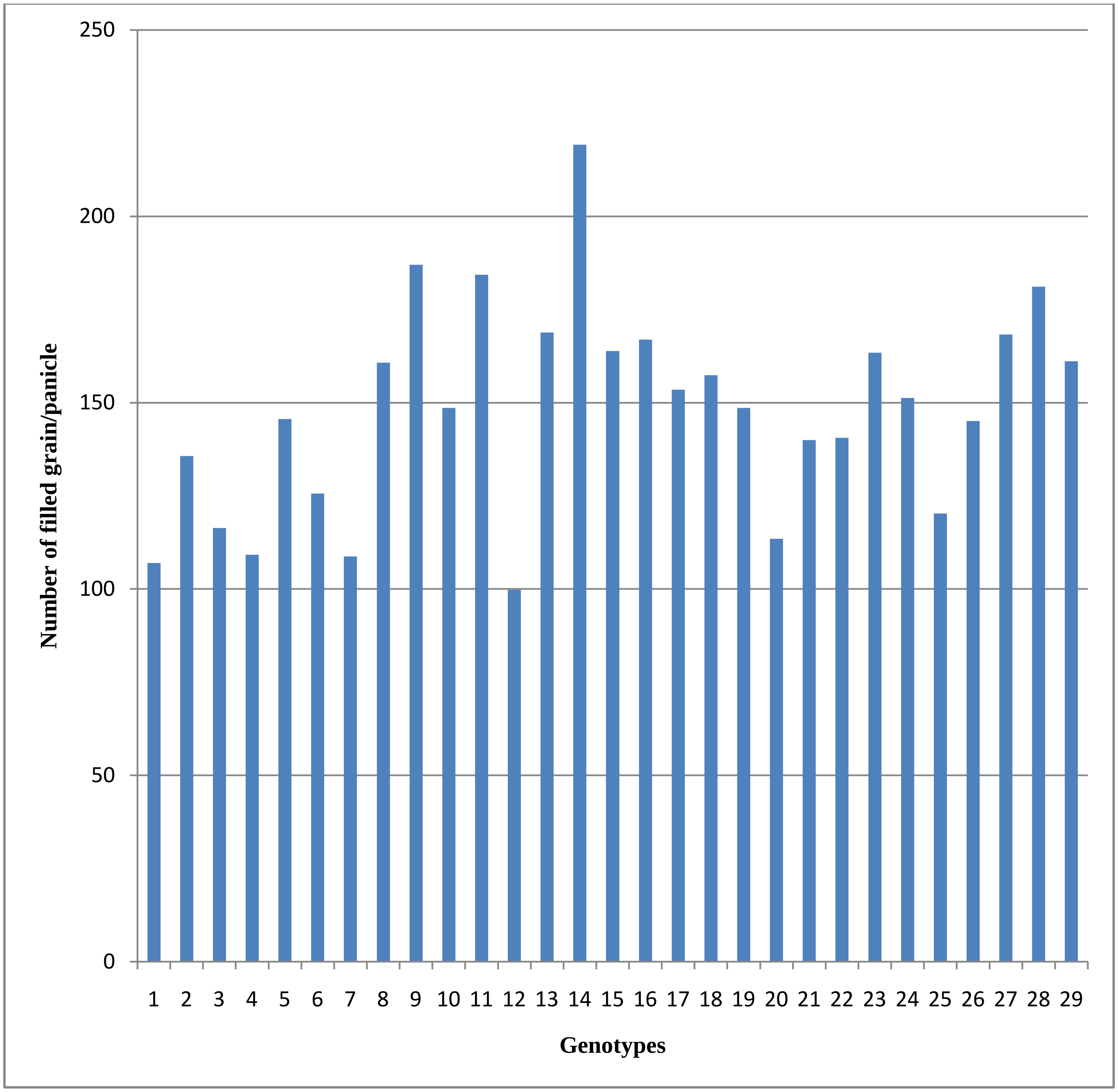

Figure 3. Mean performance of twenty nine genotypes in respect of number of filled grain per panicle

Table7a. Analysis of variances of fourteen important characters in respect of twenty nine genotypes of *Oryza sativa* L.

Source of variation	df	Mean sum of squares (MSS) characters									
		DF	DM	PH (cm)	NTT	NET	LP (cm)	NPB/P	NSB/P	TS/P	Y/H (t/ha)
Replication	2	3.81	10.48	31.80	1.24	2.18	0.06	0.96	5.87	1081.4	0.16
Genotype	28	25.62*	48.28**	283.15**	8.71**	8.80**	2.59**	3.27**	27.24**	1861.17**	5.93**
Error	56	2.76	7.78	22.53	2.32	2.47	0.65	0.74	7.24	288.07	1.30
CV%		1.37	1.91	4.58	10.42	11.31	3.45	8.42	9.22	9.79	16.83

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

DF = days to flowering, DM = days to maturity, PH = plant height, NTT = number of total tillers per plant, NET = number of effective tillers per plant, LP = panicle length, NPB/P = number of primary branches per panicle, NSB/P = number of secondary branches per panicle, TS/P = total number of spikelet per panicle

Table7b. Analysis of variances of fourteen important characters in respect of twenty nine genotypes of *Oryza sativa* L.

Source of variation	**df**	**Mean sum of squares (MSS)**				
		characters				
		NFG/P	NUFG/P	Y/P (gm)	TSW (gm	Y/H (t/ha)
Replication	2	495.001	223.52	45.76	2.06	0.16
Genotype	28	2353.18**	530.68**	181.61**	10.04**	5.93**
Error	56	284.54	91.07	28.92	2.74	1.30
CV%		11.40	37.61	15.31	6.85	16.83

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

NFG/P = number of filled grains per panicle, NUFG/P = number of filled grains per panicle, Y/P = yield per plant, TSW = thousand seed weight, Y/H = yield per hectare

Table 8a. Mean performance of twenty nine genotypes of *Oryza sativa* L. in respect of fourteen important characters

Genotype		DF	DM	PH (cm)	NTT	NET	LP (cm)	NPB/P
G1		124.00	151.30	102.00	14.77	13.67	21.59	8.20
G2		123.00	150.30	111.50	13.83	12.83	22.69	9.17
G3		127.00	152.70	111.30	15.17	13.87	22.19	9.00
G4		118.30	144.30	123.40	14.00	13.67	24.33	11.03
G5		119.70	143.70	106.00	13.80	13.30	23.20	9.97
G6		119.30	142.00	107.90	15.73	15.13	23.20	10.50
G7		118.00	145.30	116.70	12.53	11.10	23.12	9.63
G8		120.70	150.00	109.70	16.17	15.37	25.04	9.47
G9		119.00	144.00	103.20	13.40	12.97	22.92	10.90
G10		119.00	141.70	93.70	16.40	15.70	23.72	11.30
G11		119.30	142.70	102.00	12.80	12.07	23.40	12.90
G12		118.30	143.00	100.30	14.20	13.77	22.55	12.07
G13		125.70	151.00	109.50	12.27	11.40	21.42	10.23
G14		126.70	152.30	116.70	12.90	12.70	24.92	9.80
G15		126.30	149.00	102.80	14.43	13.70	23.73	10.37
G16		120.00	143.00	107.90	10.97	10.53	23.72	11.47
G17		121.00	143.00	104.50	14.63	14.53	24.35	10.60
G18		120.30	143.70	102.30	15.50	14.93	24.35	10.07
G19		121.00	141.30	94.10	15.80	14.80	23.08	9.63
G20		119.70	147.30	123.80	11.80	11.13	22.63	9.43
G21		119.00	143.70	102.90	15.17	13.37	23.46	9.30
G22		121.00	144.00	88.17	17.10	16.43	23.48	9.90
G23		123.30	144.00	87.23	14.57	13.47	24.36	10.83
G24		121.70	149.30	104.8	15.83	15.23	24.01	12.20
G25		121.00	145.70	86.38	18.93	18.27	21.91	9.00
G26		121.70	150.70	94.46	15.40	15.23	23.08	9.67
G27		120.70	147.30	101.60	16.53	15.47	23.90	10.13
G28		129.00	155.30	91.19	14.77	14.33	24.15	10.40
G29		122.00	141.30	100.60	15.27	14.57	24.32	10.27
Mean		121.58	146.31	103.68	14.64	13.92	23.41	10.26
Range	Max	129.00	155.30	123.80	18.93	18.27	25.04	12.90
	Min	118.00	141.30	86.38	10.97	10.53	21.42	8.20
LSD		2.72	4.56	7.76	2.50	2.57	1.32	1.41
CV%		1.37	1.91	4.58	10.42	11.31	3.45	8.42

DF = days to flowering, DM = days to maturity, PH = plant height, NTT = number of total tillers per plant, NET = number of effective tillers per plant, LP = panicle length, NPB/P = number of primary branches per panicle

Table 8b. Mean performance of twenty nine genotypes of *Oryza sativa* L. in respect of fourteen important characters

Genotype		NSB/P	TS/P	NFG/P	NUFG/P	Y/P (gm)	TSW (gm)	Y/H (t/ha)
G1		28.10	168.90	107.00	61.90	19.60	21.76	3.91
G2		30.67	159.70	135.70	24.00	30.33	22.50	5.53
G3		29.43	169.40	116.40	51.93	26.93	22.48	5.48
G4		28.60	170.30	109.20	61.10	29.87	26.40	6.17
G5		31.33	169.80	145.60	24.27	33.00	25.81	6.38
G6		24.90	146.80	125.60	21.17	38.80	28.07	7.42
G7		29.27	145.30	108.70	36.63	23.73	27.24	4.70
G8		30.50	180.20	160.70	19.50	54.07	25.84	10.19
G9		35.07	204.20	187.00	17.13	34.40	23.36	7.01
G10		27.27	171.00	148.60	22.17	31.67	21.41	6.81
G11		30.30	194.10	184.30	10.33	37.00	27.58	7.52
G12		25.83	132.70	99.80	33.07	26.07	25.24	5.59
G13		30.23	196.70	168.80	27.90	33.47	23.48	6.78
G14		38.03	254.60	219.20	35.40	35.40	21.08	7.21
G15		33.10	190.10	163.90	26.17	36.53	24.71	7.20
G16		28.70	187.60	166.90	19.97	33.13	22.85	6.45
G17		28.00	169.80	153.50	16.30	36.93	23.78	7.53
G18		27.03	172.80	157.40	15.73	38.20	23.17	7.67
G19		25.70	161.80	148.60	13.53	33.33	22.97	6.01
G20		28.77	141.50	113.50	27.97	22.33	24.37	4.45
G21		29.07	159.50	140.00	20.50	32.20	24.8	6.34
G22		27.13	157.10	140.60	16.53	39.93	24.92	5.59
G23		29.57	188.60	163.40	25.13	33.27	23.60	6.41
G24		27.20	160.50	151.30	9.167	49.63	26.37	9.23
G25		23.20	131.80	120.30	13.90	45.33	23.33	6.38
G26		28.50	171.50	145.10	21.80	44.73	23.93	8.16
G27		28.83	195.70	168.30	27.40	39.73	22.99	7.79
G28		33.30	198.60	181.10	17.53	44.07	22.40	9.13
G29		29.00	178.90	161.10	17.77	35.27	24.29	7.66
Mean		29.19	173.43	147.99	25.38	35.14	24.16	6.78
Range	Max	38.03	254.60	219.20	61.90	54.07	28.07	10.19
	Min	23.2	131.80	99.80	9.17	19.60	21.08	3.91
LSD		4.40	27.76	27.59	15.61	8.80	2.71	1.87
CV%		9.22	9.79	11.40	37.61	15.31	6.85	16.83

