ESTIMATION OF STANDARD HETEROSIS AND GRAIN QUALITY OF RICE HYBRIDS (*Oryza sativa* L.) CULTIVATED IN BANGLADESH

BY

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CERTIFICATE

*This is to certify that thesis entitled, "ESTIMATION OF STANDARD HETEROSIS AND GRAIN QUALITY OF RICE HYBRIDS (Oryza sativa L.) CULTIVATED IN BANGLADESH." submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in GENETICS & PLANT BREEDING**, embodies the result of a piece of bona fide research work carried out by **Md. Shahidul Islam, Roll No. 00346, Registration No. 25225/00346**, 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 a source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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Dedicated to

My

Beloved Parents

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ABSTRACT

Six hybrids and two modern check varieties of rice (*Oryza sativa* L.) were evaluated to estimates standard heterosis of important yield contributing traits, to asses genetic variation among the grain characters, to study the grain appearance and milling quality and to determine cooking and eating characters of grain at the central research farm of Sher-e-Bangla Agricultural University, Dhaka, during the period of January 2006 to June 2006. All the hybrids were superior to best yielding check BRRI dhan29 in mean performance with respect to grain yield per plant, grain weight per meter square, 1000-grain weight and harvest index and all the 6 hybrids were superior to check BRRI dhan28 with respect to number of filled spikelets, grain yield per plant, grain weight per meter square, 1000-grain weight and harvest index. Positive and significant standard heterosis over BRRI dhan28 was observed in three hybrids for days to 50% flowering, five hybrids for days to maturity & grain yield per plant, four hybrids for panicle length, two hybrids for total spikelets per panicle, biological yield, all hybrids for grain yield per square meter, harvest index and 1000-grain weight. Positive and significant standard heterosis over BRRI dhan29 was observed in four hybrids for days to maturity, harvest index and grain yield per square meter, all the hybrids for grain yield per plant and 1000-grain weight. All the hybrids showed higher grain yield per hectare (6.15 t/ha to 7.45 t/ha) than both the checks (5.50 t/ha to 6.00 t/ha) on per square meter harvest basis. In general, yield was strongly and positively related to 1000-grain weight, grain yield per plant and harvest index. Highly significant variation was observed among the genotypes for hulling percentage, milling outturn, percent head rice recovery, grain length, grain breadth, L/B ratio of grain, breadth before cooking, breadth after cooking, alkali spreading value, cooking time, elongation index, volume expansion, water absorption, amylose content and protein content. Maximum hybrids showed higher hulling percent, and milling percent than checks. Most of the hybrids showed lower head rice recovery than the check BRRI dhan28 but higher the check BRRI dhan29. Two hybrids (Sonarbangla-1 & Heera) had long slender grains, three (Richer, Aloron & Jagoron) belonged to medium slender grains and one hybrid (BRRI hybrid dhan1) belonged to long bold. Superior cooking performance over BRRI dhan29 was observed in all the hybrids for length of cooked rice elongation, kernel elongation ratio, kernel elongation index and one hybrid for volume expansion. Superior cooking performance over BRRI dhan28 was observed in two hybrids for length of cooked rice elongation, volume expansion & kernel elongation index, all the hybrids for kernel elongation ratio, three hybrids for water uptake. Protein content ranged from 7.80 to 10.00. All hybrids showed translucent grains. Maximum hybrids showed intermediate GT and intermediate amylase content. Among the hybrids Aloron gave highest yield (7.45 t/ha) and BRRI hybrid dhan1 gave lowest yield (6.15 t/ha). All the hybrids were identified having acceptable grain quality but overall performance in relation to cooking and eating point of view Sonarbangla-1 and BRRI hybrid dhan1 performed better.

Chapter 1

Introduction

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop and the staple food for 40 percent of the world population. More than 90 percent of rice is produced and consumed in Asia. World rice production more than doubled from 257 million tones in 1966 to 599 million tones in 2000. This was mainly achieved through the application of the principles of classical Mendelian genetics and conventional plant breeding methods. The current world population of 6.1 billion is expected to reach 8.0 billion by 2030 and rice production must increase by 50 percent in order to meet the growing demand. Hybrid rice is playing a vital role to produce more yields in many countries of the world. In China, hybrid rice grows well and produces higher yield than modern cultivar and attracts farmer's attention (Lin and Yuan, 1980). Out side China, India is the first country to develop and commercially exploit the hybrid technology and 17 hybrids have been released (Hossain, 2004). About 20 countries including Bangladesh in the world have started extensive research on hybrid rice.

Heterosis or hybrid vigour is manifested as an improved performance for F_1 hybrid generated by crossing two inbred parents. Heterosis can be quantitatively defined as any increase/decrease in the performance of hybrids (F_1) over its parents (Shull, 1908). Both positive and negative heterosis is useful in crop improvement, depending on the breeding objectives. In general, positive heterosis is desired for yield and negative heterosis for earliness and short stature of plants. Application of heterosis in agricultural production is a multi-billion dollar enterprise. It represents the single greatest applied achievement of the discipline of genetics. Heterosis is expressed in three ways, depending on the reference, which is used to compare the performance of a hybrid. The three ways are: mid parent, better parent and standard variety heterosis. From the practical point of view, standard heterosis is the most important because it is desired to develop hybrids, which are better than the existing high yielding varieties grown commercially by farmers.

Besides yield, the grain quality of hybrid rice is most important factor for deciding the profitability of the farmers as the grain quality which decides the price in the market. Grain quality performance in rice varies from region to region and country to country. In most countries, long – grain *indica* rice that is soft and nonsticky is preferred when cooked; in others; low-amylose *japonica* rice that is soft and sticky is preferred when cooked. In the case of hybrids, quality considerations assume greater significance as their produce is formed by F_2 seed generation. Although these hybrids yielded 15-20% higher than high-yielding popular varieties, their grain quality did not find acceptability by consumers in some parts of India and Bangladesh (Zaman *et al.,* 2002). More than twenty years of consumer preference studies have indicated that Filipinos prefer rice grains which are long, slender shaped, translucent, non-glutinous, white and aromatic(Zaman *et al.,* 2002). Between 1980s to 2000 market samples have shifted from high to intermediate amylose content and low to intermediate gelatinization temperature for softer cooked rice.

Farmers prefer a variety with better milling quality i.e. high percentage of head rice (whole kernels) as well as milled rice recovery. At the same time, milling quality influences the economic value of the grain. During milling, major effort is made to obtain the highest recovery of whole kernels. Yield of head rice recovery vary widely depending on many factors such as variety, grain type, chalkiness, drying, storing, cultural practice and milling conditions (Wasserman and Calderwood, 1972; Wittle, 1972; Adair *et al.,* 1973).

Most of the rice grown in Bangladesh is traded within the domestic market. High quality rice command premium price. The consumer's preference of local varieties to the modern high yielding varieties is mainly for the superior grain characters (Choudhury, 1991). In the regional and international markets consumer's demand for quality rice is always high. However, no universal standard of rice grain quality can be set because of wide variety of consumer's choices both between and within the country (Kaosa-ard and Juliano, 1991). People preferences differ largely in respect to size and shape of the grain. Some like bold grains and some others fine grains. Export market favors long grain and fine grain rice varieties. In Bangladesh consumer's demand for rice, as reflected by price, is mostly influenced by grain size and shape (Choudhury, 1991). Many of the traditional rice varieties are of better quality than the HYVs in terms of size and shape of the grains, cooking quality and nutrition value (Kaul *et al.*, 1982).

The amylose content of rice is considered as the main parameter of cooking and eating quality (Juliano, 1972). Intermediate to high amylose rice with low to intermediate gelatinization temperature is preferred. Cooking behavior is one of the important determinants of quality (Feillet and Marie, 1979). Rice is primarily the major source of calories but supplements protein to certain extent (Choudhury, 1991). Increasing the protein content of rice would mean our increased supply of protein in rice based diet (Nanda and Coffman, 1979). The farmers and miller's concern is to get good price of the produce (both paddy and rice) which in turn is determined by market quality standards composed of shape , size and colour of rice, percentage of hulling , milling and head rice recovery. Whereas, consumer is consumed about good cooking and eating qualities which are determined by physico-chemical properties of starch like amylose content, gelatinization temperature, gel consistency, water absorption, volume expansion, etc.

Since emergence in 1970, the Bangladesh Rice Research Institute has earned the international standard of agricultural research and heritage status by developing over 46 numbers of modern/high yielding (including one hybrid) varieties of rice. The performance of two Boro rice varieties of BRRI, namely BRRI dhan28 and BRRI dhan29 are highly commendable. These two inbred HYV rice varieties are internationally competitive and considered to be super rice varieties. The potential and cultivable commercial yield of BRRI dhan28 is 5 to 5.5 metric tones per hectare and BRRI dhan29 is 6 to 6.5 metric tones per hectare. The hybrid varieties of rice mostly cultivated in Bangladesh are imported from

China by private seed companies and only one hybrid variety BRRI hybrid dhan1 has developed by BRRI. The farmers and consumers of the country are not known about the quality of these hybrids. Hussain *et al.* (2002) reported that two rice hybrids Sonarbangla-1 (CNSGC6) and Alok 6201 released in Bangladesh during 1998-1999 are not well accepted by the producer, due to high rate of unfilled grains, grain shedding, crop lodging and poor keeping quality of cooked rice, though their yield advantage were 23% and 25% higher than that of HYVs, respectively. Both the hybrids were also less liked by consumers because of stickiness, and inferior taste. Therefore, grain quality in derived hybrids should be acceptable to farmers. Greater emphasis is being given for improving eating quality of hybrid rice during development or imported from other countries.

Keeping the foregoing problems in view, present investigation will be undertaken with the following objectives:-

Objectives

- Estimation of standard heterosis in six rice hybrids.
- To asses the genetic variation of grain characters of hybrids.
- To study the grain appearance and milling of the hybrids.
- To determine the cooking and eating characteristics of the grain.

Chapter 2

Review of literature

Literatures are cited under the following heads of the objectives:

2.1 ESTIMATION OF STANDARD HETEROSIS IN CULTIVATED RICE HYBRIDS

Shull (1908) coined the term heterosis which refers to any increase/decrease in the performance of hybrids (F_1) over its parents. From a practical point of view, standard heterosis is considered the best measure of commercially utilizable heterosis. On an average, the commercial rice hybrids were reported to show 20-30% standard heterosis for grain yield (Lin and Yuan, 1980; Yuan *et al.* 1989). Reddy *et al.* (1984) reported a hybrid with 68% heterosis, 33% heterobeltiosis and 24% standard heterosis in grain yield. Yuan *et al.* (1994) reported a 29 to 45% yield advantage of hybrids over conventional rice varieties in China. The former designed as heterobeltiosis (Fouseca and Patterson, 1968) and the latter as standard heterosis. Even since heterosis in rice was first reported by Jones (1926), the presence of significant standard heterosis for yield, yield components and several other characters has been reported by numerous rice researchers. The available literatures are presented below under the heads of the objectives of the study.

2.1.1. Plant height

Moderate to low standard heterosis for plant height across environments (2.0-13.7%) was recorded by Dwivedi *et al.* (1998). Seetharamaiah *et al.* (1999) evaluated plant height, followed by panicle length did not play significant role in the expression of heterosis. Dwarfness may be one of the most important agronomic characters, because it is often accompanied by lodging resistance and thereby adapts well to heavy fertilizer application (Futsuhara and Kikuchi, 1994). Singh and Singh (1978) reported negative heterosis for plant height, while Virmani *et al.* (1982) observed that the hybrids were almost equal to or slightly taller than the parents. Plant height is negatively correlated with lodging resistance; positive heterosis for plant height in hybrids would not be desirable. Haque *et al.* (1991) reported positive association of plant height with yield per plant but negative association with panicle per plant in modern varieties. Patnaik *et al.* (1990) found that hybrids with intermediate to tall plant height having nonlodging habit could be developed gave more than 20% grain yield than the standard checks. Young and Virmani (1990) reported that the hybrids were superior to their parents in yields were taller than the parents. Plant height increase yield in modern varieties (Saha Ray *et al.,* 1993). Haque *et al.* (1991) reported positive association of plant height with yield per plant but negative association with panicle per plant in modern varieties.

2.1.2. Days to 50% flowering

Only a few crosses showed heterobeltiosis for days to 50% flowering and spikelets per panicle. The correlation coefficient 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 (Verma, *et al.,* 2002). Vijayakumar *et al.* (1997) found that hybrids out yielded than their parents when their days to 50% flowering were similar or more than their respective restorers. They concluded that superior hybrids could be identified early by comparing their tiller number, plant height and days to 50% flowering with those of their respective restorers.

2.1.3. No. of effective tillers/plant

Heterosis was first reported by Jones who observed marked increase in culm number and grain yield in some F_1 hybrids in comparison to their parents (Virmani *et al.*, 1981). Sathya *et al.* (1999) reported significant standard heterosis for productive tillers/plant and grain yield/plant. Vishwakarma *et al.* (1999) the cross IR58025A×NDRK5042 showed higher potential for effective tillers. The high heterosis for grain yield was accomplished by heterosis for the effective tillers/plant. Padmavathi *et al.* (2000) observed the importance of number of tillers/plant influencing yield.

2.1.4. Days to maturity

The hybrid combinations Lexiang 202A×Minghui-151 showed early maturity and fine grain quality (Shijun *et al.*, 2002). Duration of Jaymati from sowing to seed is 170 days for summer, and 130 days for autumn and winter rice (Ahmed *et al.*, 1998). Xu and Wang (1980) found that days to maturity of hybrids depends on the male parent, but Ponnuthurai *et al.* (1984) reported hybrid growth duration similar to that of the shorter duration parent. Alternatively, Virmani (1999) noted that growth duration did not correlate with expression of heterosis and hence heterotic hybrids could be developed with a range of desired growth duration. Hossain (2004) reported that in generally yield strongly and positively correlated with duration of hybrids yet early maturing hybrid give as good yield as the best early medium maturity hybrids.

2.1.5. Panicle length (cm)

Pandey *et al.* (1995) studied 30 hybrids and reported that most of the crosses manifested significant heterosis for panicle length over the standard variety. Considerable amount of heterosis has been reported for this trait by Anandakumar and Sree Rangasamy (1984), Sarial (1994) and Pandy *et al.* (1995). However, Nijaguna and Mahadevappa (1983), Paramassivam and Sree Rangasamy (1988) and Manuel and Palanisamy (1989) observed the higher magnitude of negative heterosis than positive heterosis.

2.1.6. No. of filled spikelets/panicle

Rajesh and Singh (2000) reported that in hybrids, yield was primarily influenced by effective tillers per plant and fertile grains per panicle, whereas in parents it was panicle length, maturity and effective tillers per plant. Number of effective tillers per plant and fertile grains per panicle remained constant and common in explaining heterosis for yield of most of the hybrids. The heterosis for grain yield was mainly due to the significant heterosis for the number of spikelets/panicle, test weight and total dry matter accumulation (Patnaik *et al.*, 1990).

2.1.7. Total No. 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.

2.1.8. Grain yield /plant (g)

Rice ecosystem has been intensively assessed with grain yield for their contributions to heterosis and inbreeding depression (ID). Top three heterotic hybrids for five physiological traits and grain yield under both UIR and RFL ecosystems in contrast to the respective better and standard controls have been markedly identified (Verma, *et al.*, 2002). Prakash and Mahadevappa (1987) reported that hybrids V20A/IR13419-113-1 and V20A/IR9761-19-1 showed significant positive heterosis over the male parent for grain yield. Many hybrids did not express significant positive standard heterosis in terms of yield and some of its components.

Lin and Liang (1997) reported that the indica hybrids Shanyon 63 and Teyon 63 showed considerable heterobeltiosis for grain yield due to the higher number of productive tillers/plant. Tiller/plant and grains/plant were responsible for heterosis for dry matter production. Panwar *et al.* (1998) reported that the standard heterosis was found to be significant both negative and positive for grain yield/plant. The nature and extent of heterosis of various crosses manifested significant heterosis for grain yield per plant was ranged from -37.7-158.10% over the standard cultivar (Tiwari *et al.*, 2002). Relative heterosis for grain yield per plant was in the range 52.03-72.08% coupled with significant heterobeltiosis in the range 56.03-59.59%. The standard heterosis was in the range 70-46.55% for yield per plant (Pati *et al.*, 2003).

2.1.9. Biological yield (g)

Singh and Zaman (1998) reported that the cross, Jaya/Swarnaprabha, which exhibited a high heterobeltiosis for biological yield (54.9%), also showed a significant positive heterosis for grain yield. Sharma (1997) reported that biological yield /plant and HI were the most important traits contribution towards grain yield /plant in rice. High heterosis for biomass yield has demonstraded in rice hybrids. However, Heterosis for harvest index although reported (Blanco *et al.*, 1986), was less frequent than for biomass yield. Sharma (1997) revealed that biological yield /plant and HI were the most important traits contribution towards grain yield /plant in rice.

2.1.10. Harvest index

The study on the selected seven crosses revealed that heterosis over the mid and better parent were negative for days to panicle emergence and positive for panicle/ plant, grain yield/plant, dry matter production and harvest index (Ganesan *et al.*, 1997). Over 60% heterosis for yield in 4 crosses and high positive value for harvest index in crossIR8×OM201 was recorded by Nguyen and Bui (1993).Whereas Ganesan *et al.* (1997) revealed that heterosis over mid and better parent was positive for harvest index. Seven hybrids showed showed significant positive standard heterosis and ranged from -7.07 to 20.20% (Selvarani and Rengasamy, 1998). Interestingly, Patnaik *et al.* (1990) found that most of the higher yielding hybrids were accompanied by significant negative heterosis for harvest index. Sitaramaiah *et al.* (1998) observed that high yielding hybrids also recorded higher biomass yield and harvest index. It was found that the hybrids showed a superior performance because of more grains per panicle, which was indicated by higher harvest index. Ramesha *et al.* (1999) found that yield heterosis in hybrids results because of heterosis for total dry matter at different stages, coupled with heterosis for panicle dry weight, without much change in harvest index.

2.1 .11.1000-grain weight (gm)

Sitaramaiah *et al*. (1998) showed negative and significant standard heterosis for 1000grain 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. Most of the higher yielding hybrids manifested positive heterosis for harvest index and number of spikelets/panicle. Plant height, panicle per plant, grain per panicle and 1000 grain weight increase yield in modern varieties (Saha Ray *et al.,* 1993) whereas 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.

2.1.12. Grain yield

Shanyou 63 (Zhenshan 97A×Minhui 63) and Teyou 63 (longtepu A × Minhui 63) showed significant grain yield increase over Minhui 63. High positive heterobeltiosis for grain yield was indicated in the crosses having fairly high to medium diversity estimates which may be utilized in hybridization program in order to increase the chances of getting high heterotic manifestation (Sarathe and Perraju, 1990). Seetharamaiah *et al.* (1999) evaluated standard heterosis for grain yield was manifested through more number of spikelets/panicle and number of ear bearing tillers/m^2. Heterosis for grain/plant was mainly due to high number of grains/panicle and 1000 grain weight. Yolanda and Das (1996) reported on the extent of heterosis for grain yield /plant. Genetic diversity was not related with heterosis for grain yield, panicle number, and panicle length, number of grains /panicle and 1000grain weight.

2.2. ASSESMENT OF GENETIC VARIATION OF IMPORTANT GRAIN CHARACTERS AMONG THE HYBRIDS

The extent of genetic variability existing of genotype of a crop plant is an index of its genetic dynamism. Plant breeding revolves around selection which can be effectively practiced only in the presence of variability of desired traits. Hence, the success of breeding depends entirely upon the variability. The modern varieties had higher values in terms of length, ratio of length to width and ratio of length to thickness. Local varieties had higher values in terms of width, thickness and ratio of width to thickness. High heritability along with low genetic advance was exhibited for amylose content only indicating that this trait was under the influence of environment. Remaining traits exhibited high heritability along with high to moderate genetic advance suggesting that these characters could be of great importance for selecting better genotypes in rice improvement programmes. (Kumar, *et al.* 2006).

Genetic variation among the hybrids for total milled rice percentage was non-significant. 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 (Gravois, 1994). Hussain *et al.* (1987) studied the quality status of indigenous upland rice and observed that the characters like water uptake and volume expansion showed the greatest genetic variability. Broad sense heritability and genetic advance were high for volume expansion (98.1 and 30.5%) and water uptake (92.1 and 34.2%), respectively.

2.3. STUDY OF THE MILLING AND GRAIN APPEARANCE OF THE HYBRIDS

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 the estimate of the quality 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 epistasis, 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.*, 2000). Adu-Kwarteng *et al.* (2003) found good grain size and shape (L/W-3.12), good endosperm appearance, milling quality (TMR-67.2%) and higher amylase content (22.87-30.78%) in the breeding lines.

2.3.1. Milling outturn

The proportions of the various components vary according to the method of milling used and the variety of rice, Generally, the hulls 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 100 g of rough rice, 70 g of milled rice is obtained and 20g of this is broken, head rice recovery is 50%. The head rice recovery may very from 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, 1982). 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 were controlled by both seed genotype and maternal genotype. Derived from the cross Jaya x 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 from 67 to 71% and head rice outturn from 88 to 97%. Barber and de Barber (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).

2.3.2. Head rice recovery

Gravois (1994) reported that the value of rough rice is often determined by the percentage of head rice and total milled rice produced after milling. 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 experimental 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 tested experimental hybrids exhibiting high head rice yields (Shobha Rani *et al.* 2002).

2.3.3. Grain size and shape

The appearance of milled rice is important to consumers. Thus, grain size and shape are among the first criteria of rice quality that breeders consider in developing new varieties for release for commercial production (Adair *et al.*, 1966). A length breadth ratio from 2.5 to 3.0 has been considered widely acceptable as long as the length is more than 6mm (Kaul 1970). Consumers prefer rice with a translucent endosperm and pay a premium price for it, even though opacity disappears during cooking and does not alter eating quality. Preference for grain size and shape vary from one group of consumers to another. Some ethnic groups prefer short bold grains, some prefer medium long grains and others highly prize long slender grains. In general, long grains are preferred in the Indian subcontinent, but in Southeast Asia, the demand is for medium to medium long rice. In temperate areas, short grain varieties are prevalent. There is a strong demand for long grain rice on the international market. The milling and marketable qualities depends upon the size and shape of the grain. Grain size as length and breadth, whereas shape is generally expressed as length/breadth ratio. Begum *et al.* (2001) reported on some Iranian and BRRI rice varieties and found that length of Iranian varieties varied from 6.19 to 7.83 mm and L/B ratio from 3.0 to 4.1. BRRI varieties were from 3.60 to 6.82 mm long and had L/B ratio from 2.10 to 3.61. Biswas *et al.* (2001) estimated the length and L/B ratio of milled rice samples ranged from 4.7 to 6.2 mm and 2.1 to 3.2 mm, respectively in some Binni rice varieties and compared with BR25 and Nizersail.

2.3.4. Endosperm translucency

Grain appearance is also largely determined by endosperm opicity, the amount of chalkiness on the dorsal side of the grain (white belly), on the ventral side (white back), or in the centre (white centre) and the condition of the "eye" or pit left by the embryo when it is milled. Rice samples with damaged eyes have a poor appearance and low market value. Similarly, the greater the chalkiness, the lower the market acceptability. The starch granules in the chalky areas are less densely packed *vis-a-vis* translucent areas. Therefore, the chalky areas are not as hard as the translucent areas and the grains with chalkiness are more prone to breakage during milling. Milled grains are visually scored for the presence of absence of white belly, white back, white centre, degree of translucency and breakage at the basal-ventral end of the grain referred to as the condition of the eye. Charuwan-Bangwaek (1994) observed the results from the scanning electron microscope indicating that chalky areas had loose compaction of starch granules which were of different sizes and round in shape compared to translucent grains which had compact granules of regular shape. Igbeka *et al* (1991) observed that translucency is affected mainly by soaking and steaming parameters for example colour by soaking, steaming and drying; broken grain mainly by drying; and deformed grain; only by soaking parameters and equilibrium time. Kumar *et al.* (1994) concluded that endosperm appearance is primarily dedicated by the amylase content. It varies from waxy to dull to translucent as amylase content increases. If one parent has waxy or dull endosperm and the other has translucent. Waxy, dull and translucent grains cannot be identified individually after cooking, but still consumers do not like the variation in endosperm appearance.

2.3.5. Grain type

Biswas *et al.* (1992) found that length of the grain is more variable and important than width and thickness or shape. Bold grains give low head rice recovery because of high breakage. Grains with short to medium length break less than long grains during milling. Thus, grain size and shape have direct affect of head rice (Shobha Rani *et al.* 2003).

2.4 DETERMINATION OF THE COOKING AND EATING CHARACTERISTICS OF THE GRAIN

The cooking and eating quality of rice has attracted more attention recently. Cooking and eating characteristics are largely determined by the properties of the starch that makes up 90% of milled rice. Gelatinization temperature, amylose content and gel consistency are the important starch properties that influence cooking and eating characteristics. In combination with previous reports, confirmed that either the waxy gene itself or a genomic region tightly linked to it plays a major role in determining the cooking and eating quality of rice (Rui *et al.*, 2005). Cooking and eating qualities of rice are largely depends upon the properties of starch that makes up 90% of milled rice. Cooking quality preference very in different countries of the world (Azeez and Shafi, 1966). Rice is one cereal that is consumed mainly as whole milled and boiled grain. The desired properties may very from one ethnic group or geographical region to another and may very from country to country (Juliano *et al*,1964). Quality in rice may therefore be considered from the viewpoint of milling quality; grain size, shape and appearance and cooking characteristics. Several component traits collectively determine cooking and eating qualities of rice are reviewed below:

2.4.1. Kernel elongation ratio

Kernel elongation, in general, is given as 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 grains while in most varieties the expansion is relatively more breadth wise (Azeez and Shafi, 1986; Juliano, 1972 and Sadhukhan and Chattopadhyay, 2001). During storage, grain hardness and gelatinization temperature increase which allows more swelling and elongation during cooling (Ahuja *et al.*, 1995). 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 (Guo *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. 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. Singh *et al.* (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.