NSB/P = number of secondary branches per panicle, TSP = total number of spikelet per panicle, NFG/P = number of filled grains per panicle, NUFG/P = number of filled grains per panicle, Y/P = yield per plant, TSW = thousand seed weight, Y/H = yield per hectare

4.1.13 Yield per plant

Significant variations were observed among 29 genotypes (181.61**) at the level of 1% probability for yield per plant. Yield per plant was recorded highest in G8 (54.04gm) and the lowest was found in G1 (19.06g) (Table 8b). The G8 (54.04 gm) was found higher yield per plant than two checks varieties the G28 (BRRI Dhan29) (44.07) and G29 (BRRI Dhan28) (35.27). Varietal differences of grain yield were stated by Biswas *et al*., (1998). This dissimilarity in the grains yield might be due to the environment (Mahpattra, 1993) or the relationship of grain yield per plant with a range of yield causative characteristics like: number of grains per panicle, grain weight and correlation with these traits. The genotypes, which produced higher number of effective tillers per hill and higher number of grains per panicle also showed higher grain yield in rice (Kusutani *et al*., 2000).

4.1.14 Yield per hectare (t/ ha)

Significant variations were observed among 29 genotypes (5.93**) at the level of 1% probability for yield per hectare. Among the 29 genotypes G8 (10.19 t/ha) showed the maximum yield per hectare and the minimum one was in G1 (3.91 t/ha) (Table 8b). The G8 (10.19 t/ha) and G24 (9.23 t/ha) was found higher yield per hectare than two checks varieties the G28 (BRRI Dhan29) (9.13 t/ha) and G29 (BRRI Dhan28) (7.66 t/ha) but G8 (8.18 t/ha) was shown higher yield per hectare than checks varieties G29 (BRRI Dhan28) (7.66 t/ha). The performance of any line is finally estimated on the basis of grain yield, which in turn is the result of contributions by many characters. Hossain (2004) reported that higher biological yield does not always supply higher yield. He also suggested that it is enviable to select lines having higher spikelet fertility united with high biomass and harvest index, than those producing lower biological yield with higher harvest index.

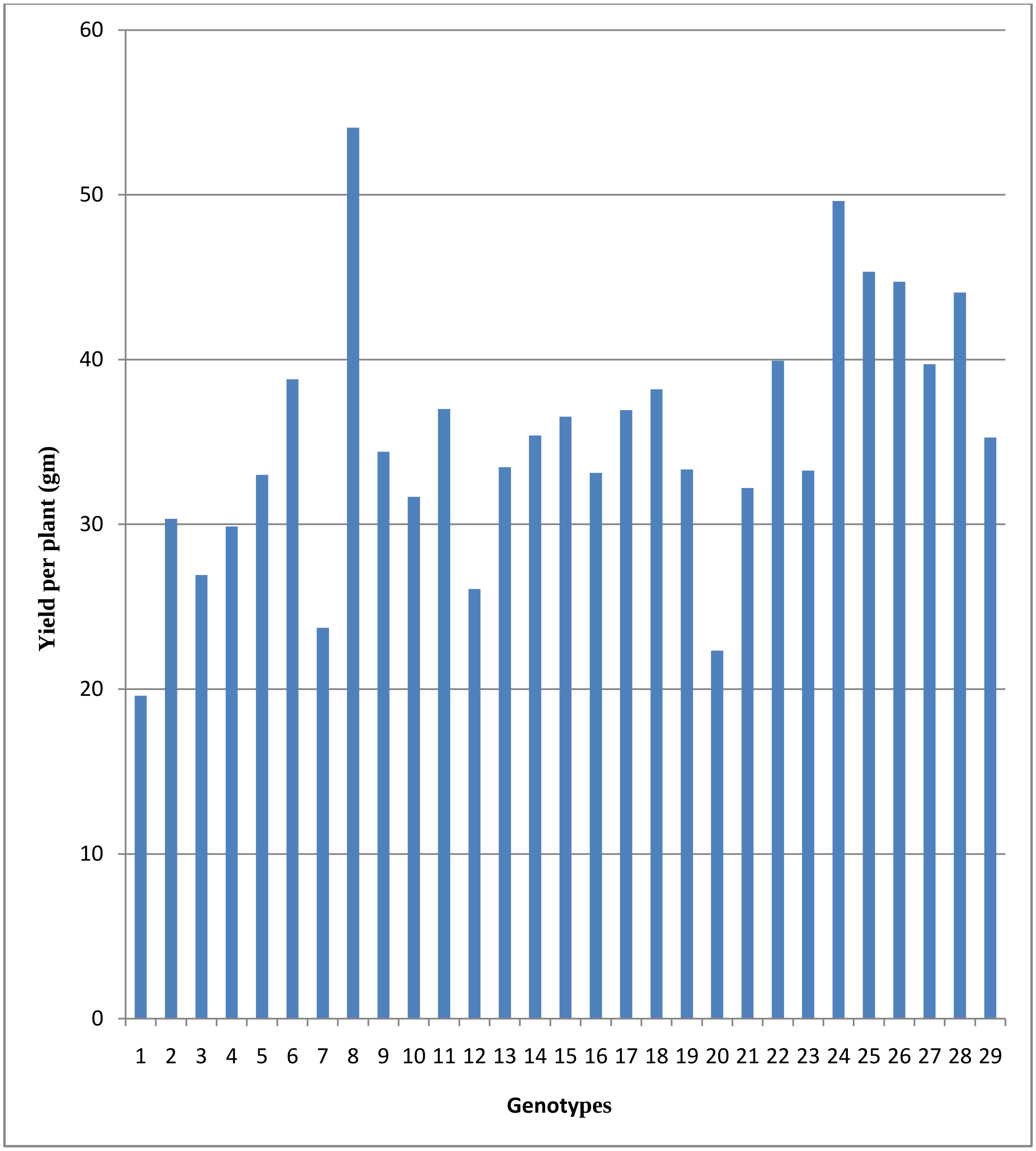

Figure 4. Mean performance of twenty nine genotypes in respect of yield per plant

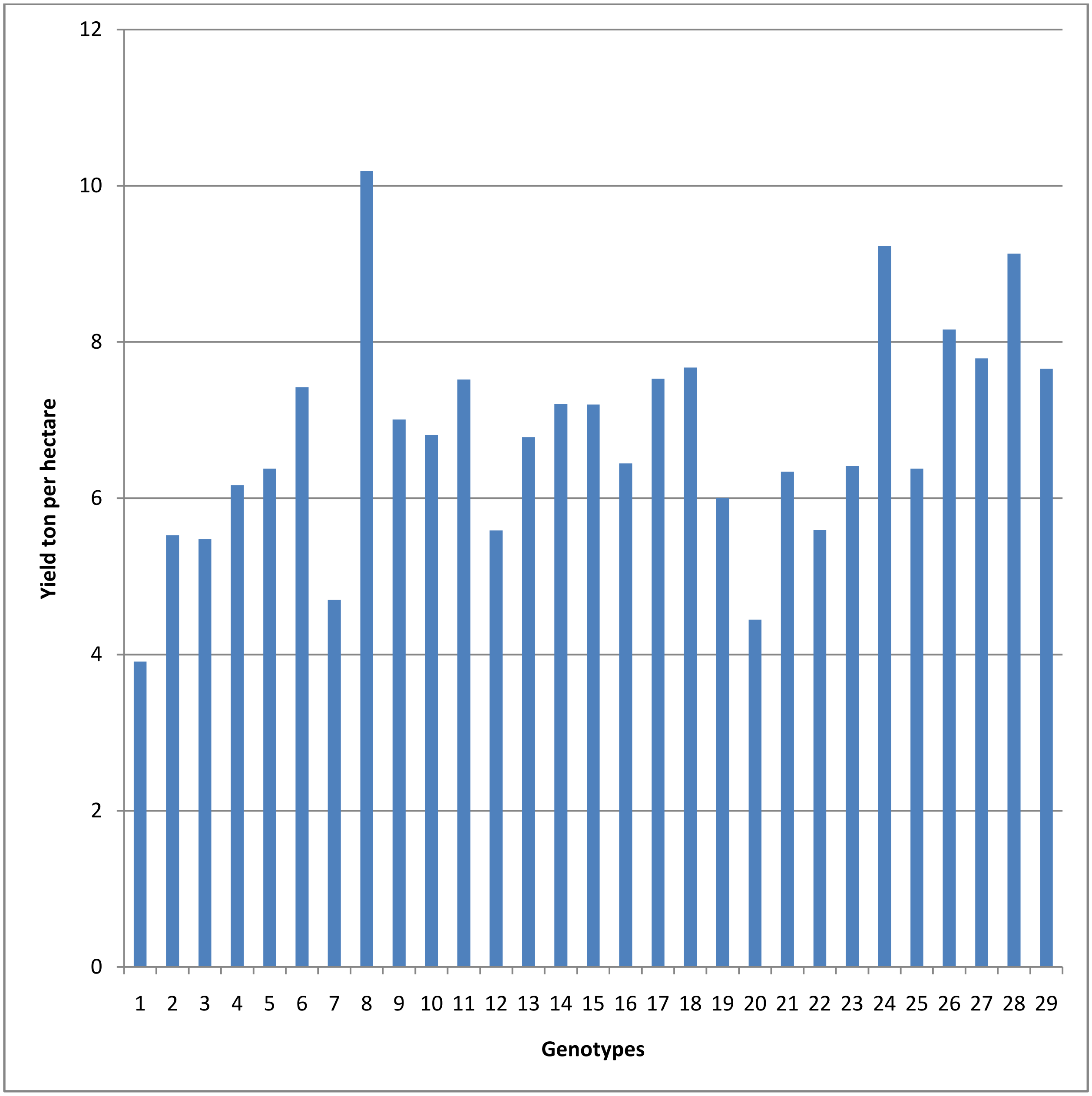

Figure 5. Mean performance of twenty nine genotypes in respect of yield ton per hectare

4.2 Assessment of milling and grain appearance

When rice is threshed, the hull (lemma and palea) leftovers unbroken- this is known as ‘rough rice’. The hull is detached (about 20% of the kernel weight) to turn out brown rice. Supplementary milling removes the cellulose (the seed coat, embryo, and some endosperm) to turn out powdered rice. A milled/powdered rice grain contains around 85% starch and 5% protein. The superiority of rice is determined by grain appearance, cooking quality and nutritional value. The grain is essential for farmers as it determines the market value and to clients as it determines their acceptability. Quality in rice is a permutation of numerous physico-chemical characters of the grain. The physical properties of the rice grain are determined by grain color, profile and size, grain weight, inflexibility of the endosperm, manifestation of the powdered kernels, hulling and milling recovery. Starch, proteins, minerals and vitamins make up the chemical components of the rice grain. The market value depends on physical attributes, while consumer’s first choice (cooking, eating and nutritive value) depends on chemical traits. Interestingly, both are inter-dependent.

4.2.1 Analysis of variances

The analysis of variance (ANOVA) presented in Table 9b showed some significant variation for all the milling quality characters studied. A wide range of variation was observed for characters like, milling per cent, hulling per cent, head rice recovery (HRR %). The present findings on wide variation for quality traits are in agreement with reports of Sood (1978) and Sandeep (2003).

The existence of wide range of variation for quality traits provides opportunity to choose advanced lines of desirable quality characteristics for development of variety. At the same time advanced lines can be improved for quality traits following appropriate breeding method.

4.2.2 Mean performance of quality characters (before cooking)

The results on mean performance of various quality characters before cooking of the lines and check variety have been presented characterized in table 10b and table 10c. The discussion is as follows:

4.2.2.1 Hulling (%)

Hulling of rice for different advanced line of rice varied significantly. Among 29 genotypes, the lowest hulling were observed in G26 (74.66) and highest was observed in G13 (78.13) (Table 10b). Whereas the G28 (BRRI Dhan29) (75.71) and G29 (BRRI Dhan28) (76.68) were recorded with hulling of rice. (Table 10b). Sandeep (2003) found 71.67% to 84.56% hulling per cent during characterization of 20 new plant type genotypes in rice.

4.2.2.2 Milling outturn (%)

The total yield of milled rice which can be obtained from a unit of rough rice is termed as milling recovery and is generally expressed in percentage (Khush *et al*., 1979). It assumes importance because it 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 from18 to 26 percent and the nature of alluron layer. Milling return of rice for different boro line of rice varied significantly. Among 29 genotypes, the highest Milling outturn were observed in G2 (69.80%), G24 (69.80%) and lowest was observed in G26 (66.53%) (Table 10c). Whereas the G28 (BRRI Dhan29) (67.13%) and G29 (BRRI Dhan28) (68.77%) were recorded with hulling of rice. The genotypes G3 (69.52%), G14 (69.65%), G19 (69.57%), G23 (69.64%) were shown higher milling outturn than two check varieties.

4.2.2.3 Head rice recovery (HRR %)

Head rice is the proportion of the whole grain in the milled rice. It depends on varietal characters as well as drying conditions (Adair *et al*., 1973). Head rice recovery of rice for different boro line of rice varied significantly. The highest value of head rice recovery was found in G10 (67.65%) and the lowest value was found in G7 (58.84%) (Table 10c).The G10 was shown higher head rice recovery than checks the G28 (BRRI dhan-29) (60.81%) and G29 (BRRI dhan-28) (66.40%). The genotypes G9 (67.38%) and G17 (67.18%) were shown higher value than two check varieties. 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 post harvest stages are known to influence grain breakage during milling (Shobha Rani, 2003). 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.

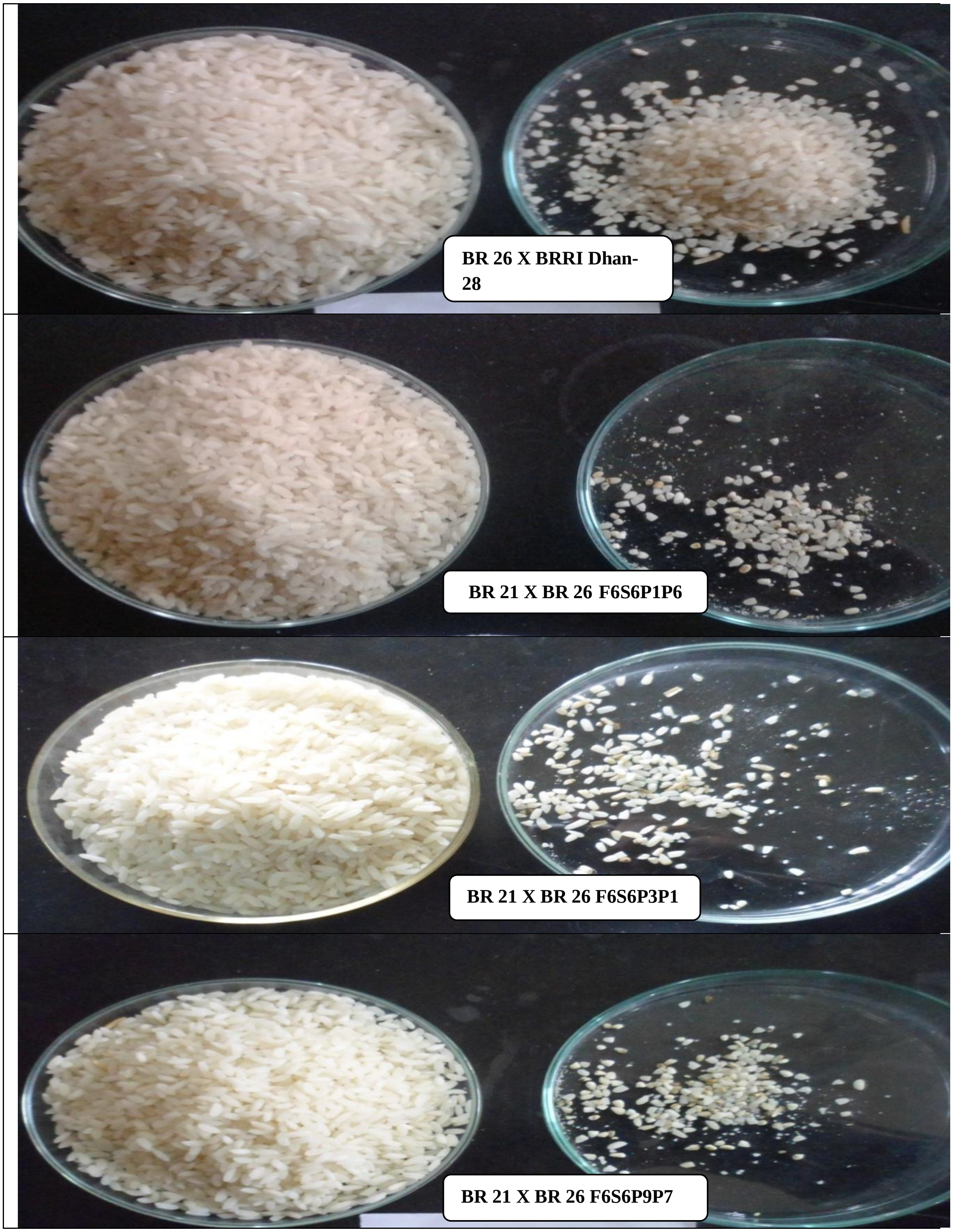

Plate 7: Photograph showing variation in Head rice recovery (HRR %)

Table 9a. Analysis of variances of nineteen important characters of quality in respect of twenty nine genotypes of *Oryza sativa* L.

Source of variation	df	Mean sum of squares (MSS)										
		Characters										
		(RR)(L) (mm)	(RR)(B) (mm) (mm)	(RR) (L/B)	(UR)(L)(mm)	(UR)(B)(mm)	(UR) (L/B)	(CR)(L)(mm)	(CR)(B)(mm)	(CR) (L/B)	KLR	EI
Replication	2	0.08	0.001	0.001	0.003	0.004	0.001	0.006	0.001	0.001	0.019	0.003
Genotype	28	1.07	0.058	0.32	0.69	0.051	0.332	0.904	0.236	0.219	0.015	0.03
Error	56	0.001	0.001	0.003	0.002	0.004	0.003	0.004	0.001	0.002	0.006	0.001
CV%		0.40%	0.40%	1.6%	0.23%	0.75%	2.03%	0.75%	0.79%	1.56 %	8.99%	2.51 %

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

RR(L) = Length of rough rice, RR(B) = Breadth of rough rice, L/B(RR) = L/B ratio of rough rice, UR(L) = Length of uncooked rice, UR(B) = Breadth of uncooked rice, L/B(UR) = L/B ratio of uncooked rice, CR(L) = Length of cooked rice, CR(B)= Breadth of cooked rice, L/B(CR) = L/B ratio of cooked rice, KLR= Kernel elongation ratio, EI = Elongation index

Table 9b. Analysis of variances of nineteen important characters in respect of twenty genotypes of *Oryza sativa* L.

Source of variation	**df**	**Mean sum of squares (MSS)**							
		Characters							
		VE (%)	WA (%)	Hu(%)	MU (%)	HRR (%)	ASV	Amylose (%)	Protein (%)
Replication	2	2.586	0.738	0.012	0.027	0.184	0.242	1.7	0.078
Genotype	28	339.503**	9670.150**	2.359**	2.005**	20.354**	2.198**	3.2**	0.725
Error	56	0.779	0.609	0.006	0.016	0.189	0.443	0.413	0.029
CV%		3.27%	0.41%	0.10%	0.19%	0.68%	11.24%	2.53%	2.16%

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

VE = Volume expansion, WA = Water absorption, Hu = Hulling, MU = Milling outturn, HRR = Head rice recovery, ASV = Alkali spreading value

Table 10a. Mean performance of twenty nine genotypes of *Oryza sativa* L. in respect of nineteen important quality characters