2.4.2. Water absorption (uptake) percentage and Volume expansion

Marzempi and Edi (1990) concluded that expansion volume is 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 water 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 a.* 2005).

2.4.3. Gelatinization temperature

The time required for cooking is determined by the gelatinization temperature (GT). It is the range of temperature within which starch granules begin to swell irreversibly in hot water and ranges from 55 to 79^{0}c. The GT is correlated with the extent of disintegration of milled rice in dilute alkali solution and hence an indirect estimate of the GT. Gelatinization temperature may be classified as low (Below 70^{0}), intermediate (70^{0} to 74^{0}) or high (above 74^{0}) (Little *et al.* 1958). 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 or 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% HOH) 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 amylose content. No varieties are known with a high GT and high amylose content.

2.4.4. Amylose content

Many of the cooking and eating characteristics of milled rice are influenced by the ratio of two kinds of starch, amylose and amylopectin in rice grain (Sanjiva Rao *et al.*, 1952). Amylose is the linear fraction of starch in the nonglutinnous varieties, whereas amylopectin, the branched fraction, makes up the remainder of the starch. Amylose content correlates negatively with taste panel scores for cohesiveness, tenderness, color and gloss of boiled rice. Amylose is almost absent from waxy (glutinous) rice. Such rice does not expand in volume, is glossy and sticky and remains firm when cooked. This rice is the staple food of people in northern and north-eastern Thailand and Lao PDR. A great majority of the rice from Vietnum, Thailand, Myanmar and the Indian subcontinent has high amylose content. This rice shows a high degree of flakiness. It cooks dry, is less tender, and becomes hard upon cooling. Low-amylose rice cooks moist and sticky. All of the japonica varieties of temperate regions have a low Amylose content. Varieties grown in Philippines, Malaysia and Indonesia have intermediate amylose content and cook moist and tender and do not become hard upon cooling. Marzempi and

Edi (1990) found that with the increase of harvesting time amylose, carbohydrate and protein content are increased; they also concluded that expansion volume is also affected by the change of amylose content. Wu-DianXing *et al.* (2000) reported that several elite lines with moderate apparent amylose content (AAC) were identified in progenies derived from the cross between Lemont and Z95-210. Isoamylase 1 is essential for amylopectin biosynthesis in rice endosperm, and that alternation of the isoamylase activity is an effective means to modify the physicochemical properties and granular structure of starch (Fujita *et al.*, 2003). Bao *et al.* (2000) reported that amylose content and gelatinization temperature were controlled by the main genetic effects as well as by genotype X environment interaction effects. Amylose content in rice endosperm is a key determinant of eating and cooking quality. Only interaction with the mature mRNA resulted in reduced amylose synthesis. Varying degrees of reduction in amylose content, up to 96%, were found in seeds derived from transformants (Liu *et al.* 2003). Islam and Virmani (1990) observed that all the hybrids showed high amylose content than the parents. Mckenzie and Rutger (1983) reported that high amylase content appeared to be controlled by a single dominant gene. Chang and Li (1981) studied the inheritance of Amylose content in F_1 and F_2 populations and found that high Amylose content is controlled by a single incompletely dominant gene. Puri and Siddiq (1980) studied that Amylose content was inherited in a complex manner, which did not fit any Mendelian ratios.

2.4.5. Protein content

The source of protein for human consumption in a majority of the developing countries is cereals and pulses. Since rice is the staple food for Asians and forms a major item in their diet, the need for improving the quantity of protein in rice is of paramount importance. Milled rice protein is one of the principal protein sources for human being. It is seemed that there is a considerable potentiality for the quantitative and quantitative improvements rice proteins (Bhowmik *et al.*, 1990 and Satoh *et al.*, 1990).

Chapter 3

Materials and Methods

MATERIALS AND METHODS

The details of the materials and methods employed have been presented below:

3.1.1 Experimental Site

Field experiment was conducted at the central research farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from January 2006 to June 2006. The experimental site was located at 8.45 m elevation above sea level with latitude of $23^0\ 46'$ and longitude of $90^0\ 23'$ presented in Appendix l.

3.1.2. Soil

The experiment was carried out in a typical rice growing soil. The medium high land belonging to the Madhupur Tract of Agro-ecological Zone-2 (UNDP, 1988). Soil of the experiment plot was sandy loam in texture. The land was well drained with good irrigation facilities. The nutrient status of soil of farm area determined at the Soil Resources Development Institute (SRDI), Khamar Bari, Farmgate, Dhaka the Morphological, Physical and Chemical Characteristics or analysis is presented in Appendix ll.

3.1. 3. Climate

The experimental area is under the sub tropical climate characterized by the three (3) distinct seasons. The monsoon or rainy season extending from May to October, winter or dry season from November to February and the pre-monsoon period or hot season from March to April. Information regarding monthly maximum and minimum temperature, rainfall, relative humidity, Soil temperature and sunshine as recorded by Bangladesh Meteorological Department, Agargaon, Dhaka, during the period of study have presented in Appendix lll.

3.1. 4. Plant materials

Five hybrid rice varieties imported by different private seed companies and one hybrid released by BRRI and two check varieties also released by BRRI were used for this experiment. The name and origin of these genotypes are presented in Table 1.

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

Varieties/ Genotypes	Origin	Imported by
Sonarbangla-1(CNDGC-6)	Imported from China	Mollika Seed Company
Jagoron (GB 4)	Imported from China	BRAC
Aloron	Imported from China	BRAC
Heera99-5	Imported from China	Supreme Seed Company
Richer101	Imported from China	Chens Crop Science
BRRI hybrid dhan1	Released by BRRI	
BRRI dhan28	Released by BRRI	
BRRI dhan29	Released by BRRI	

3.1. 5. Design and layout

The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. The genotype was randomly assigned to each plot within each replication.

3. 1. 6. Land preparation

The experimental plot was prepared by deep ploughing followed by harrowing and laddering. Weeds and stables were removed during final ploughing. Seed was sowed 05^{th} January 2006 and seedling were transplanted 12^{th} February 2006

3.1.7. Transplantation

Thirty days old seedlings were transplanted in 3m×2m plot with 25cm×20cm between rows and plants, respectively with single seedling/ hill.

3.1.8. Fertilizer application

Fertilizers were applied at the rate of 60:40:40 kg/ha N, P and K respectively. Total P&K fertilizer were used as basal dose and total N splited into three installments. First installment with basal dose, second installment 15 days after first installment and third is 15 days after second installment. Gypsum and Zinc Sulphate were also applied as a source of S & Zn at the rate of 60 kg and10 kg per hectare as basal dose.

3.1. 9. Irrigation and drainage

The experimental field was irrigated properly and adequate water was ensured through out the whole crop growth period. A good drainage system was also maintained for immediate release of excess rainwater from the field.

3.1.10. Intercultural operation

Weeding was done during top dressing of urea to break the soil crust, keep the crop free from weeds and incorporate fertilizer into the soil for reducing the loss of urea. Irrigation was given at a regular interval to maintain 2-3 cm water depth up to hard dough stage of rice. Ripcod was sprayed two times to keep the infestation of rice bug and other insect pests to minimum level.

3.1.11. Data Collections

Data were recorded on physiological characters and yield components for all the entries on five randomly selected plants from the middle rows in each replication as follows:

3.1.11.1. Plant height: Height (cm) of the plant from the ground level to the tip of the main panicle was measured in cm.

3.1.11.2. Days to 50% flowering: Number of days required for 50% of the plants to show panicle emergence, from the date of sowing were recorded.

Plate 1. Intercultural operation in vegetative stage

Plate 2. A field view in flowering stage

Plate 3. A field view in ripening stage

3.1.11.3. Number of effective tillers per plant: Total number of panicle bearing tillers in a plant counted at the time of harvesting.

3.1.11.4. Days to maturity: Number of days required from sowing to physiological maturity was recorded.

3.1.11.5. Panicle length: The length of the panicle from its base to the tip of the panicles excluding awns was measured in cm.

3.1.11.6. Number of filled spikelets per panicle: Number of filled spikelets (grain) present on the main panicle was recorded.

3.1.11.7. Total number of filled spikelets per panicle: Total number of spikelets on the main panicle was recorded by adding up filled and unfilled spikelets.

3.1.11.8. 1000-grain weight: 1000 grains were counted from a random sample drawn from bulk produce and weight in g was recorded at 14% moisture level.

3.1.11.9. Biological yield per plant: The plants harvested at maturity were sun dried uniformly till constant moisture level was attained and weighted in g.

3.1.11.10. Grain yield per plant: Grain yield in g per plant was taken after harvesting, threshing, cleaning, and drying the produce to 14% moisture level.

3.1.11.11. Grain yield per plot: Grain yield in g per ten plants of each replication was taken after harvesting, threshing, cleaning, and drying the produce to 14% moisture level and calculated for $3m \times 2m = 6m^2$ in kg.

3.1.11.12. Grain yield per hectare: Grain yield per plot was converted into grain yield per hectare in kg.

3.1.11.13. Harvest index (HI): The ratio of grain weight to total aboveground plant dry weight (Biological yield). HI was computed by using the following formula:

$$HI = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (Total dry weight)}}$$

Analysis of variance: Differences between genotypes for the characters studied were tested for significance by the "Analysis of Variance" technique. Analysis of variance was done on the basis of following model:

$$Yij = m + gi + rj + eij$$

Where, Yij = phenotypic observation on i^{th} genotype in j^{th} replication

m = general mean

gi = effect of i^{th} genotype

rj = effect of j^{th} replication

eij = random error associated with i^{th} genotype and j^{th} replication

Table 2. The structure of Analysis of Variance (ANOVA)

Source of variation	Df	MSS	Expected MSS	F-value
Replication	(r-1)	M_r	$\sigma_e^2 + g\sigma_r^2$	
Treatment/genotype/hybrids/ Parents/checks	(g-1)	M_g	$\sigma_e^2 + r\sigma_g^2$	M_g / M_e
Error	(r-1)(g-1)	M_e	σ_e^2	
Total	(rg-1)			

Where, r = Number of replication,

G= Number of genotypes (treatments),

M_r, M_g and M_e= Mean sum of squares due to replications, genotypes and error respectively

σ_e^2= Error variance= M_e

σ_g^2= Genotypic variance = $(M_g - M_e)/r$ and

σ_p^2= Phenotypic variance = $\sigma_e^2 + \sigma_g^2$

MSS due to genotype were tested against the error variance using 'F' test at p=0.05 or p=0.01 with degree of freedom for higher and lower value of variance.

Estimation of mean, range, standard error and critical difference: Mean value of each character was worked out by dividing the total with corresponding number of observations, while the lowest and highest value for each character were taken as the range. Significance of all source of variation was tested against error mean square at error degree of freedom. Standard error of difference (SEd) between pair of genotypes (treatments) mean was computed as, Standard error of difference (SEd) = $(2Me/r)^{1/2}$

In order to test the significance between two entries, critical difference (CD) was calculated as follows:

Critical difference (CD) =SEd ×'t' value (5% or 1%) at error d.f.

Coefficient of variation was calculated as follows in percent.

$$CV\ (\%) = \frac{\sqrt{MSS}}{\text{Grand mean}} \times 100$$

3.2. ESTIMATION OF STANDARD HETEROSIS IN CULTIVATED RICE HYBRIDS

The heterosis was calculated in terms of difference of F_1's from standard variety (ST), and was expressed as percentage. The level of heterosis were tested using student's't' test. Measurement of heterosis is quite simple. It is generally expressed as percent increase or decrease in the performance of a hybrid in comparison with the reference variety or a parent (Virmani *et al.*, 1997).

$$\text{Standard heterosis (\%)} = \frac{\overline{F_1} - \overline{CV}}{\overline{CV}} \times 100$$

$SE_{(F1\text{-}CV)} = (2Me/r)^{1/2}$

$t = (F_1\text{-}CV)/\ SE_{(F1\text{-}CV)}$

Where, Me = Error mean sum of squire from RBD ANOVA

r = replication

$\overline{F_1}$= Mean of F_1

$\overline{CV}$= Mean of check variety

SE = Standard error of difference of means

3.3. ASSESMENT OF GENETIC VARIATION OF IMPORTANT GRAIN CHARACTERS AMONG THE HYBRIDS

3.3.1. Genotypic and phenotypic variance: Genotypic and phenotypic variances were estimated by the following formula:

$$\text{Genotypic variance} = \frac{\text{Treatment MSS} - \text{Error MSS}}{\text{Number of replications}}$$

The phenotypic variances = Genotypic variances + environmental (error) variances given by the following formula:

$$\sigma^2_p = \sigma^2_g + \sigma^2_e$$

3.3.2. Genotypic and phenotypic coefficient of variability (PCV and GCV): Genotypic and phenotypic coefficient of variability were estimated by using the following formula given by Johnson *et al.* (1993).

$$\text{Genotypic coefficient of variation (GCV)} = \frac{\text{Genotypic variance}}{\text{Grand mean}} \times 100$$

$$\text{Phenotypic coefficient of variation (PCV)} = \frac{\text{Phenotypic variance}}{\text{Grand mean}} \times 100$$

3.3.3 Heritability (h^2): Heritability in broad sense was calculated as follows:

$$\text{Heritability } (h^2_b)\ (\%) = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

Where, $\sigma^2 g$ = Genotypic variance

σ^2_p = Phenotypic variance

3.3.4. DMRT analysis: Mean comparisons were done by Duncan's Multiple Range Test (DMRT) method.

3.4. STUDY OF THE MILLING AND GRAIN APPEARANCE OF THE HYBRIDS

3.4.1. 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,

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

3.4.2. 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,

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

3.4.3. Head Rice Recovery: 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,

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

3.4.4. Kernel length 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.

3.4.5. Kernel 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 breadth by slide calipers.

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

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

3.4.7. 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 in Table 3 and 4.