Genotype		RR(L) (mm)	RR(B) (mm)	RR (L/B)	UR(L) (mm)	UR(B) (mm)	UR (L/B)	CR(L) (mm)
G1		7.91	2.34	3.39	6.003	2.19	2.74	7.12
G2		8.22	2.73	3.01	6.003	2.38	2.52	7.80
G3		8.49	2.67	3.15	6.32	2.32	2.72	7.65
G4		9.17	2.49	3.70	7.24	2.23	3.27	7.91
G5		8.90	2.86	3.11	6.09	2.46	2.53	7.51
G6		9.46	2.76	3.44	6.73	2.30	2.92	9.003
G7		9.49	2.52	3.78	6.33	2.26	2.80	8.47
G8		8.80	2.65	3.33	6.95	2.44	2.84	7.89
G9		8.18	2.79	2.93	5.54	2.29	2.42	7.86
G10		7.89	2.65	2.98	5.89	2.27	2.55	7.22
G11		8.20	2.67	3.08	5.76	2.36	2.45	6.88
G12		7.29	2.60	2.86	6.35	2.31	2.75	8.26
G13		8.92	2.63	3.40	6.41	2.26	2.79	8.65
G14		8.83	2.46	3.59	6.45	2.18	2.80	7.69
G15		8.73	2.46	3.56	6.90	2.22	3.15	8.50
G16		9.14	2.56	3.57	6.35	2.35	2.7	7.51
G17		9.22	2.45	3.77	6.24	2.14	2.91	8.12
G18		8.84	2.50	3.53	6.43	2.22	2.89	7.77
G19		8.76	2.46	3.57	6.54	2.13	3.07	8.16
G20		8.59	2.55	3.22	6.58	2.33	2.82	9.01
G21		9.29	2.42	3.88	6.98	2.21	3.17	7.58
G22		9.69	2.46	3.93	7.37	2.24	3.28	8.03
G23		9.22	2.44	3.77	6.86	2.23	3.07	8.53
G24		9.94	2.65	3.74	7.29	2.44	2.99	8.007
G25		9.41	2.38	3.94	6.99	2.00	3.49	8.63
G26		9.33	2.75	3.40	6.86	2.11	3.30	8.16
G27		9.36	2.35	4.01	7.26	1.84	3.94	8.98
G28		8.69	2.51	3.42	6.17	2.2	2.82	8.29
G29		9.16	2.64	3.48	6.45	2.31	2.79	8.31
Mean		8.86	2.57	3.47	6.53	2.25	2.91	8.05
Range	Max	9.94	2.86	4.01	7.37	2.46	3.94	9.01
	Min	7.29	2.34	2.86	5.54	1.84	2.42	6.88
LSD		0.52	0.02	0.90	0.05	0.05	0.09	0.10
CV%		0.43%	0.40%	1.61%	0.23%	0.75%	2.03%	0.75%

RR (L) = Length of rough rice, RR(B) = Breadth of rough rice, L/B(RR) = L/B ratio of rough rice, UR(L) = Length of uncooked rice, UR(B) = Breadth of uncooked rice, L/B(UR) = L/B ratio of uncooked rice, CR(L) = Length of cooked rice

Table 10b. Mean performance of twenty nine genotypes of *Oryza sativa* L. in respect of nineteen important characters

Genotype		CR(B) (mm)	CR(L/B) (mm)	KLR	EI	VE	WA	Hu
G1		2.71	2.63	0.95	0.99	40.90	187.10	75.14
G2		2.99	2.62	0.94	0.98	20.67	160.20	76.00
G3		2.59	2.96	0.95	0.98	21.90	81.10	76.52
G4		2.59	3.06	0.92	1.08	21.73	109.60	76.99
G5		2.92	2.62	0.81	1.00	26.97	216.90	75.92
G6		2.94	3.06	0.75	0.96	26.10	186.70	76.54
G7		3.15	2.70	0.74	1.04	39.13	233.60	75.79
G8		2.64	2.98	0.88	0.95	53.84	230.70	75.90
G9		3.27	2.38	0.72	1.02	45.70	285.30	76.28
G10		2.58	2.82	0.82	0.93	12.50	168.10	75.76
G11		2.85	2.41	0.84	1.02	30.40	149.30	75.69
G12		3.13	2.68	0.77	1.05	30.43	186.10	75.40
G13		2.87	3.02	0.74	0.94	29.17	213.70	78.13
G14		2.72	2.85	0.83	1.05	20.00	256.40	77.75
G15		2.77	3.10	0.82	1.03	32.00	216.70	76.55
G16		2.79	2.70	0.84	1.005	34.78	160.00	75.47
G17		2.91	2.79	0.76	1.04	16.00	228.10	75.87
G18		2.52	2.95	0.82	0.93	12.50	116.30	75.87
G19		2.60	3.17	0.80	0.97	24.00	176.20	77.95
G20		3.67	2.48	0.74	1.14	41.67	348.80	76.48
G21		2.86	2.66	0.92	1.19	16.00	178.90	76.06
G22		2.66	3.02	0.91	1.08	26.09	163.50	76.73
G23		3.33	2.60	0.79	1.19	40.00	257.60	77.34
G24		2.98	2.73	0.91	1.12	20.83	115.10	77.95
G25		2.73	3.17	0.80	1.10	12.50	203.80	76.13
G26		2.54	3.23	0.84	1.02	16.67	152.50	74.66
G27		3.02	3.09	0.81	1.32	29.17	180.00	75.12
G28		2.34	3.54	0.74	0.79	20.20	186.60	75.71
G29		2.83	2.99	0.78	0.94	20.80	126.90	76.68
Mean		2.84	2.86	0.83	1.03	26.98	188.82	76.29
Range	Max	3.67	3.54	0.95	1.32	53.84	348.8	78.13
	Min	2.34	2.38	0.72	0.79	12.50	81.10	74.66
LSD		0.05	0.07	0.13	0.05	1.44	1.28	0.13
CV%		0.79%	1.56%	8.99%	2.51%	3.27%	0.41%	0.10%

CR (B)= Breadth of cooked rice, L/B(CR) = L/B ratio of cooked rice, KLR= Kernel elongation ratio, EI = Elongation index, VE = Volume expansion, WA = Water absorption, Hu = Hulling

Table 10c. Mean performance of twenty nine genotypes of *Oryza sativa* L. in respect of nineteen important characters

Genotype		MU	HRR	ASV	Amylose	Protein
G1		68.09	64.18	4.60	24.67	7.90
G2		69.80	62.34	6.60	24.33	7.90
G3		69.52	65.39	7.00	26.23	7.90
G4		67.68	65.69	6.70	25.37	7.90
G5		68.39	60.18	7.00	24.67	7.90
G6		68.75	63.03	6.60	25.50	7.90
G7		68.24	58.84	7.00	25.33	7.90
G8		67.78	60.92	5.36	25.33	7.90
G9		68.59	67.38	5.10	24.00	7.90
G10		68.65	67.65	4.80	26.00	7.90
G11		67.88	66.93	5.30	26.50	7.90
G12		68.13	64.22	7.00	24.20	7.90
G13		68.89	61.36	5.50	25.70	7.90
G14		69.65	61.74	4.80	23.50	7.90
G15		68.79	63.64	5.10	27.50	7.90
G16		67.51	64.87	5.50	25.00	7.90
G17		68.48	65.26	6.00	25.80	7.90
G18		68.48	67.18	6.00	25.80	7.90
G19		69.57	66.80	5.60	23.70	7.60
G20		68.02	59.67	7.00	24.20	8.30
G21		68.44	60.55	6.80	24.90	7.30
G22		67.59	65.11	5.20	26.00	8.50
G23		69.64	65.09	5.00	25.50	7.90
G24		69.80	66.50	6.30	26.40	7.20
G25		67.83	63.78	7.00	24.50	7.90
G26		66.53	62.97	7.00	25.40	7.70
G27		68.44	60.83	5.70	25.90	7.70
G28		67.13	60.81	4.80	26.80	8.50
G29		68.77	66.40	5.23	27.50	7.20
Mean		68.45	63.77	5.92	25.39	7.86
Range	Max	69.80	67.65	7.00	27.50	8.50
	Min	66.53	58.84	4.60	23.50	7.20
LSD		0.21	0.71	1.09	1.05	0.28
CV%		0.19%	0.68%	11.24%	2.53%	2.16%

MU = Milling outturn, HRR = Head rice recovery, ASV = Alkali spreading value

4.2.2.4 Grain dimension

The milling and saleable qualities depend basically upon the size and shape of the grain. Grain dimension is expressed as length, breadth and thickness, where as shape is generally expressed as ratio between the length and breadth. With respect to grain dimension, dissimilarity is found in equipment studied, as we can see from performance of each genotype (Table 11). Grain size and shape are among the first criterion of rice quality that breeders think about in emergent new varieties for discharge for profit-making (Adair, *et al*., 1973). Grain length is an main physical property, which attracts consumer's attention. The people of Bangladesh like long, slender, shiny grain. Length and breadth ratio of the grains indicates the fine quality of the grain.

The appearance of milled rice is important to the consumer, which in turn assumes importance to the producer and miller. Therefore grain size and shape of milled rice are the foremost characteristics of rice quality that breeders consider in developing new varieties for release commercial production (Adair *et al*., 1966). Preference for grain size and shape vary from one group of consumers to another. Some ethnic groups prefer short bold grains, while medium and long slender grains are preferred by others. In general, medium to long grains are preferred in the Indian subcontinent while the country is also replete with hundreds of short grain aromatic types and long basmati types the later commanding highest premium in both domestic and international markets. In temperate areas short grain varieties of japonica types are prevalent. Extra long grain types are preferred in Thailand. While grain size and shape of milled rice can be visually classified, more precise measurement are needed for classification and for critical comparison of hybrids/ lines. In present study, the grain shape and size are characterized following Ramaiah Committee classification (1965). The lines or hybrids are classified into long slender (LS), short slender (SS), long bold (LB) and short bold (SB). In the present study, some genotypes G4, G15, G19, G21, G22, G23, G24, G25, G26, G27 are long slender. Two check variety BRRI Dhan-28, BRRI dhan- 29 and some genotypes G1, G2, G3, G5, G7, G8, G10, G12, G13, G14, G16, G20 are medium slender. Genotypes G6, G17, G18 are long bold and G9, G11 are short bold.

Table 11. Classification of grain types of Boro lines and check variety on the basis of systematic classification of rice proposed by Ramaiah Committee (1965)

Long slender (LS) (Length 6 mm & above L/B ratio 3 and above)	**Short Slender (SS) (Length less than 6 mm L/B ratio 3 and above)**	**Medium Slender (MS) (Length 6 mm & above L/B ratio 2.5 to 3.0)**	**Long Bold (LB) (Length 6 mm & above L/B ratio less than 3.0)**	**Short Bold (SB) (Length less than 6 mm L/B ratio less than 2.5)**
G4, G15	-	G1, G2, G3	G6	G9
G19, G21	-	G5, G7, G8	G17	G11
G22, G23	-	G10, G12, G13	G18	
G24, G25	-	G14, G16, G20		
G26, G27	-	G28, G29		

4.2.2.5 Length, Breadth and L/B ratio of rough rice

Shoba Rani (2003) reported that bold grains give low head rice recovery because of high breakage. Grains with short to medium long grains break less than long grains during milling. Thus grain size and shape have direct effect on yield of head rice. Length, breadth and their ratio of rough rice for different line of Boro rice varied non- significantly (Table 9a). The highest length of rough rice was taken in G24 (9.94 mm) and the lowest length of rough rice was taken in G12 (7.29 mm) among 29 genotypes (Table 10a). The G24 was shown higher length of rough rice

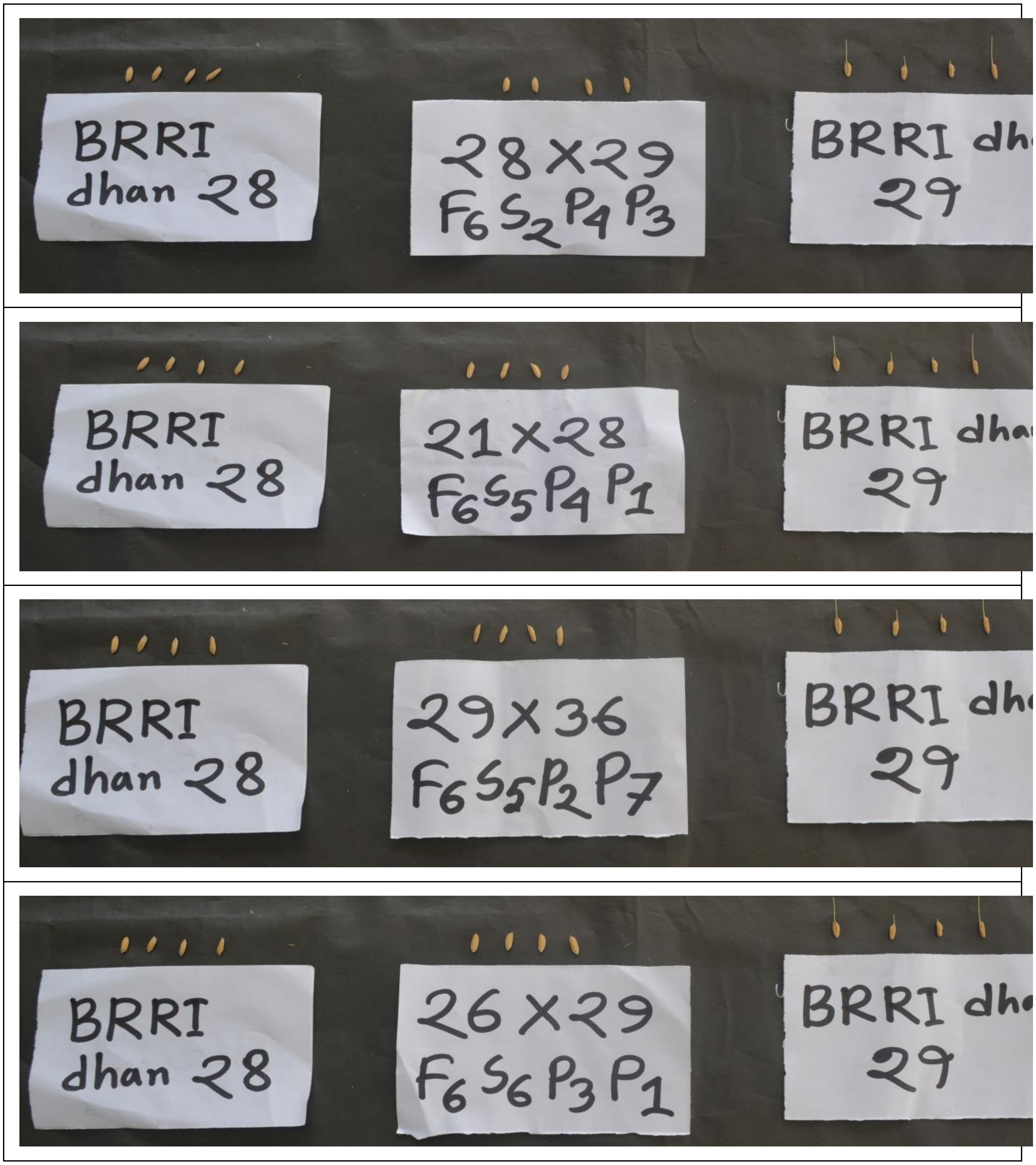

Plate 8: Photograph showing length, breadth of rough rice different genotypes with parents

than checks the G28 (BRRI dhan-29) (8.69mm) and G29 (BRRI dhan-28) (9.16mm). Among 29 genotypes, the lowest breadth of rough rice were observed in G1(2.34mm) which is very closed to G25(2.38mm),G27(2.35mm) and highest was observed in G5(2.86)(Table 10a). Whereas the G28 (BRRI dhan-29) (2.51mm) and G29 (BRRI dhan-28) (2.64mm) were recorded with breadth of rough rice. The G1, G25 and G27 were shown lower breadth of rough rice than the two checks varieties. Among 29 genotypes, the genotype G27 (4.01) was shown higher L/B ratio of rough rice than two checks the G28 (BRRI dhan-29) (3.42) and G29 (BRRI dhan-28) (3.48) and the minimum one was in G12 (2.86) (Table 10a). Vraktamath (1987) observed that kernel breadth enhanced the milling output and HRR was strongly associated with milling percentage.

4.2.2.6 Length, Breadth and L/B ratio of uncooked rice:

Length, breadth and their ratio of uncooked rice for different line of Boro rice varied non- significantly (Table 9a). The highest length of uncooked rice was taken in G22 (7.37 mm) and the lowest length of uncooked rice was taken in G1 (6.03mm) and G2 (6.03mm) which are near to G5 (6.09mm) among 29 genotypes (Table 10a). The G22 was shown higher length of uncooked rice than checks the G28 (BRRI dhan-29) (6.17mm) and G29 (BRRI dhan-28) (6.45mm). Among 29 genotypes, the lowest breadth of uncooked rice were observed in G27 (1.84mm) and highest was observed in G5 (2.46mm) and G8 (2.44mm) (Table 10a). Whereas the G28 (BRRI dhan-29) (2.20mm) and G29 (BRRI dhan-28) (2.31mm) were recorded with breadth of rough rice. The G12 (2.31mm) shown the same result as check variety G29 (BRRI dhan- 28) and G2 (2.38), G3 (2.32), G11 (2.36), G16 (2.35), G20 (2.33) were shown higher breadth of rough rice than the two check varieties. Among 29 genotypes, the highest ratio of uncooked rice were observed in G27 (3.94) and lowest was observed in G9 (2.42) which are similar to

Plate 9: Photograph showing length, breadth of uncooked and cooked rice of different genotypes with parents

G2 (2.55), G5 (2.53), G10 (2.55) and G11 (2.45) (Table 10a). Whereas the G28 (BRRI Dhan-29) (2.82) and G29 (BRRI Dhan-28) (2.79) were recorded with L/B ratio of uncooked rice. The G13 (2.79) shown the same result as check variety G29 (BRRI Dhan- 28) and G4 (3.27), G15 (3.15), G19 (3.07), G21 (3.17), G22 (3.28), G23 (3.07), G25 (3.49), G26 (3.30) were shown higher L/B ratio of uncooked breadth of rice than the two check varieties.

4.3 Cooking and eating characteristics of the grain

4.3.1 Analysis of variances

The analysis of variance (ANOVA) presented in Table 9a and 9b showed both significant and non-significant variation for all the milling quality characters studied. A wide range of variation was observed for characters like, length, breadth, L/B ratio of cooked rice, kernel elongation ratio, water uptake (%), volume expansion (%) and alkali spreading value, amylose and protein. The present findings on wide variation for quality traits are in agreement with reports of Sood (1978) and Sandeep (2003).

4.3.2 Mean performance of quality characters

The results on mean performance of various quality characters after cooking of the lines and check variety have been presented characterized in Table 10b and 10c. The discussion is as follows:

4.3.2.1 Length, breadth and ratio of cooked rice

Length, breadth and their ratio of cooked rice for different Boro line varied non-significantly (Table 9a). The highest length of cooked rice was taken in G6 (9.03 mm), G20 (9.01mm), G27 (8.98mm) and the lowest length of cooked rice was taken in G11 (6.88mm) (Table 10a). The G6 was shown higher length of cooked rice than checks the G28 (BRRI dhan-29) (8.29mm) and G29 (BRRI dhan-28)

(8.31mm). Among 29 genotypes, the lowest breadth of cooked rice were observed in G28 (BRRI dhan- 29) (2.34mm) and highest was observed in G20 (3.67mm) (Table 10b). Whereas the G28 (BRRI Dhan-29) shown lowest breadth and G29 (BRRI dhan-28) (2.83mm) were recorded with breadth of cooked rice. The genotypes G7 (3.15mm), G9 (3.27mm), G12 (3.13mm), G23 (3.33mm), G27 (3.02mm) were shown higher breadth of cooked rice than the two check varieties (Table 10b). The highest L/B ratio of cooked rice was taken in G28 (BRRI dhan-29) (3.54) and the lowest L/B ratio of cooked rice was taken in G9 (2.38) (Table 10b). The G4 (3.06), G6 (3.06), G13 (3.02), G15 (3.10), G19 (3.17), G22 (3.02), G25 (3.17), G26 (3.23) and G27 (3.09) were shown higher L/B ratio of cooked rice than checks the G29 (BRRI dhan-28) (2.99) but lower than G28 (BRRI dhan-29) (3.54) (Table 10b).Some rices show extreme elongation on cooking particularly in presoaked grains while most in most varieties the expansion is relatively more breadth wise (Azeez and Shafi, 1986; Juliano, 1972 and Sadhukhan and Chattopadhay, 2001). Shoba Rani (2003) reported kernel length after cooking of nine released hybrids of India ranging from 10.2 to 12.4 mm. Soroush *et al.*, (1995) showed cooked kernel length 10.62 to 12.32 mm. Sandeep (2003) found kernel length/ breadth ratio after cooking of 20 new plant type genotypes which was ranged from 2.04 to 3.95. Soroush *et al*., (1995) showed L/B ratio of cooked kernel 3.69 to 4.30.

4.3.2.2 Kernel elongation ratio

Kernel elongation ratio for different line of Boro rice varied non-significantly (Table 9a). The highest ratio of kernel elongation was found in G3 (0.96) and the lowest ratio of kernel elongation was found in G9 (0.72) (Table 10b). The G3 was shown higher ratio of kernel elongation than checks the G28 (BRRI dhan-29) (0.74) and G29 (BRRI dhan-28) (0.78). The genotypes G1 (0.95), G2 (0.94), G4 (0.92), G21 (0.92), G22 (0.91), G24 (0.91) were shown higher ratio than two check varieties. Kernel Elongation ratio (L_1 /L_0) is a measure of kernel elongation upon cooking resulting from swelling of starch granules by uptake of water (Juliano, 1979). Pilaiyar (1988) proposed elongation ratio to be best index of quality compared to elongation index and proportionate change. Significant association of L/B ratio with kernel elongation was reported by Deosarker and Nerker (1994). Chauhan *et al*. (1995) pointed out significant positive correlation between kernel elongation and cooked kernel length. Kernel elongation was primarily influenced by kernel shape and size.

4.3.2.3 Elongation index

Elongation index for different line of Boro rice varied non-significantly (Table 9a). The highest index found in G27 (1.32) and lowest in G28 (0.79).