Table 3. 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 4. Classification of rice on the basis of length/Breadth ratio

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

(Robin Graham, 2002)

3.5. DETERMINATION OF COOKING AND EATING CHARACTERISTICS OF THE GRAIN

3.5.1. Kernel length and breadth of cooked rice: Individual kernels of the sample were taken separately in long labeled test tubes and presoaked in 5 ml of tap water for 30 minutes. After that, the tubes were placed in a water bath maintained at boiling temperature, for 8-9 minutes. After cooking the test tubes 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.

3.5.2. Kernel Length/Breadth ratio of cooked rice: L/B ratio of cooked kernel was computed according to following formula:

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

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

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

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

3.5.4. 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.

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

Where, $L_1/B_1$and L_0/B_0 represent length/ Breadth before and after cooking, respectively.

3.5.5. 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 (100^0C) for 6 to 7 minutes. The sample tubes were then out and cooled under room temperature for 10 minutes.

3.5.6. 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.

3.5.7. Imbibition ratio: Volume expansion ratio was calculated by calculating the volume of cooked and uncooked milled rice by water displacement.

$$\text{IR} = \frac{\text{Volume of cooked rice}}{\text{Volume of uncooked rice}}$$

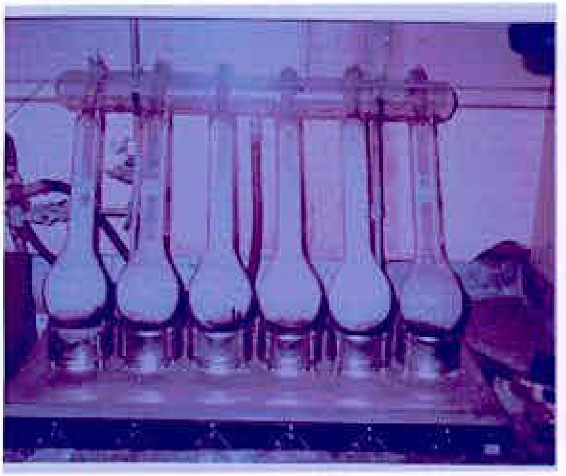

Plate 4. Rice samples are digested in digestion chamber during estimation of protein in micro-Kjeldahl method

Plate 5. Rice samples are destilated in destilation chamber during estimation of protein in micro-Kjeldahl method

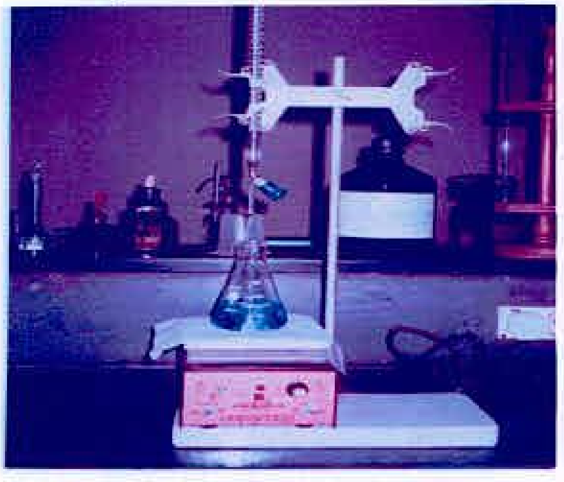

Plate 6. Titration of rice samples during protein estimation

Plate 7. Rice samples are kept undisturbed with chemicals in amylose estimation

Plate 8. Rice samples are cooking in microwave oven for determination of cooking time

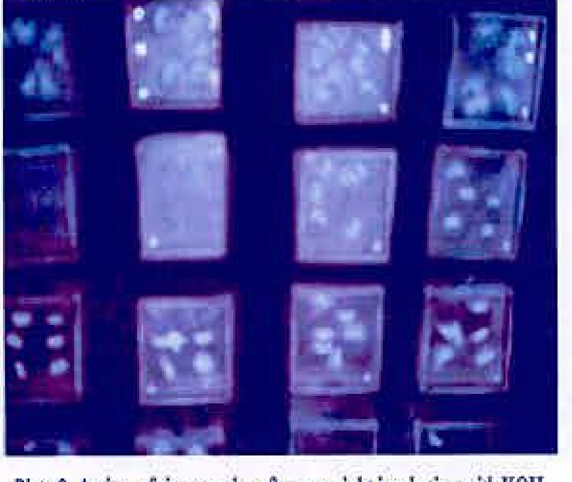

Plate 9. A view of rice samples after overnight incubation with KOH for determination of alkali spreading value

Table 5. Classification of rice on the basis of amylose content

Sl No.	Amylose content (%)	Categories
1	0-2	Waxy
2	3-9	Very low
3	10-19	Low
4	20-25	Intermediate
5	>25	High

(Source: Virmani, 1994)

Table 6. Numerical scale for scoring gelatinization temperature of rice

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

Table 7. 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

3.5.8. Estimation of Amylose: Amylose content was determined according to Juliano (1979). 100mg of rice powder was taken into a 100ml volumetric flask, and 1ml of 95% ethanol and 9ml of 1M sodium hydroxide were added. The contents were heated in a boiling water bath to gelatinize the starch. After cooling 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.

3.5.9. 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 immediately 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,

$$N (\%) = \frac{\text{Amount of HCl} \times \text{N of HCl} \times .014}{\text{grams of sample}} \times 100$$

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

3.5.10. Alkali spreading value: Alkali spreading value was determined according to procedure of Little *et al.* (1958). A sample of eight whole milled rice kernels from each entry was placed in small petriplates (5 cm wide) containing 10 ml of 1.7% potassium hydroxide (KOH) solution. The petriplates were covered and placed in an incubator maintained at 30 ± 1^0C 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 wad calculated on a 7 point numerical scale (Table 6) proposed by Jennings *et al.* (1979) and IRRI (1980).

3.5.11. Cooking time: For determination of cooking time, the rice samples were taken in long test tube with water and placed in water at boiling temperature (100^0C) on Hot plate. When the starch granules are disappeared then rice samples were seems to be cooked. Time was determined by stop watch.

3.6. Statistical analysis

The various statistical packages were used for data analysis and these are MS Excel 2000(Microsoft), Microsoft Word, Microsoft power point and, MSTATC (CIMMYT) for windows. For each character, analysis of variance (ANOVA), means, range were calculated by computer using MSTATC software; the mean values were separated by DMRT then analyzed for genotypic and phenotypic variance, genotypic and phenotypic coefficient of variation, heritability, genotypic and phenotypic correlation coefficient.

Chapter 4

Results and Discussion

RESULTS AND DISCUSSION

The experimental results obtained from the present investigation are presented here under the following heads:-

- Estimation of standard heterosis in six rice hybrids.
- Assessment of the genetic variation of important grain characters among the hybrids.
- Study of the milling and grain appearance of the hybrids.
- Determination the cooking and eating characteristics of the grain.

A total of 6 selected hybrids, and 2 commercial checks were evaluated for yield and some yield contributing characters. The results of mean performance for various yield contributing characters are presented under the following sub heads:

4.1. Analysis of variance

Analysis of variance was carried out and the mean sums of squares for various characters are presented in Table 8. 'F' test revealed highly significant variation among 8 genotypes for all the characters studied.

4.2. Mean performance

Mean performance of hybrids with checks for all the traits have been presented character wise in Table 9.

Table 8. Analysis of variance (ANOVA) for yield and its related characters in hybrids and check varieties

Sl. No.	Characters	Mean Sum of Squares (MSS)		
		Replication	Variety	Error
	d.f.	2	7	14
1.	Plant height (cm)	9.113	144.876**	12.665
2.	Days to 50% flowering	12.500	469.310**	0.452
3.	Total tillers/plant	2.167	9.119**	1.833
4.	Number of effective tillers/plant	0.344	3.52**	1.14
5.	Number of ineffective tillers/plant	0.375	2.857**	0.375
6.	Days to maturity	2.29	94.56**	6.23
7.	Panicle length (cm)	0.501	1.557**	1.069
8.	Number of filled spikelet /panicle	40.50	234.29*	17.64
9.	Number of unfilled spikelet /panicle	8.375	942.623**	5.185
10.	Total number of spikelet /panicle	185.792	1779.708**	90.315
11.	1000-grain weight (g)	2.00	37.872**	1.71
12.	Biological yield /plant (g)	25.825	237.876**	27.544
13.	Grain yield/plant (g)	0.926	102.154**	2.65
14.	Harvest index	1.62	241.11*	9.43
15.	Grain yield/plot (kg)	0.011	0.726*	0.03
16.	Grain yield/m^2	21.140	19879.63**	39.184

*Significant at 5% level, ** Significant at 1% level

Table 9. Mean performances for yield and its related characters in hybrids and check varieties

SL No.	Variety	PH (cm)	DFF	DTM	NET	PL (cm)	NFS	TNS	TGW (g)	BW/P (g)	GYP (g)	HI (%)	GW/m² (g)
1	Sonarbangla-1	89.52	97.00	139.00	14.33	27.47	145.33	165.67	28.32	29.59	46.47	61.10	725.80
2	Jagoron	85.80	97.00	140.00	14.00	27.34	129.00	133.67	28.24	26.03	46.22	63.97	666.66
3	Hira	87.70	97.33	145.00	16.67	27.53	132.33	162.33	26.24	40.41	42.90	51.49	620.00
4	Aloron	91.73	119.66	143.30	17.00	28.57	136.67	153.33	29.10	28.00	47.87	63.09	745.00
5	Richer	82.80	119.00	135.00	15.66	27.80	124.67	137.67	29.04	32.55	44.30	57.64	646.00
6	BRRI hybrid dhan1	100.31	123.33	149.00	16.33	27.60	145.00	214.00	25.62	46.45	42.88	48.00	615.00
Mean		**89.65**	**108.89**	**141.82**	**15.67**	**27.68**	**135.50**	**165.78**	**27.76**	**33.84**	**45.11**	**57.55**	**669.69**
7	BRRI dhan28	101.54	95.33	140.30	15.00	25.96	124.67	145.33	20.01	49.68	30.45	38.00	550.00
8	BRRI dhan29	97.50	117.33	160.00	15.30	27.50	144.00	182.00	21.20	31.01	36.87	54.32	600.00
Mean		**99.52**	**106.33**	**150.15**	**15.15**	**26.70**	**134.34**	**163.67**	**20.61**	**40.35**	**33.66**	**46.16**	**540.42**
Grand mean		**92.12**	**108.25**	**141.60**	**15.54**	**27.44**	**135.21**	**164.72**	**25.97**	**37.09**	**42.25**	**54.70**	**637.37**
SEd±		8.437	0.55	2.04	0.87	0.84	3.43	7.76	1.07	4.28	1.38	2.54	5.11
CV (%)		3.86	0.62	1.76	9.98	3.76	3.11	5.75	5.04	14.80	4.00	5.45	10.56
CD (%)		18.08	1.18	4.38	1.87	1.80	7.36	16.64	2.30	9.19	2.96	0.09	214.66

PH=Plant height, DFF=Days to 50% flowering, DTM=Days to maturity, NET=Number of effective tillers/plant, PL=Panicle length, NFS=Number of filled spikelet, TNS=Total number of spikelet, TGW=Thousand grain weight, BW/P=Biomass weight per plant, GYP=Grain yield per plant, HI=Harvest index, GW/m²=Grain weight per sq. meter.