4.3.2.4 Water absorption (%)

Water absorption for different advanced line of rice varied significantly (Table 9b). The highest value of water absorption was found in G20 (348.80) and the lowest value of water absorption was found in G3 (81.10) (Table 10b). The G20 was shown higher ratio of water absorption than checks the G28 (BRRI dhan-29) (186.60) and G29 (BRRI dhan-28) (126.9). The genotypes G5 (216.90), G7 (233.60), G4 (0.92), G21 (0.92), G22 0.91), G24 (0.91) were shown higher ratio than two check varieties. Water uptake is considered an important economic attribute of rice as it gives indirect measure of volume increase on cooking. Water uptake shows a positive and significant influence on grain elongation, while volume expansion did not influence grain elongation as reported by Sood and Siddiq (1986). Earlier studies of rice in general suggested the extent of variation for this character to range between 194 to 250% (Juliano *et al*., 1965; Juliano *et al*., (1969). Hogan and Planck (1958) observed that shot and medium grain varieties of the USA have high water absorption as compared to long grain types. Sood and Siddiq (1980) have reported still wider range (74-439%) of variation for this character. 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.

4.3.2.5 Volume expansion (%)

Volume expansion for different advanced line of rice varied significantly (Table 9b). Among 29 genotypes, the highest volume expansion of rice were observed in G8 (53.84) and lowest was observed in G18 (12.50) and G25 (12.50) (Table 10b). Whereas the G17 (16.00) and G21 (16.00) same lowest volume expansion. G28 (BRRI dhan-29) (20.20) and G29 (BRRI dhan-28) (20.80) were recorded with volume expansion of rice. The genotypes G1 (40.90), G7 (39.13), G9 (45.70), G11 (30.40), G12 (30.43), G15 (32.00), G16 (34.78), G20 (41.67), G23 (40.00) were shown higher volume expansion of rice than G28 (BRRI dhan-29) (20.20) and G29 (BRRI dhan-28) (20.80) (Table 10b). Volume expansion of kernels on cooking is considered another important measure of consumer preference. More volume of cooked rice from a given quantity is a matter of great satisfaction to an average rice consumer irrespective of the fact whether the increased volume is due to length-wise or breadth-wise expansion. 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.

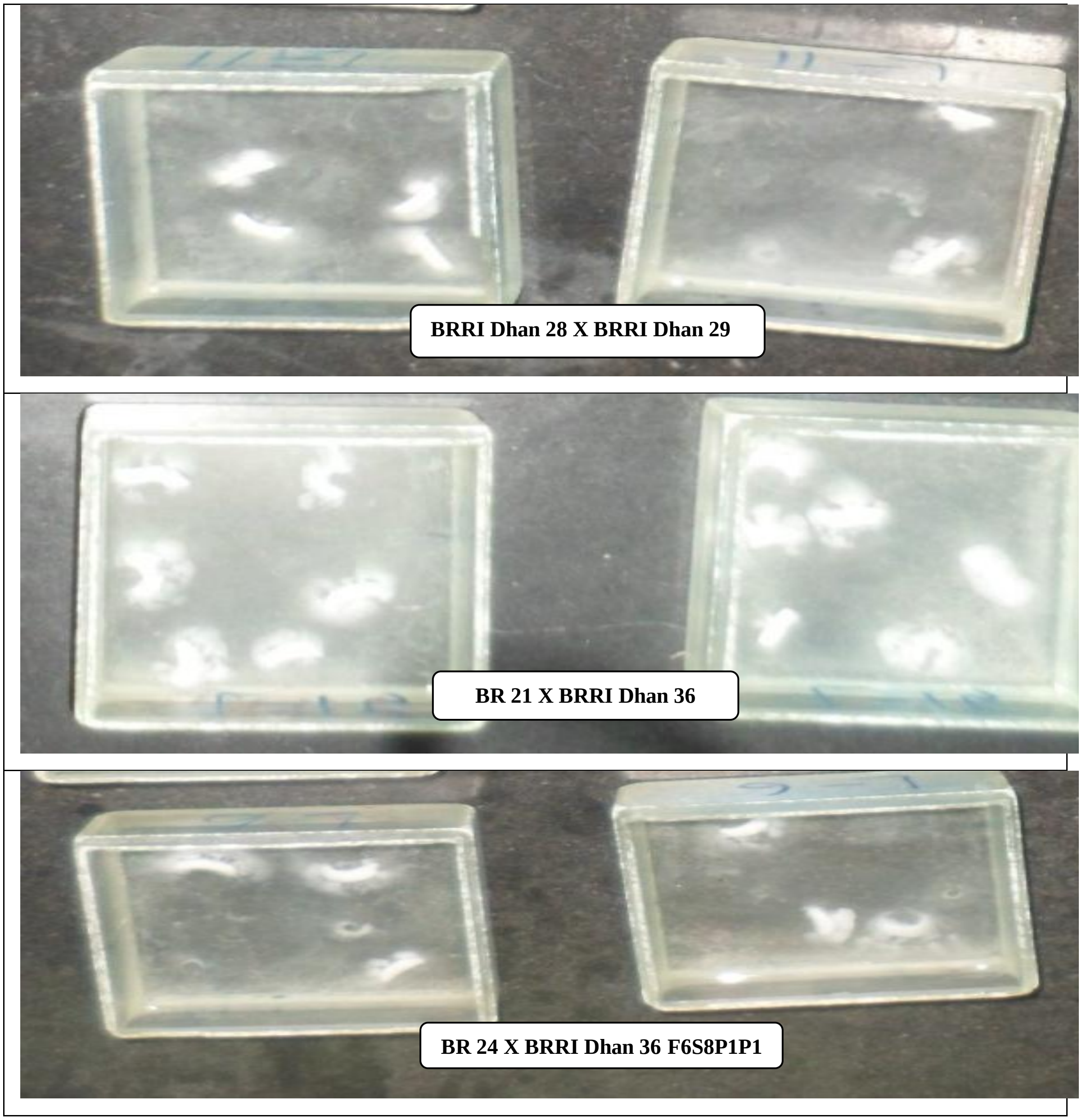

Plate 10: Photograph showing variation in alkali spreading value

4.3.2.6 Alkali spreading value (ASV)

Alkali spreading value is inversely related to gelatinization temperature. It is the range of temperature within which granules begin to swell irreversibly in hot water. 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. In the present study, statistically significant variation was recorded for alkaline spreading value for different Boro line of rice (Table 9b). Among 29 genotypes, the highest alkali spreading value were observed in G3 (7.00), G5 (7.00), G7 (7.00), G12 (7.00), G20 (7.00), G25 (7.00), G26 (7.00) and lowest was observed in G1 (4.6) (Table 10c). Whereas the G28 (BRRI dhan-29) (4.8) and G29 (BRRI dhan-28) (5.23) were recorded with alkali spreading value of rice. 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) (Beachell and Stansel, 1963; Juliano *et.al*., 1965; Kongseree 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.

Table 12: Classification of different Boro lines and check varieties on the basis of alkali spreading score, alkali spreading value and GT types

Lines	Alkali spreading value	Alkali digestion	GT types
G1	4.5	Intermediate	Intermediate
G2	6.5	High	Low
G3	7.0	High	Low
G4	6.9	High	Low
G5	7.0	High	Low
G6	6.8	High	Low
G7	7.0	High	Low
G8	5.2	Intermediate	Intermediate
G9	5.0	Intermediate	Intermediate
G10	4.8	Intermediate	Intermediate
G11	5.3	Intermediate	Intermediate
G12	7.0	High	Low
G13	5.5	Intermediate	Intermediate
G14	4.8	Intermediate	Intermediate
G15	5.1	Intermediate	Intermediate
G16	5.5	Intermediate	Intermediate
G17	6.0	High	Low
G18	5.8	Intermediate	Intermediate
G19	5.6	Intermediate	Intermediate
G20	7.0	High	Low

G21	6.8	High	Low
G22	5.2	Intermediate	Intermediate
G23	5.0	Intermediate	Intermediate
G24	6.3	High	Low
G25	7.0	High	Low
G26	7.0	High	Low
G27	5.7	Intermediate	Intermediate
G28	4.8	Intermediate	Intermediate
G29	5.2	Intermediate	Intermediate

4.3.2.7 Amylose content

In the present study, statistically significant variation was recorded for amylose percentage for different Boro line of rice (Table 9b). Amylose content strongly influences the cooking and eating characteristics of rice. Rice with a high amylose content (25-30%) tends to cook firm and dry, whereas rice with a intermediate amylose content (20-25%) tends to be softer and stickier and rice with a low amylose content (<20%) is generally quite soft and sticky. Waxy rice has a zero amylose content and is often referred to as sticky rice. Japonica rice tends to be low amylose, tropical japonica tends to be intermediate or high and Indica rices fall into all the amylose classes.

During the cooking process, the starch granules in the grain expand and amylose leaches from them. As the cooked rice cools, the leached amylose chains line up, lock together and form a gel. In theory, the higher the amylose content of rice, the firmer the cooked grain of rice will be. Amylose is also responsible for the way that rice hardens on cooling. When rice cools to room temperature or beyond, the chains of amylose crystallize. This phenomenon is called retrogradation. Retrogradation is also related to proteins. The gel seems to be strengthened by proteins.

Among 29 genotypes, the lowest amylose were observed in G14 (23.50) and highest was observed in G15 (27.5) and G29 (BRRI Dhan 28) (27.5) (Table 10c). Whereas the G28 (BRRI Dhan29) (26.80) were recorded with amylase of rice.

Frei *et al.* (2003) report great variations in the amylose: amylopectin ratio in rice grains of different varieties that allow their classification as waxy (1-2% amylose), very low amylose content (2-12%), low amylose content (12-20%), intermediate amylose content (20-25%) and high amylose content (25-33%).Considering the metabolic effects, Frei *et al.* (2003) report that starchy foods with high amylose levels are associated with lower blood glucose levels and slower emptying of the human gastrointestinal tract compared to those with low levels of this macromolecule. These conditions are relevant, especially in the formulation of diets for diabetics, because the slower digestion and absorption of carbohydrates help to maintain regular levels of glucose in the blood and to reduce insulin response, probably due to increased time of intestinal transit (Behall *et al.*, 1988). This variation, associated with food processing, can result in different glycemic and insulinemic responses, and hormonal profiles (Goddard *et al.*, 1984). Usually rice grains with low amylose content are more palatable (Ramirez, 1991), which can explain the higher feed intake that, associated with the higher digestibility of amylopectin, influenced the body weight gain of the animals. This hypothesis is supported by the research carried out by Sclafani *et al.* (1987) with rats, which demonstrated that the animals have receptors that discriminate between the tastes of carbohydrates like starch, what leads to the preference of consuming branched-chain starch (amylopectin) rather than unbranched starch (amylose).Physicochemical properties and cooking charecterstics of rice depends on amylose content (Saikia *et al.*, 2012)Amylose content of milled rice is determined by using the colorimetric iodine assay index method (Merca and Juliano, 1981). Amylose content is an important factor that determines the eating quality of rice. Higher amylose content corresponds to harder texture in general. However, varieties with the same amylose content do not always have similar cooking properties. NERICA varieties show a wide range of amylose content from 15.4 to 28.5% with an average of 25.0% (Futakuchi and Sie, 2009).

Table13: Classification of different Boro lines and check varieties on the basis of amylose content and types

Lines	**Amylose percentage**	**Types**
G1	24.0	Intermediate
G2	24.5	Intermediate
G3	26.0	High
G4	25.5	High
G5	24.8	Intermediate
G6	25.8	High
G7	25.5	High
G8	25.5	High
G9	24.0	Intermediate
G10	26.0	High
G11	26.5	High
G12	24.2	Intermediate
G13	25.7	High
G14	23.5	Intermediate

G15	27.5	High
G16	25.0	High
G17	25.8	High
G18	26.1	High
G19	23.7	Intermediate
G20	24.2	Intermediate
G21	24.9	Intermediate
G22	26.0	High
G23	25.5	High
G24	26.4	High
G25	24.5	Intermediate
G26	25.4	High
G27	25.9	High
G28	26.8	High
G29	27.5	High

4.3.2.8 Protein

Statistically non-significant variation was recorded for protein percentage for different Boro line of rice (Table 9b)The protein content in the current study are within the range reported by Rosniyana *et al.* (2011) that protein content in rice range from 8.85 to 9.91% for white rice and brown rice respectively. In addition, Banerjee *et al.* (2011) reported the protein content range from 4.91 to 12.08% in 258 diverse rice landraces maintained in the Germplasm Section of Indira Gandhi Agricultural University at Raipur, Chhattisgarh. Srisawas and Jindal (2007), found the protein content in 14 rice varieties ranged from 6.38 to 8.99%.

The highest value of protein was found in G28 (BRRI Dhan 29) (8.50), G22 (8.5), G20 (8.3) and the lowest value was found in G29 (BRRI Dhan 28) (7.2), G24 (7.2) (Table 10c).The other genotypes was shown the range of protein value (7.30-7.90). In this study, Protein percentage ranges from 7.2-8.5%.

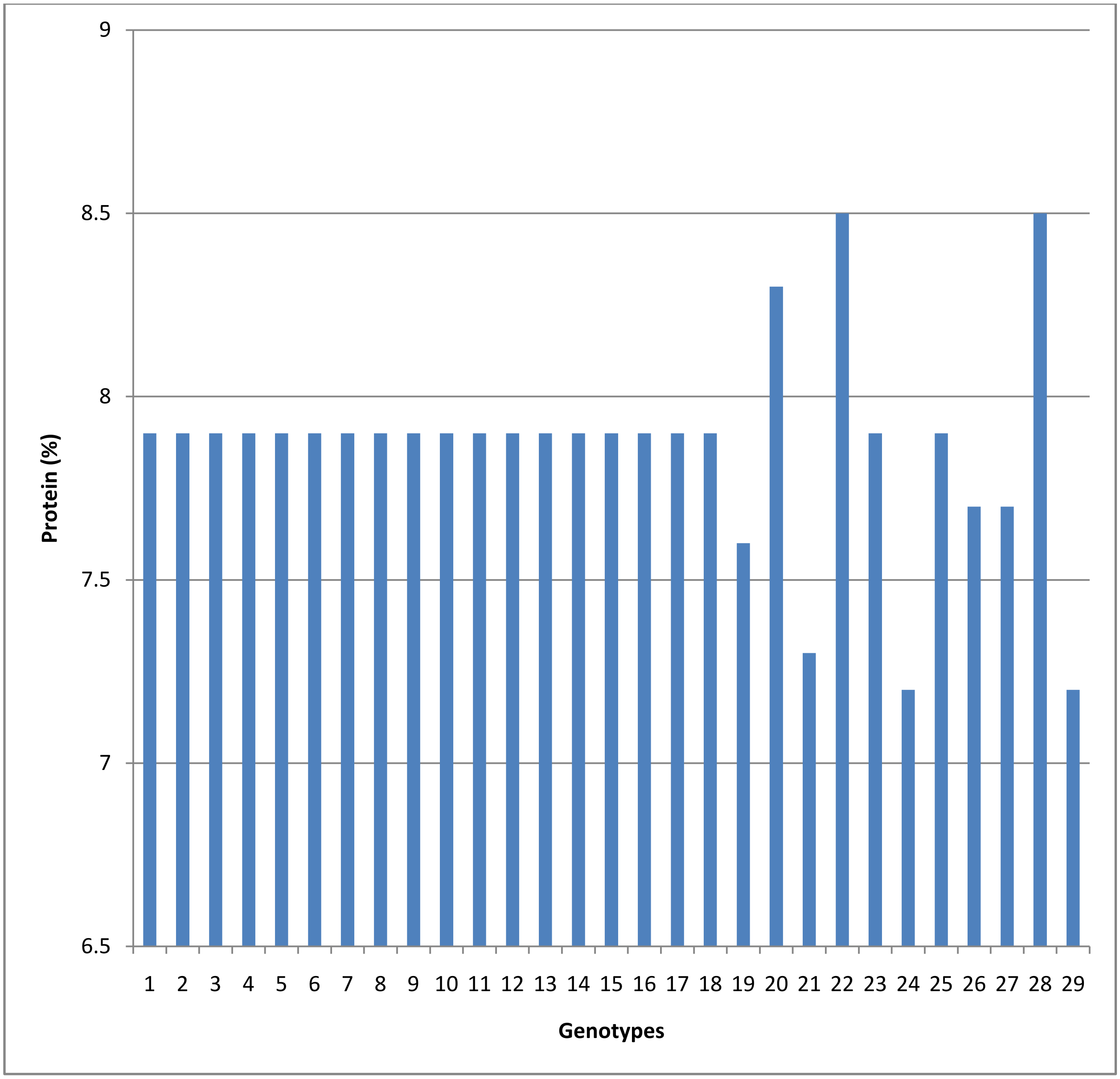

Figure 6. Mean performance of twenty nine genotypes in respect of protein (%)

CHAPTER V

SUMMARY AND CONCLUSION

The present study was undertaken with 29 genotypes of *Oryza sativa* L. at the Sher-e-Bangla Agricultural University Farm, Bangladesh during December 2014 to May 2015. Seedlings were transplanted in the main field in Randomized Complete Block Design (RCBD) with three replications. Data on various yield attributing characters such as, days to flowering, days to maturity, number of total tillers per plant, number of effective tillers per plant, panicle length (cm), number of primary branches per panicle, number of secondary branches per panicle, number of filled grains per panicle, number of unfilled grains of per panicle, total number of spikelet per panicle, yield per plant (gm), thousand seed weight and yield per hectare were recorded.

From variability analysis of 29 genotypes of *Oryza sativa* L, it was observed that significant variation existed among all the genotypes used for most of the characters studied. The lowest days to flowering was observed in G7 (BR 21× BRRI dhan 28F6S5 P6 P3) and highest was observed in G28 (BRRI dhan-29).The yield of G7 was 4.7t/ha and check varieties were 9.13 t/ha and 7.66 t/ha respectively. The highest days to maturity was taken in G28 (BRRI dhan-29) and the minimum days to maturity was taken in G19 (BR 26 × BRRI dhan- 28 F6 S1 P9 P4), G29 (BRRI dhan-28) and G10 (BR 21× BRRI dhan -29 F6 S6 P2 P4). Here the genotypes G10, G19, G29 have shown the yield 6.81t/ha,6.01t/ha respectively: both were near to the check variety G29 (7.66 t/ha).Plant height exhibited highest in G20 (BR 26 × BRRI dhan 29-F6 S6 P3 P1) and lowest in G25 (BRRI dhan- 29×BRRI dhan- 36 F6 S5 P2 P4). G25 (BRRI dhan- 29×BRRI dhan- 36 F6 S5 P2 P4) showed the maximum number of total tillers per plant,it's yield was 6.38t/ha and the minimum one was in G16 (BR 24 × BRRI dhan- 36 F6 S8 P1 P1). The highest number of effective tillers per plant was recorded in G25 (BRRI dhan- 29×BRRI dhan -36 F6 S5 P2 P4) whereas the minimum number of effective tillers per plant was recorded in G16 (BR 24 × BRRI dhan- 36 F6 S8 P1 P1). The highest panicle length was observed in G8 (BR 21 × BRRI dhan- 28 F6 S5 P7 P6); it's some characters have shown better performance than check varieties such as yield per plant (54.07gm), yield per hectare (10.19t/ha) and the minimum panicle length was observed in G13 (BR 24 × BR 26 F6 S5 P1 P3). Highest number of primary branches per panicle was recorded for G11 (BR 21 × BRRI Dhan- 29 F6 S6 P6 P2) while the minimum number of primary branches per panicle was recorded for G1 (BR 21 × BR 26 F6 S6 P1P6). The highest number of secondary branches per panicle was recorded in G14 (BR 24 × BR 26 F6 S5 P3 P2) where as the minimum number of secondary branches per panicle was observed in G25 (BRRI dhan- 29×BRRI dhan- 36 F6 S5 P2 P4). The total number of spikelet per panicle was maximum in G14 (BR 24 × BR 26 F6 S5 P3 P2) and minimum was observed in G25 (BRRI dhan- 29×BRRI dhan- 36 F6 S5 P2 P4). The number of filled grains per panicle was recorded highest in G14 (BR 24 × BR 26 F6 S5 P3 P2) and minimum was recorded in G12 (BR 21 × BRRI dhan- 36 F6 S1 P4 P1). The G4 (BR 21× BRRI dhan- 28 F6 S5 P2 P1) and G1 (BR 21 × BR 26 F5 S6 P1P6) showed the highest number of unfilled grains per panicle and the G24 (BRRI dhan- 28×BRRI dhan- 29 F6 S2 P4 P3) showed the minimum number of unfilled grains per panicle but it's yield per plant (49.63gm), yield per hectare (9.23t/ha) which is better than check varieties. Thousand seed weight was found maximum in G6 (BR 21× BRRI dhan- 28 F6 S5 P4 P2) where as the minimum thousand seed weight was found in G14 (BR 24 × BR 26 F6 S5 P3 P2). Yield per plant was recorded highest in G8 (BR 21× BRRI dhan- 28 F6 S5 P7 P6) and the lowest was found in G1 (BR 21× BR 26 F5 S6 P1 P6). Genotype G8 (BR 21× BRRI dhan- 28 F5S5 P7 P6) showed the maximum yield per hectare and the minimum one was in G1 (BR 21× BR 26 F5 S6 P1 P6).

Data on various quality attributing characters such as, length of rough rice (mm), breadth of rough rice(mm), L/B ratio of rough rice, length of uncooked rice (mm), breadth of uncooked rice(mm), L/B ratio of uncooked rice, length of cooked rice (mm), breadth of cooked rice(mm), L/B ratio of cooked rice, kernel elongation ratio, elongation index, volume expansion, water absorption, hulling, milling outturn, head rice recovery, alkali spreading value, amylose, protein were recorded.