4.3. Plant height (cm)

Plant height of the hybrids ranged from 82.80 cm in Richer to 100.31 cm in BRRI hybrid dhan1, with a mean of 89.65 cm. For the checks the value ranged from 97.50 cm for BRRI dhan29 and 101.54 cm for BRRI dhan28, with a mean of 99.52 cm. The grand mean value for this trait was 92.12 cm. The group of genotypes that showed higher plant height were constituted by BRRI dhan28, BRRI hybrid dhan1 and BRRI dhan29. The group of genotypes that showed lower plant height was constituted by Heera, Jagoron and Richer. The average plant height of hybrids studied in the present study was shorter than the checks. Khush (1999) reported that short stature reduces the susceptibility of rice crop to lodging and leads to higher harvest index. A plant height of 90-100 cm is considered ideal for maximum yield. The average plant height of the hybrids (89.65 cm) of present studies showed ideal height.

4. 4 Days to 50% flowering

The number of days taken for 50% flowering of the hybrids ranged from 97.00 days in case of Sonarbangla-1 and Jagoron to 123.33 days in BRRI hybrid dhan1 with a mean of 108.89 days. Between the checks, BRRI dhan28 showed the least flowering (95.35 days) and BRRI dhan29 showed more days of flowering (117.33 days), with mean of 106.33 days. Hybrids showed higher days of flowering than checks. Among the all genotypes, it ranged from 95.33 days to 123.33 days. The grand mean for the character of all genotypes was 108.25 days. The group of genotypes that showed maximum days to flowering were constituted by BRRI hybrid dhan1 (123.33 days), Aloron (119.66 days)) and Richer (119.00 days), respectively. The group of genotypes that showed minimum days to flowering were constituted by BRRI dhan28 (95.33 days), Heera (97.33 days), Sonarbangla-1 (97.00 days) and Jagoron (97.00 days), respectively. These three hybrids matured earlier and ultimately reduced the crop duration. As a result one to two irrigations saved and crop would be also escape from insect infestations. The hybrid BRRI hybrid dhan1 took long duration for 50% flowering (123.33 days), which would be little difficult to fit in presently practiced cropping system.

4. 5. Days to maturity

The days to maturity among hybrids ranged from 135.00 days for Richer to 149.00 days for BRRI hybrid dhan1, with a mean of 141.82 days. Between the checks, BRRI dhan28 matured earlier (138.30 days) than BRRI dhan29 (148.00 days). The range for days to maturity among all the genotypes varied from 135.00 days to 149.00 days with a grand mean of 142.20 days. The group of genotypes that showed maximum days to maturity constituted by BRRI hybrid dhan1 (149.00 days), BRRI dhan29 (148.00 days) and Heera (145.00 days). The group of genotypes that showed least number of days to maturity constituted by Richer (135.00 days), BRRI dhan28 (138.30 days), Sonarbangla-1 (139.00 days), Jagoron (140.00 days) and Aloron (125 days). Khush (1999) reported that the optimum growth duration for maximum rice yield in the tropics is thought to be 120 days from seed to seed. Growth duration of about 120 days allows the plant to utilize more soil nitrogen and solar radiation and resulting in high yield. However, for adaptation to various cropping system, varieties with varying growth duration of 100-130 days are required. According to some reports from China most of the hybrids have longer growth duration than the high yielding varieties (Lin and Yuan, 1980; Tian *et al.,* 1980 and Wu, 2000). In the present study, hybrids took less time (141.82 days) than checks (143.15 days) for mean days to maturity. Aloron took 143.30 days for maturity but perform best yielding in respect of grain yield per plant (52.56g) compared to other hybrids and checks.

4.6. Number of effective tillers/plant

Among the hybrids, the range for this trait varied from 14.00 in Jagoron to 17.00 in Aloron, with a mean of 15.67. In case of checks, it was 15.00 for BRRI dhan28 and 15.30 for BRRI dhan29 with a mean of 15.15. Hybrids showed intermediate number of effective tillers per plant. Among all the genotypes, Aloron showed highest number of effective tillers (17.00) and Jagoron showed least number of effective tillers (14.00) with a grand mean of 15.54. The group of genotypes that showed higher number of effective tillers per plant was constituted by Aloron (17.00), Heera (15.67) and BRRI hybrid dhan1 (16.33). The group of genotypes that showed least number of effective tillers per plant was constituted by Jagoron (14.00), Sonarbangla-1 (14.33), BRRI dhan28 (15.00), BRRI dhan29

(15.30) and Richer (15.66). Earlier many workers reported that higher numbers of productive tillers are responsible 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) reduced tillering habit (6-10 tillers/plant) would give higher yield than the modern varieties having 20-25 tillers. He observed that only 14-15 of these tillers produce panicles which are small and rest remaining unproductive. Reduced tillering facilitates synchronous flowering and maturity and more uniform panicle size. Genotypes with lower tiller number are also reported to produce a larger proportion of heavier grains (Padmaja Rao, 1987).

4.7. Panicle length (cm)

Rice hybrids in general have large panicles and more spikelets than conventional varieties. In present study, among the hybrids, the length of panicle ranged from 27.34cm in Jagoron to 28.57 cm in Aloron, with a grand mean of 27.44 cm. Between the checks, the length was 25.96cm for BRRI dhan28 and 27.50 cm for BRRI dhan29 with a mean of 26.70cm. The group of genotypes that showed longer panicle length constituted by Aloron (28.57cm), Richer (27.80cm) and BRRI dhan29 (27.50 cm). The group of genotypes that showed shorter panicle length was constituted by BRRI dhan28 (25.96cm), Jagoron (27.34cm), Sonarbangla-1 (27.47cm) and BRRI dhan29 (27.50cm). Wang and Tang (1988) reported that the length of panicle varied from 26.30 cm to 27.00 cm among the *indica /japonica* hybrids. In present study the range of panicle length of hybrids was 27.34cm to 28.57cm which was comparatively higher than *indica/japonica* hybrids. Relative appearance of hybrids with checks for panicle size is presented in Plate 10.

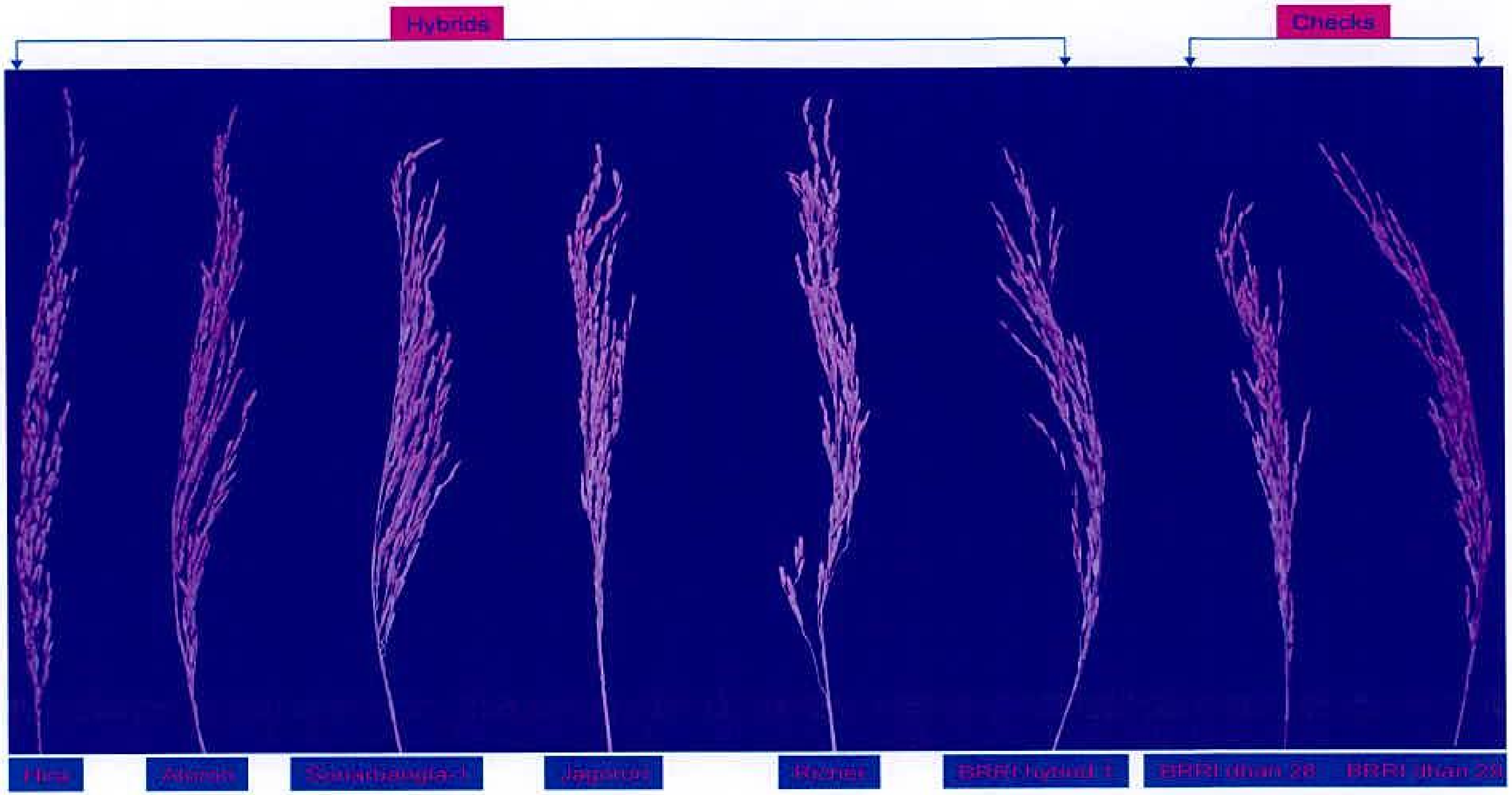

Plate 10. Comparative view of panicles of hybrids and checks

4.8. Number of filled spikelets/panicle

The mean of hybrid for this character was 135.50, with the range being 124.67 to 145.33. Among the all genotypes, the number of filled spikelets varied from 124.67 in Richer and BRRI dhan28 to 145.33 in Sonarbangla-1, with a grand mean of 135.21. The group of genotypes that showed higher number of filled spikelets was constituted by Sonarbangla-1 (145.33), BRRI hybrid dhan1 (145.00), and BRRI dhan29 (144.00). The group of genotypes that showed least number of filled spikelets was constituted by Richer (124.67), BRRI dhan28 (124.67), Jagoron (129.00) and Heera (132.33). Viraktamath *et al.*, (2002) concluded that spikelet fertility was lower in hybrids than inbreeds and within the panicle, spikelet fertility was lower in the basal half in both inbreeds and hybrids, but extent of spikelet fertility in the hybrids was low. Though all the hybrids have higher number of total grains per panicle, it still has scope of further improvement in spikelet fertility which would perhaps enhance the level of heterosis.

4.9. Total number of spikelets/panicle

The range for total number of spikelets among hybrids varied from 133.67 to 214.00 with a mean value of 165.78. Between the checks, BRRI dhan29 had 182.00 spikelets while BRRI dhan28 had 145.33 spikelets with a mean of 163.67. Among the all genotypes, BRRI hybrid dhan1 showed highest number of total spikelets (214.00) and Jagoron showed least number of total spikelets (133.67), with a grand mean of 164.72. The group having high spikelet number was constituted by the genotypes BRRI hybrid dhan1 (214.00), BRRI dhan29 (182.00) and Sonarbangla-1 (165.67). The group having least number of total spikelets was constituted by Jagoron (133.67), Richer (137.67), BRRI dhan28 (145.33), Aloron (153.33) and Heera (162.33). Positive association between grain number per panicle and grain yield has been reported by number of workers (Chauhan *et al.*, 1986; Janagle *et al.*, 1987; Kalaimani and Kadambavanaundaram, 1988). Interestingly it is observed that number of filled spikelets, total number of spikelets and spikelet fertility show positive but non significant association among those characters.

4.10. 1000-grain weight (g)

The highest thousand grain weight (29.04g) was observed in Richer and the lowest (20.01g) in BRRI dhan28 with a grand mean of 25.97g. Between the checks, 1000-grain weight was 20.01g for BRRI dhan28 and 21.20g for BRRI dhan29, with a mean of 20.61g. The highly performing group was constituted by the genotypes Richer (29.04g), Aloron (29.10g), Sonarbangla-1 (28.32g) and Jagoron (28.24g). The group which showed lowest 1000-grain weight was constituted by BRRI dhan28 (20.01g) and BRRI dhan29 (21.20g). Vijayakumar *et al*. (1997) and Hossain (2004) reported high correlation between 1000 grain weight and grain yield per plant.

4.11. Biomass weight/plant (g)

Among the hybrids, biomass weight per plant ranged widely from 26.03g in Jagoron to 46.45g in BRRI hybrid dhan1, with a mean value of 33.84g. Between the checks, BRRI dhan29 showed lower value (30.01gm) and BRRI dhan28 showed higher value (49.68gm), with a mean value of 40.35g. The hybrids showed lowest biomass weight per plant compared to the checks. Among the all genotypes, BRRI dhan28 showed maximum biomass weight per plant (49.68gm) and Jagoron showed minimum biomass weight per plant (26.03gm), with a grand mean of 37.09g. The highly performing group was constituted by the genotypes BRRI dhan28 (49.68gm) and BRRI hybrid dhan1 (46.45gm). The group which showed lowest value was Jagoron (26.03gm), Heera (28.00gm), Sonarbangla-1 (29.59gm) and BRRI dhan29 (31.01gm). The superiority of hybrids for biomass over conventional varieties is reported widely. Blanco *et al.*, (1990) reported 10-20% superiority of hybrids for total biological yield and grain yield. Biomass production increased with growth duration (ranging from 110 to 138 days) both in hybrids and inbreeds. Kim and Rutger (1988) noted that hybrids that give high grain yields also produce high biomass.

4.12. Grain yield per plant (g)

Among the hybrids, grain yield per plant ranged widely from 42.88g in BRRI hybrid dhan1 to 47.87g in Aloron, with a mean value of 45.11g. Between the checks, BRRI dhan29 showed higher values (36.87g) than BRRI dhan28 (30.45g), with a mean value of 33.66g. The hybrids showed higher grain yield per plant compared to the checks. Among the all genotypes, Aloron showed maximum grain yield per plant (47.87g) and BRRI dhan28 showed minimum grain yield per plant (30.45g), with a grand mean of 42.25g. The highly performing group was constituted by the genotypes Aloron (47.87g), Sonarbangla-1 (46.47g) and Jagoron (46.22g). The group which showed lowest value was BRRI dhan28 (30.45g), BRRI dhan29 (36.87g), BRRI hybrid dhan1 (42.88g) and Heera (42.90g). The performance of any hybrid is finally estimated on the basis of the grain yield, which in turn is the result of contributions by many characters. In some studies, increased grain yield of the hybrids was due to heterosis in panicle number and spikelet number (Chang *et al.*, 1973; Carnathan *et al.*, 1972; Devarathinam, 1984; Hsu *et al.*, 1969; Saini *et al.*, 1974). Hossain (2004) reported that higher biological yield does not always contribute higher yield. He also suggested that it is desirable to select hybrids having higher spikelet fertility combined with high biomass and harvest index, than those producing lower biological yield with higher harvest index. Murayama and Sarker (2002) reported that the higher grain yields of indica/japonica hybrids were attributed to higher dry matter production rather than higher harvest index of the hybrids.

4.13. Harvest index (%)

The mean value of harvest index was recorded as percent and range varied from 48.00 percent to 63.97 percent, in case of hybrids. Between the checks, BRRI dhan29 showed higher value of harvest index (54.32%) than BRRI dhan28 (38.00%), with a mean value of 46.16%. Among the all genotypes, Jagoron showed maximum harvest index (63.97%) and BRRI dhan28 showed minimum harvest index (38.00%), with a grand mean of 54.70%. The highly performing group included Jagoron (63.97%), Aloron (63.09%) and Sonarbangla-1 (61.10%). The group with least performance for this character was constituted by the genotypes BRRI dhan28 (38.00%), BRRI hybrid dhan1 (48.00%), BRRI dhan29

(54.32%) and Heera (51.49%). Sitaramaiah *et al.* (1998) observed that high yielding hybrids had higher biomass and harvest index. Significant positive association between grain yield and harvest index has also been reported by several other workers (Vinaya Rai and Murty, 1989). Hossain (2004) reported that hybrids show strong positive relationship between grain yield and harvest index.

4.14. Grain yield per square meter (g)

Among the hybrids, grain yield per square meter ranged widely from 615.00g in BRRI hybrid dhan1 to 745.00g in Aloron with a mean value of 699.69g. Between the checks, BRRI dhan29 showed more grain yield (597.50g) than BRRI dhan28 (483.33g), with a mean value of 540.42g. The hybrids showed highest grain yield per square meter compared to the checks. Among the all genotypes, Aloron showed maximum grain yield (745.00g) and BRRI dhan28 showed minimum grain yield (483.33g) per square meter, with a grand mean of 637.37g. The highly performing group was constituted by the genotypes Aloron (745.00g), Sonarbangla-1 (725.50g) and Jagoron (666.66g). The group which showed lowest value was BRRI dhan28 (483.33g), BRRI dhan29 (597.50g), Heera (620.00g) and BRRI hybrid dhan1 (615.00g) (Table 9). Murayama and Sarker (2002) reported that the higher grain yield of indica/japonica hybrids were attributed to higher dry matter production rather than higher harvest index of the hybrids, although low spikelet fertility limited yield potential in some of them. Iftekharuddaulla (2003) found that higher number of grains/panicle, bold grains, more panicles/m^2 and higher harvest index had positive and higher direct effect on grain yield.

4.13. STANDARD HETEROSIS IN CULTIVATED RICE HYBRIDS

Yield components analysis indicated that yield has been mainly due to heterosis in one or more of its components. The present study involved experiments to investigate the nature and magnitude of heterosis for 15 yield determining characters and grain yield of 6 hybrids over check BRRI dhan28 and BRRI dhan29. Considerable heterosis has been observed both in positive and negative directions. Heterosis as percent deviation in the performance of hybrids from the checks (standard heterosis) has been calculated and the values are presented in Table 10. The nature and magnitude of heterosis is presented character wise hereunder:

4.13.1 Plant height

The magnitude of standard heterosis for plant height ranged from -18.48 to -5.31 over BRRI dhan28 and -15.07 to 2.88 over BRRI dhan29. For plant height, compared with different checks, one hybrid (Richer) showed significant negative heterosis (-18.48) over the check BRRI dhan-28 and rest of all showed non-significant negative heterosis over the check BRRI dhan28, when compared with BRRI dhan29, one hybrid (BRRI hybrid dhan1) showed non-significant positive heterosis (2.88) and rest of all hybrids showed non significant negative heterosis. From the over all values, most of the hybrids showed significant negative heterosis over the two checks indicated their nature of dwarfness.

Though heterosis in negative direction is desired with respect to plant height under normal crop growing condition but in ill drained deep water condition, the taller hybrid would fit better. Positive heterosis in plant height has been reported by Chang *et al.* (1973), Govinda Raj (1983), Amirthadevarathnam (1983), Kim and Rutger (1988), Sharma and Mani (1990) While, Singh and Singh (1978) reported negative heterosis for plant height. Chang *et al.* (1971) opened that positive heterosis for plant height might introduce the problem of lodging. However, Ponnuthurai *et al.* (1984) conceptualized that taller plant may have better plant canopy for photosynthesis.

4.13.2 Days to 50% flowering

Heterosis for this trait ranged from -4.32 to 20.81 over BRRI dhan28 and -20.27 to 0.01 over BRRI dhan29. For this character, three hybrids (Heera, Richer and BRRI hybrid dhan1) showed highly significant positive heterosis; one hybrid (Sonarbangla-1) showed highly significant negative heterosis and one (Jagoron) showed non-significant positive heterosis as compared to the check BRRI dhan28. When compared with BRRI dhan29 five hybrids (Sonarbangla-1, Jagoron, Heera, Richer and Aloron) showed highly significant negative heterosis (-20.27, -16.89, -8.78, -8.78 and -15.31) and one (BRRI hybrid dhan1) showed non-significant positive heterosis (0.01).

Table10. Standard heterosis (%) for yield and related characters in hybrids

Sl. No.	Hybrids	Plant height (cm)		Days to 50% flowering		Days to maturity		Number of effective tiller/plant	
		Heterosis over		Heterosis over		Heterosis over		Heterosis over	
		BRRI Dhan28	BRRI Dhan29	BRRI Dhan28	BRRI Dhan29	BRRI Dhan28	BRRI Dhan29	BRRI Dhan28	BRRI Dhan29
1	Sonarbangla-1	-11.84	-8.18	-4.32**	-20.27**	0.51	-6.08**	-4.47	-6.34
2	Jagoron	-15.50	-11.99	-0.01	-16.89**	1.23	-5.41**	-6.67	-8.50
3	Heera	-13.63	-10.04	9.45**	-8.78**	4.84**	-2.03**	11.13	8.95
4	Aloron	-9.66	-5.91	1.62	-15.31**	3.62*	-3.18**	13.33*	11.11
5	Richer	-18.48*	-15.07	9.45**	-8.78**	-2.39	-8.74**	4.40	2.35
6	BRRI hybrid dhan1	-5.31	2.88	20.81**	0.01	7.74**	0.68	8.87	6.73

Table10. (Continued)

Sl. No.	Hybrids	Panicle length (cm)		Number of filled spikelets/Panicle		Total number of spikelets/Panicle		1000-grain weight (g)	
		Heterosis over		Heterosis over		Heterosis over		Heterosis over	
		BRRI Dhan28	BRRI Dhan29	BRRI Dhan28	BRRI Dhan29	BRRI Dhan28	BRRI Dhan29	BRRI Dhan28	BRRI Dhan29
1	Sonarbangla-1	5.82	-0.11	16.57**	0.92	13.99**	-26.33*	41.53**	33.58**
2	Jagoron	5.32	-0.58	3.47	-10.42**	-8.25	-40.59**	41.13**	33.21**
3	Heera	6.05	-0.11	6.14*	-8.14**	2.06	-31.58*	31.13**	23.77**
4	Aloron	10.05**	3.89	9.63**	-5.09	11.47	-10.99*	45.43**	37.26**
5	Richer	7.09*	1.09	0.00	-13.42**	-5.27	-9.34*	45.13**	36.89**
6	BRRI hybrid dhan1	0.68	0.36	16.31**	0.69	13.53**	-4.88*	28.04**	20.85*

Table 10 (Continued)

Sl. No.	Hybrids	Biomass weight/Plant (g)		Grain yield/Plant (g)		Harvest index (%)		Grain yield/m^2	
		Heterosis over		Heterosis over		Heterosis over		Heterosis over	
		BRRI Dhan28	BRRI Dhan29	BRRI Dhan28	BRRI Dhan29	BRRI Dhan28	BRRI Dhan29	BRRI Dhan28	BRRI Dhan29
1	Sonarbangla-1	-4.58	-40.44**	52.61**	26.04**	60.79**	12.48*	31.90**	20.92**
2	Jagoron	-16.06*	-47.61**	51.78**	25.36**	68.34**	17.77**	21.21**	10.00**
3	Heera	-9.70	-43.64**	40.89**	16.35**	35.50**	-5.21	12.73**	3.33*
4	Aloron	30.32*	-18.65*	57.21**	29.83**	66.03**	16.15**	35.45**	24.17**
5	Richer	4.95	-34.39**	45.48**	20.15**	51.68**	6.11	17.45**	7.67**
6	BRRI hybrid dhan1	49.79**	-6.50	40.82**	16.30**	26.32**	-11.63*	11.82**	2.50*

*Significant at 5% level, **Significant at 1% level

From over all results, it is clear that three hybrids showed significant negative heterosis over the check BRRI dhan29 indicating their earliness. The highly significant positive heterosis over the checks observed in case of Sonarbangla-1, Jagoron, Aloron, Heera, Richer and BRRI hybrid dhan1indicating their lateness as compared to check the check BRRI dhan28. Negative heterosis for days to 50% flowering has been reported by several workers (Chang *et al.,* 1973; Singh *et al.,* 1980; Fujimaki and Yoshida, 1984; Govinda Raj and Siddiq, 1986; Manuel and Palansiamy, 1989, Sharma and Mani, 1990 and Young and Virmani, 1990). However, some studies have shown both positive and negative heterosis for this character (Karunakaran, 1968). Early duration coupled with high standard heterosis for grain yield would of advantage in areas with short growing seasons or multiple cropping systems. In this regard, Sonarbangla-1, Jagoron and Heera are promising varieties.

4.13.3 Days to maturity

Heterosis for this trait ranged from -2.39 to 7.74 over BRRI dhan28 and -8.74 to 0.68 over BRRI dhan29. For this character, when compared with BRRI dhan28, two hybrids (Heera and BRRI hybrid dhan1) showed highly significant positive heterosis (4.84 and 7.74), one hybrid (Aloron) showed significant positive heterosis (3.62), two hybrids (Sonarbangla-1 and Jagoron) showed nonsignificant positive heterosis and one (Richer) showed non-significant negative heterosis (-2.39). With respect to BRRI dhan29, five hybrids (Richer, Sonarbangla-1, Jagoron, Aloron, and Heera) showed highly significant negative heterosis (-8.74, -6.08, -5.41, -3.18 and -2.03) and one (BRRI hybrid dhan1) showed non significant positive heterosis (0.68). Interestingly in the present investigation hybrid Richer which has significant negative heterosis gives the moderate yield among the hybrids. Lin and Yuan (1980) have reported negative heterosis. Virmani (1999) observed varying growth duration ranging from 105 to 136 days with no correlation between growth duration and expression of heterosis. Hence heterotic hybrids could be developed with a range of desired growth duration.