From variability analysis of 29 genotypes of *Oryza sativa* L, it was observed that significant variation existing among all the genotypes used for most of the characters studied. The highest length of rough rice was recorded in G24 (BRRI dhan- 28 × BRRI dhan- 29 F5 S2 P4 P3) and lowest was recorded in G12 (BR 21 × BRRI dhan- 36 F5 S1 P4 P1). Highest breadth of rough rice was observed in G5 (BR 21 × BRRI dhan- 28 F5 S5 P4 P1) and lowest observed in G1 (BR 21 × BR 26 F5 S6 P1P6). The highest L/B ratio of rough rice was observed in G27 (BRRI dhan- 29 × BRRI dhan- 36 F5 S5 P3 P1) and lowest was G12 (BR 21 × BRRI dhan- 36 F5 S1 P4 P1).The highest length of of uncooked rice was found in G22 (BRRI dhan- 28 × BRRI dhan- 29 F5 S2 P2 P1) and lowest was found in G1 (BR 21 × BR 26 F5 S6 P1P6), G2 (BR 21 × BR 26 F5 S6 P3 P1). Highest breadth of uncooked rice was observed in G5 (BR 21 × BRRI dhan- 28 F5 S5 P4 P1) and lowest was in G27 (BRRI dhan- 29 × BRRI dhan- 36 F5 S5 P3 P1). The highest L/B ratio of uncooked rice was found in G27 (BRRI dhan- 29 × BRRI dhan- 36 F5 S5 P3 P1) and lowest was in G9 (BR 21 × BRRI dhan- 29 F5 S6 P1 P1). The highest length of cooked rice was recorded in G6 (BR 21 × BRRI dhan- 28 F5 S5 P4 P2) and lowest was in G11 (BR 21 × BRRI dhan- 29 F5 S6 P6 P2). The G20 (BR 26 × BRRI dhan- 29 F5 S6 P3 P1) showed the highest breadth of cooked rice and lowest in G28 (BRRI dhan- 29).The highest L/B ratio of cooked rice observed in G28 (BRRI dhan- 29) and lowest in G9 (BR 21 × BRRI dhan- 29 F5 S6 P1 P1). Highest kernel elongation ratio was found in G3 (BR 21 × BR 26 F5 S6 P9 P7) and lowest in G9 (BR 21 × BRRI dhan- 29 F5 S6 P1 P1). The highest elongation index found in G27 (BRRI dhan- 29 × BRRI dhan- 36 F5 S5 P3 P1) and lowest in G28 (BRRI dhan- 29).The highest volume expansion was observed in G8 (BR 21

× BRRI dhan- 28 F5 S5 P7 P6) and lowest was in G18 (BR 26 × BRRI dhan- 28 F5 S1 P9 P3), G25 (BRRI dhan- 29 × BRRI dhan- 36 F5 S5 P2 P4). The highest water absorption was recorded in G20 (BR 26 × BRRI dhan- 29 F5 S6 P3 P1) and lowest was in G3 (BR 21 × BR 26 F5 S6 P9 P7). Highest hulling was found in G13 (BR 24 × BR 26 F5 S5 P3P1) and lowest was G26 (BRRI dhan- 29 × BRRI dhan- 36 F5 S5 P2 P7). The highest milling outturn observed in G2 (BR 21 × BR 26 F5 S6 P3 P1) and G24 (BRRI dhan- 28 × BRRI dhan- 29 F5 S2 P4 P3) and lowest was in G26 (BRRI dhan- 29 × BRRI dhan- 36 F5 S5 P2 P7). The highest head rice recovery was observed in G10 (BR 21 × BRRI dhan- 29 F5 S6 P2 P4) and lowest was in G7 (BR 21 × BRRI dhan- 28 F5 S5 P6 P3). The highest alkali spreading value was found in G3 (BR 21 × BR 26 F5 S6 P9 P7), G5 (BR 21 × BRRI dhan- 28 F5 S5 P4 P1), G7 (BR 21 × BRRI dhan- 28 F5 S5 P6 P3), G12 (BR 21 × BRRI dhan- 36 F5 S1 P4 P1), G20 (BR 26 × BRRI dhan- 29 F5 S6 P3 P1), G25 (BRRI dhan- 29 × BRRI dhan- 36 F5 S5 P2 P4), G26 (BRRI dhan- 29 × BRRI dhan- 36 F5 S5 P2 P7) and lowest was in G1 (BR 21 × BR 26 F5 S6 P1P6). The highest amylose was found in G15 (BR 24 × BR 26 F5 S5 P4 P4), G29 (BRRI dhan- 28) and lowest was in G14 (BR 24 × BR 26 F5 S5 P3 P2). The highest protein was recorded in G28 (BRRI dhan- 29), G22 (BRRI dhan- 28 × BRRI dhan- 29 F5 S2 P2 P1), G20 (BR 26 × BRRI dhan- 29 F5 S6 P3 P1) and lowest was in G29 (BRRI dhan- 28), G24 (BRRI dhan- 28 × BRRI dhan- 29 F5 S2 P4 P3).

Findings:

1. G8 (BR 21 × BRRI dhan 28 F6S5P7P6) have shown lowest days of flowering, days of maturity; highest panicle length, yield per plant, yield per hectare than two check varieties.G24 (BRRI dhan 28 × BRRI dhan 29 F5S2P4P3) have shown highest yield per plant and yield per hectare than check varieties.

2. For amylose content G15 (BR 24× BR 26 F6S5P4P4) have shown same as G29 (BRRI dhan- 28) and G10 (BR 21×BRRI dhan- 29 F6S6P2P4), G22 (BRRI dhan- 28×BRRI dhan- 29 F6S2P1P1), G24 (BRRI dhan- 28×BRRI dhan- 29 F6S2P4P3) have shown near results G28 (BRRI dhan- 29)

Suggesions:

Considering the situation of the present experiment further studies in the following area may be suggested:

1. Promising lines such as G8, G10, G15, G20, G22, G24 with high level and good grain quality may further be investigated in multiplications trial for regional adaptability.

2. Keeping in view the market acceptability of the lines should be further improved for high yield with high quality through breeding.

Though the yield and quality of the tested selected lines is higher and superior in respect of the checks. Therefore, it is essential to develop variety possessing more stable yield performance, improve grain quality with higher yield potential.

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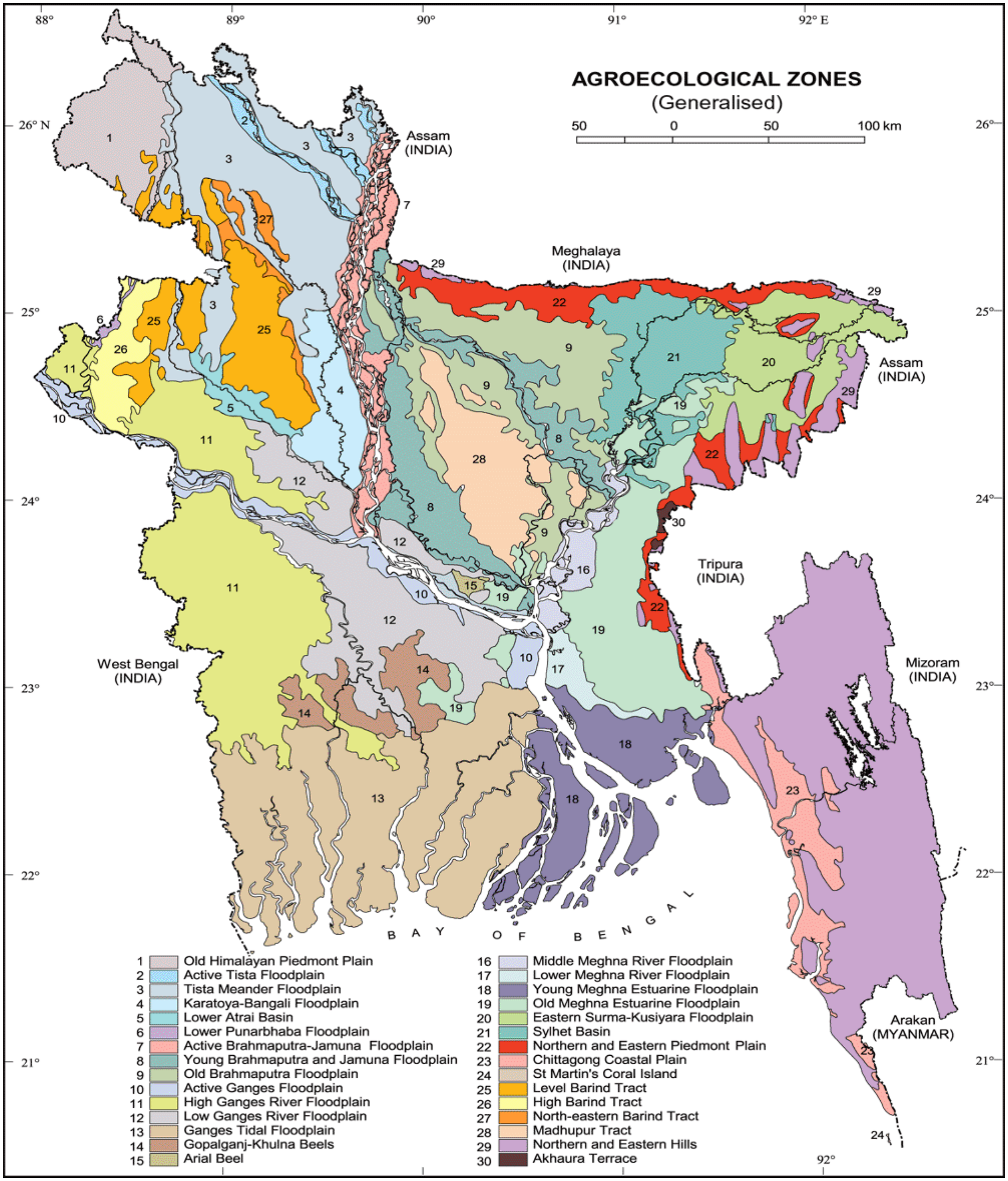
APPENDICES

Appendix I. Map showing the experimental site under the study



Appendix II: Morphological, physical and chemical characteristics of initial soil (0-15 cm depth) of the experimental site analyzed from Soil Resources Development Institute (SRDI) laboratory, Khamarbari, Farmgate, Dhaka

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 and chemical composition of the soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	6.1
Organic carbon (%)	0.82%
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00

Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI)

Appendix III. Monthly record of air temperature, relative humidity, rainfall, and sunshine (average) of the experimental site during the period from December 2015 to July 2016

Month (2011)	Air temperature (^{0}c)		Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
July	36.0	24.6	83	563	3.1
August	36.0	23.6	81	319	4.0
September	34.8	24.4	81	279	4.4
October	26.5	19.4	81	22	6.9
November	25.8	16.0	78	00	6.8
December	22.4	13.5	74	00	6.3

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka–1212