4.13.5 Number of effective tillers/plant

Heterosis for this trait ranged from -6.67 to 13.33 over BRRI dhan28 and -8.50 to 11.11 over BRRI dhan29. For this character, when compared with BRRI dhan28, one hybrid (Aloron) showed significant positive heterosis, two hybrids (Sonarbangla-1 & Jagoron) showed non-significant negative heterosis (-4.47 & -6.67) and rest of all hybrids (Heera, BRRI hybrid dhan1 and Richer) showed non significant positive heterosis (11.13, 8.87 and 4.40). With respect to BRRI dhan29, two hybrids (Sonarbangla-1& Jagoron) showed nonsignificant negative heterosis (-6.34 & -8.50) and rest of all hybrids (Richer, BRRI hybrid dhan1, Heera and Aloron) showed non significant positive heterosis (2.35, 6.73, 8.95 and 11.11). Although many workers (Namboodri,1963; Rao, 1965; Singh and Singh, 1978; Govinda Raj, 1983; Kumar *et al.,* 1994) have reported positive heterosis for number of effective tillers but some times increasing tillering in rice hybrids lead to increase sterility mainly due to imbalanced source and sink relationship. Presence of high heterosis for this character may not result in high yield, especially in those hybrids where spikelet fertility is greatly affected due to varying levels of fertility restoration or poor panicle exertion. It has been reported that in hybrids, the reduction in number of effective tillers is compensated by increased number of spikelet per panicle (Virmani *et al.*, 1982). A comparative performance of heterosis over the checks has been graphically presented in Fig. 1 and Fig 2, respectively.

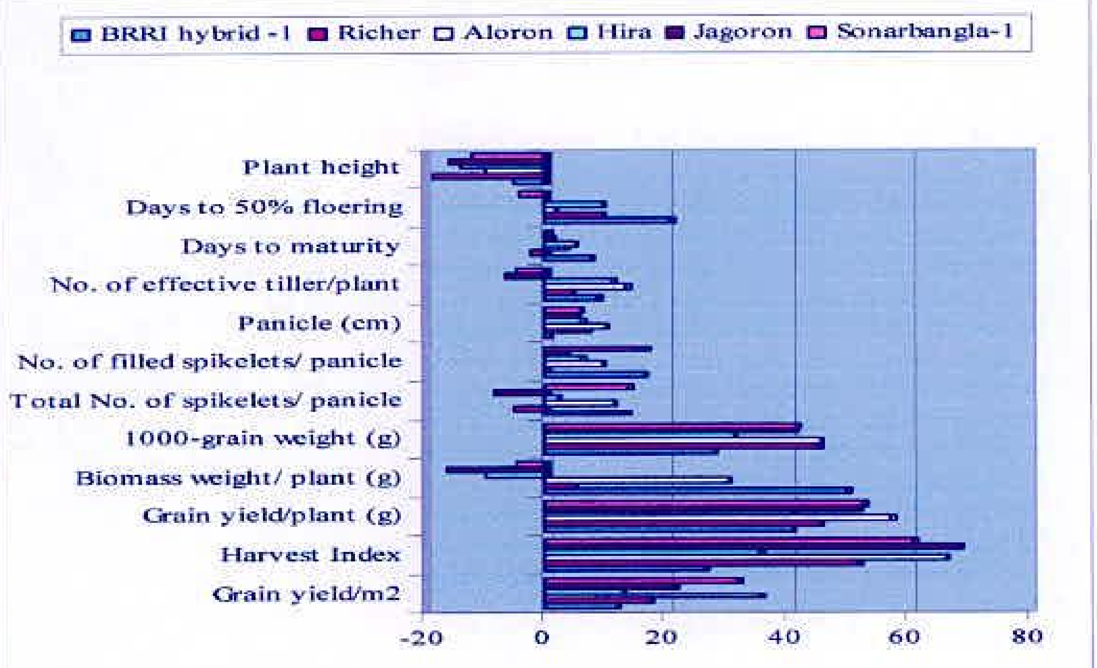

Figure 1. Standard heterosis over BRRI dhan 28 for yield and yield contributing traits

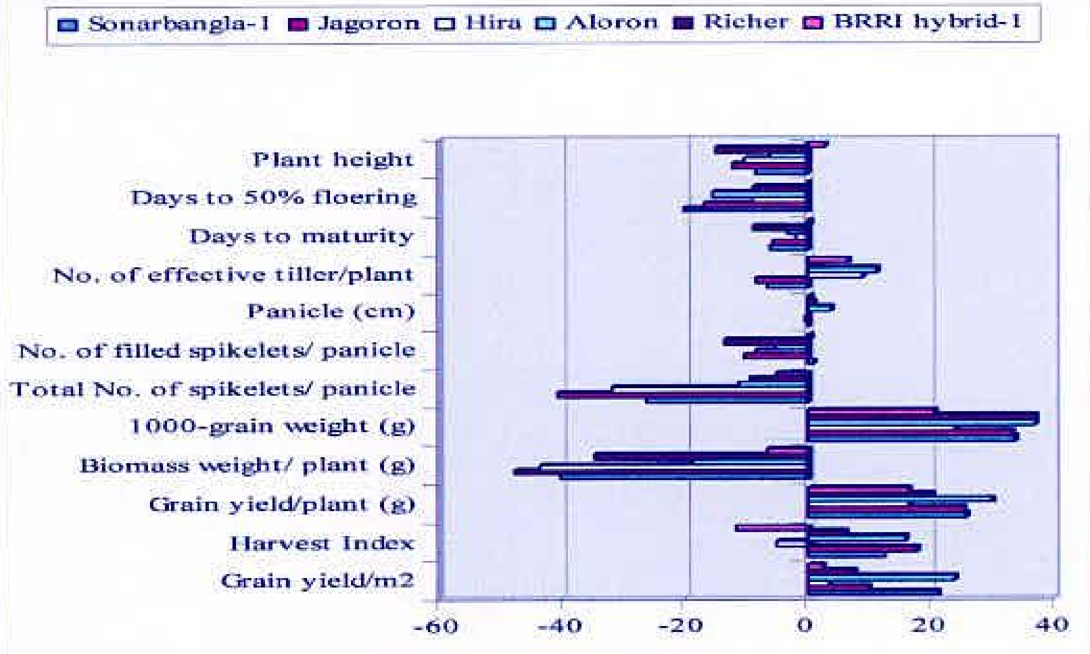

Figure 2. Standard heterosis over BRRI dhan 29 for yield and yield contributing traits

4.13.6 Panicle length (cm)

Heterosis for this trait ranged from 5.32 to 10.05 over BRRI dhan28 and -0.58 to 3.89 over BRRI dhan29. For this character, when compared with BRRI dhan28, one hybrid (Aloron) showed highly significant positive heterosis (10.05), one hybrid (Richer) showed significant positive heterosis (7.09) and rest of four (Jagoron, Sonarbangla-1, Heera and BRRI hybrid dhan1) showed non-significant positive heterosis. With respect to BRRI dhan29, three hybrids (Sonarbangla-1, Heera and Jagoron) showed non-significant negative heterosis (-0.11, -0.11 and -0.58) and three (Aloron, Richer and BRRI hybrid dhan1) showed non significant positive heterosis (3.89, 1.09 and 0.36). Hence information on panicle length alone may not be sufficient in predicting the grain yield. Considerable amount of heterosis has been reported for this trait by Anadakumar and Sree Rangasamy (1984), Sarial (1994) and Pandey *et al.* (1995). However, Nijaguna and Mahadevappa (1983), Paramasivam and Sree Rangasamy (1988) and Manuel and Palanisamy (1989) observed the higher magnitude of negative heterosis than positive heterosis.

4.13.7 Number of filled spikelets/panicle

Heterosis for this trait ranged from 0.00 to 16.57 over BRRI dhan28 and -13.42 to 0.92 over BRRI dhan29. For this character, when compared with BRRI dhan28, three hybrids (Aloron, BRRI hybrid dhan1 and Sonarbangla-1) showed highly significant positive heterosis (9.63, 16.31 and 16.57). With respect to BRRI dhan29, three hybrids (Heera, Jagoron & Richer) showed highly significant negative heterosis (-8.14, -10.42 & -13.42), two hybrids (Sonarbangla-1 and BRRI hybrid dhan1) showed non-significant positive heterosis (0.92 and 0.69) and one hybrid (Aloron) showed non-significant negative hetertosis (-5.09). Number of filled spikelets per panicle seems to be most important factor contributing to grain yield, especially in hybrids. Virmani *et al.* (1982) concluded that heterosis in yield was primarily due to increased filled spikelets per panicle. In case of standard heterosis, high heterosis for filled grains per panicle, resulting in higher grain yield has been reported by several workers (Sharma and Mani, 1990; Patel *et al.*, 1994; Pandey *et al.*, 1995; Rao *et al.*, 1996).

4.13.8 Total number of spikelets/panicle

Heterosis for this trait ranged from -8.25 to 13.99 over BRRI dhan28 and -4.88 to -40.59 over BRRI dhan29. For this character, when compared with BRRI dhan28, two hybrids (Sonarbangla-1 and BRRI hybrid dhan1) showed highly significant positive heterosis (13.99 and 13.53), two (Aloron and Heera) showed non significant positive heterosis (11.47 and 5.50) and two (Jagoron, BRRI hybrid dhan1) showed non significant negative heterosis (-8.25, -5.27). With respect to BRRI dhan29, one hybrid (Jagoron) showed highly significant negative heterosis (-40.59) and rest of all (Heera, Sonarbangla-1, Aloron, Richer, and BRRI hybrid dhan1) showed significant negative heterosis (-31.58, -26.39, -10.99, -9.34 and -4.88). Positive heterosis in the present investigation is in conformity with the findings of Virmani *et al.* (1981, 1982) who concluded that the heterosis for grain yield was mainly due to more spikelets and somewhat 1000-grain weight. Considerable amount of heterosis for total number of spikelets per panicle was observed in earlier studies (Sharma and Mani, 1990; Patnaik *et al.*, 1990).

4.13.9 1000-grain weight (g)

Heterosis for this trait ranged from 28.04 to 45.43 over BRRI dhan28 and 20.85 to 37.26 over BRRI dhan29. For this character, when compared with BRRI dhan28, all six hybrids (Aloron, Richer, Sonarbangla-1, Jagoron, Heera, and BRRI hybrid dhan1) showed highly significant positive heterosis (45.43, 45.13, 41.53, 41.13, 31.13 & 28.04). With respect to BRRI dhan29, five hybrids (Aloron, Richer, Sonarbangla-1, Jagoron and Heera) showed highly significant positive heterosis (37.26, 36.89, 33.58, 33.21 & 23.77) and one hybrid (BRRI hybrid dhan1) showed significant positive heterosis (20.85). For 1000 grain weight, incase of heterosis over both the checks, all of the hybrids showed significant positive heterosis indicating their more weight than BRRI dhan28 and BRRI dhan29. Many earlier workers have reported that the yield increase of rice hybrids is significantly contributed by 1000 grain weight (Virmani *et al.*, 1982; Ponnuthurai *et al.*, 1984; Patnaik *et al.*, 1990; Pandey *et al.*, 1995; Rao *et al.* 1996; Padmavathi *et al.*, 1996).

4.13.10 Biomass weight/plant (g)

Heterosis for this trait ranged from -16.06 to 49.79 over BRRI dhan28 and -6.50 to -47.61 over BRRI dhan29. For this character, when compared with BRRI dhan28, one hybrid (BRRI hybrid dhan1) showed highly significant positive heterosis (49.79), one hybrid (Aloron) showed significant positive heterosis (30.32), two (Heera & Sonarbangla-1) showed non-significant negative heterosis (-9.70 & -4.58), one (Richer) showed non significant positive heterosis (4.95) and one (Jagoron) showed significant negative heterosis (-16.06). With respect to BRRI dhan29, four hybrids (Jagoron, Heera, Sonarbangla-1, and Richer) showed highly significant negative heterosis (-47.61, -43.64, -40.44, -34.39), one (Aloron) showed significant negative heterosis (-18.65) and one (BRRI hybrid dhan1) showed non significant negative heterosis (-6.50). Studies at IRRI (Balanco *et al.*, 1990) based on 57 hybrids and 43 inbreed established 10-20% superiority of hybrids for total biological yield and grain yield.

4.13.11 Grain yield/plant (g)

Heterosis for this trait ranged from 40.82 to 57.21 over BRRI dhan28 and 16.30 to 29.83 over BRRI dhan29. For this character, when compared with checks all the six hybrids (Aloron, Sonarbangla-1, Jagoron, Richer, Heera, and BRRI hybrid dhan1) showed highly significant positive heterosis. The extent of heterosis for grain yield in rice has been reported in various studies. Rutger and Shinjyo (1980) recorded significant superiority over check of 16 to 63 % in 11 out of 153 rice hybrids. Virmani *et al.*, (1982) reported maximum levels of 73% heterosis, 57% heterobeltiosis and 34% standard heterosis. Heterosis for grain yield ranging from -48.7 to 72.6 percent in 66 hybrids was reported by Mahapatra and Mohanty (1986). In china, a yield advantage of 20 to 30 percent has been obtained from hybrids over the commercial varieties (Lin and Yuan, 1980). Sarial (1994) reported that among 76 hybrids, 40 were significantly superior in yield to their respective check varieties with superiority range of 76.64 to 284.55%.

4.13.12 Harvest index (%)

Heterosis for this trait ranged from 26.32 to 68.34 over BRRI dhan28 and -11.63 to 17.77 over BRRI dhan29. For this character, when compared with BRRI dhan28, all hybrids (Jagoron, Aloron, Sonarbangla-1, Richer, Heera and BRRI hybrid dhan1) showed highly significant positive heterosis (68.34, 66.03, 60.78, 51.68, 35.50 and 26.32). With respect to BRRI dhan29, two hybrids (Jagoron and Aloron) showed highly significant positive heterosis (17.77 and 16.15), one hybrid (Sonarbangla-1) showed significant positive heterosis (12.48), one hybrid (Richer) showed non-significant positive heterosis (6.11), one hybrid (Heera) showed highly non-significant negative heterosis (-5.21) and one hybrid (BRRI hybrid dhan1) showed significant negative heterosis (-11.63). High yielding hybrids also showed significant standard heterosis in total dry matter and harvest index (Kim, 1985; Ponnuthurai *et al.*, 1984; Virmani *et al.*, 1981).

4.13.13 Grain yield/sq. m (g)

Heterosis for this trait ranged from 11.82 to 35.45 over BRRI dhan28 and 2.50 to 24.17 over BRRI dhan29. For this character, when compared with BRRI dhan28, all six hybrids (Aloron, Sonarbangla-1, Jagoron, Richer, Heera and BRRI hybrid dhan1) showed highly significant positive heterosis (35.45, 31.90, 21.21, 17.45, 12.73 & 11.82 percent, respectively). With respect to BRRI dhan29, four hybrids (Aloron, Sonarbangla-1, Jagoron & Richer) showed highly significant positive heterosis (24.17, 20.92, 10.00 & 7.67 percent, respectively) and rest of two hybrids (Heera and BRRI hybrid dhan1) showed significant positive heterosis (3.33 & 2.50 percent). The extent of heterosis for grain yield in rice has been reported in various studies. Rutger and Shinjyo (1980) recorded significant superiority over check of 16 to 63 % in 11 out of 153 rice hybrids. In china, a yield advantage of 20 to 30 percent has been obtained from hybrids over the commercial varieties (Lin and Yuan, 1980). Average of -98.00 to 78.00 percent superiority over check has been observed in hybrid rice experiments in India (Govinda Raj and Siddiq, 1986; Bijral *et al.*, 1989; Patnaik *et al*, 1990; Murity *et al.*, 1991; Sarial, 1994) reported that among 76 hybrids, 40 were significantly superior in yield to their respective check varieties with superiority range of 76.64 to 284.55%.

4.13.14 Yield per plot and yield advantage over checks

The range for grain yield per plot was from 3.30kg in BRRI dhan28 to 4.50kg in Aloron with a mean of 3.94kg. Between the checks, BRRI dhan28 showed lower yield (3.30kg) than BRRI dhan29 (3.60kg) per plot, with a mean yield of 3.45kg per plot. The highly performing groups were Aloron, Sonarbangla-1 and Jagoron. The group of hybrids that showed lower yield per plot was BRRI hybrid dhan1, Heera and Richer, but inspite of their lower yield, the entire lower group showed higher yield per plot than both the checks. The yield per hectare for hybrids ranged from 7450.00kg to 6150.00kg, with a mean of 6696.63kg. The yield advantage for hybrids over BRRI dhan28 ranged from 11.82 to 35.45 and 2.50 to 24.17% over BRRI dhan29. BRRI hybrid dhan1 showed lowest yield advantage and Aloron showed highest yield advantage over both the checks. For this trait all the hybrids showed highly significant positive yield advantage over the check BRRI dhan28. When compared to BRRI dhan29 four hybrids showed highly significant positive yield advantage (Table 11).

On the basis of performance, all the hybrids seem to be promising for multilocation testing for consideration of commercial cultivation, as the present observation involved only one location and relatively small plots. Of the 6 hybrids, all have shown desirable grain quality characters. Early maturing (135.00 days) hybrid Richer has given yield over 6.46 t/ha and good grain quality is likely to bring high profit to farmers by virtue of it's remarkably yield increased and short duration. Similarly, hybrid Aloron gave good yield performance with 7.45t/ha and Sonarbangla-1 gave 7.25t/ha with combination of good grain quality are expected to enhance the productivity and profitability of farmers. A comparative performance of yield advantage over the checks and grain yield kg per hectare has been graphically presented in Fig. 3 and Fig 4, respectively.

Table 11 Yield advantage of hybrid over standard check

Sl. No.	Hybrid	Mean yield/Plot (kg) (3m×2m=6m²)	Yield (kg/ha)	Yield advantage over checks (%)	
				BRRI Dhan28	BRRI Dhan29
1	Aloron	4.50	7450.00	35.45**	24.17**
2	Sonarbangla-1	4.45	7255.00	31.90**	20.92**
3	Jagoron	4.00	6666.60	21.21**	10.00**
4	Richer	3.95	6460.00	17.45**	7.67**
5	Heera	3.80	6200.00	12.73**	3.33*
6	BRRI Hybrid dhan1	3.75	6150.00	11.82**	2.50*
	Mean	**4.10**	**6696.93**	-	-
7	BRRI Dhan29	3.60	6000.00	9.09**	0.00
8	BRRI Dhan28	3.30	5500.00	0.00	-8.33**
	Mean	**3.45**	**5750.00**	-	-
	Grand mean	**3.94**	**6460.20**	-	-
	Me	0.01	-	-	-
	SEd±	0.45	-	-	-
	CV (%)	1.50	-	-	-
	CD (5%)	0.57	-	-	-

*Significant at 5% level of significance, **Significant at 1% level of significance, Me= Error means sum of square

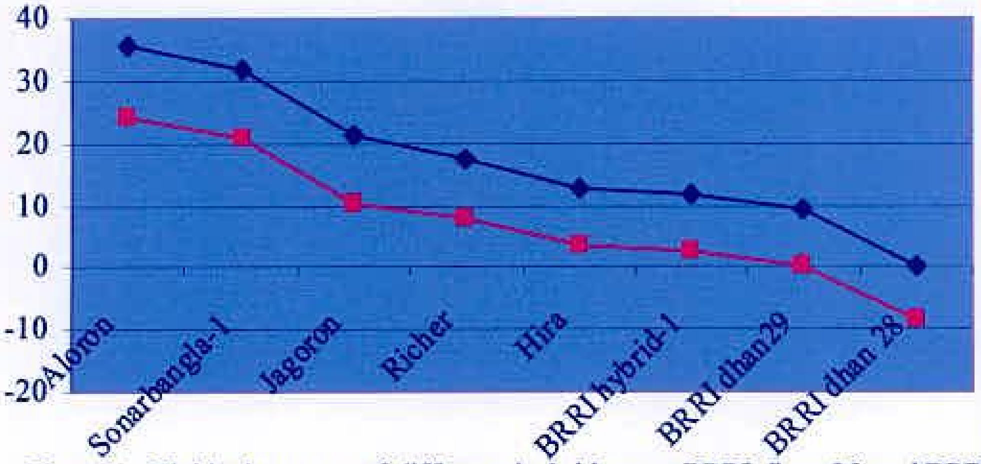

Figure 3. Yield advantage of different hybrids over BRRI dhan 28 and BRRI dhan 29

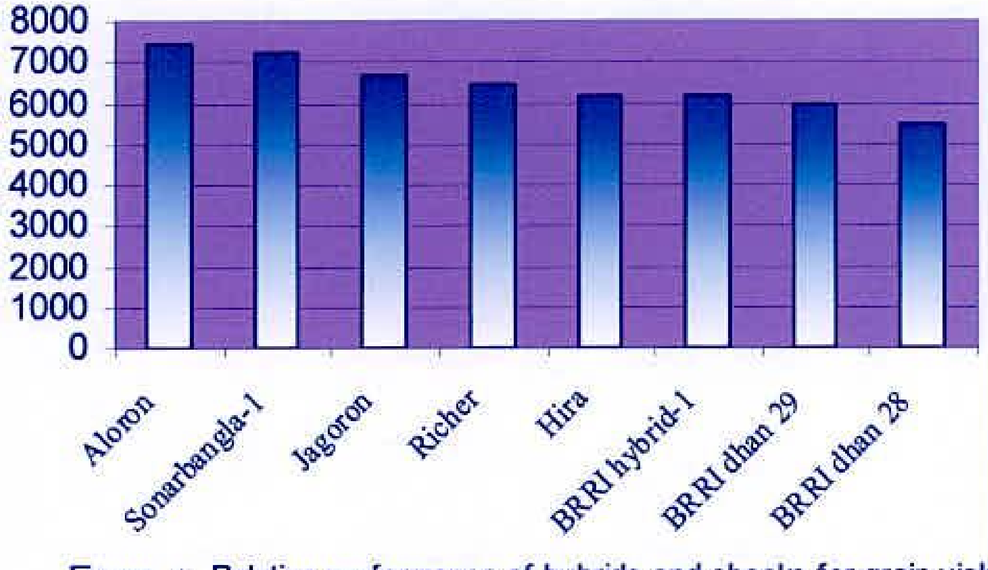

Figure 4. Relative performance of hybrids and checks for grain yield (kg/ha)

4.14 ASSESMENT OF GENETIC VARIATION OF IMPORTANT GRAIN CHARACTERS AMONG THE HYBRIDS

The estimates of mean, range, genotypic and phenotypic coefficient of variation ((GCV & PVC) and broad sense heritability for the quality characters studied are presented in Table 12. As revealed by the table phenotypic coefficient of variation ranged from 1.20 to 129.40 percent. The traits like hulling percent (brown rice recovery), kernel elongation index, grain shape after cooking (L_1/B_1), volume expansion, amylose content, protein content, alkali spreading value, water uptake , grain breadth after cooking and grain shape before cooking (L_0/B_0) had PCV values 46.75, 4.39, 3.60, 18.00, 71.76, 31.04, 49.23, 20.43, 4.04 and 7.54 percent, respectively. Similarly, grain shape of brown rice (L_b/B_b), grain shape of rough rice (Lr /Br), grain length after cooking, head rice recovery, and milling percent were recorded as 6.64, 11.41, 4.17, 129.40 and 15.82 percent respectively. The values for estimate genotypic coefficient of variation (GCV) has same trend as of PVC with slightly lower to corresponding PCV for all the traits. For instance, water uptake percent had 6.80 as GCV value and 20.43 as PCV values. Similarly, volume expansion expression value showed 5.90 GCV and 18.00 PCV. The broad sense heritability ranged from 22.01 for breadth of rough rice to 33.29 for head rice recovery. It was recorded quite high for characters like volume expansion, amylose content, kernel elongation index, grain length/ breadth ratio of cooked rice and grain length of milled rice, where as the character like kernel elongation ratio, L/B ratio of rough rice, hulling, grain breadth of brown rice and milling showed relatively low estimates of broad sense heritability. The analysis of variance (ANOVA) presented in Table 13 show highly significant variation for the quality characters studied. A wide range of variation is observed for characters like alkali spreading value, kernel elongation index, volume expansion (%), amylose percent, water uptake (%), grain L/B ratio of rough rice, grain L/B ratio of milled rice, and head rice recovery (HRR %). Heritable components of variation are quite high for characters such as water uptake, volume expansion, amylose content, grain length, length/breadth ratio of grains and head rice recovery. The present findings on wide variation for quality traits as well as heritability are in agreement with reports of Sood (1978) and Sandeep (2003).

Table 12. Estimation of mean, range and coefficient of variation (Genotypic and Phenotypic) of various quality characters in rice hybrids

Sl. No.	Characters	GM	Range	Coefficient of variation		H^2(%) bs
				Genotype	Phenotype	
1.	Length of rough rice	9.30	8.61-10.16	4.67	14.53	32.17
2.	Breadth of rough rice	3.08	2.41-2.98	00.87	4.01	22.01
3.	Length/Breadth ratio of rough rice	3.03	3.09 -4.01	3.40	11.41	29.99
4.	Length of brown rice	7.28	7.10 -7.80	00.80	3.55	22.69
5.	Breadth of brown rice	2.82	2.60 -3.50	2.35	7.52	31.32
6.	L/B ratio of brown rice	2.58	2.03 -2.73	1.79	6.64	27.00
7.	Hulling (%)	79.63	77.65-9.25	13.80	46.75	29.58
8.	Milling outturn (%)	71.69	68.5 -74.00	4.83	15.82	30.55
9.	Head Rice Recovery	60.49	48.23-3.65	43.07	129.40	33.29
10.	Grain length uncooked rice	6.35	6.00 -6.80	8.06	26.45	30.50
11.	Grain breadth uncooked rice	2.28	2.00 -2.50	1.22	4.02	30.43
12.	L/B ratio uncooked rice	2.76	2.50-3.10	2.39	7.54	31.77
13.	Alkali spreading value	4.30	3.00 -5.10	16.32	49.23	33.16
14.	Cooking time	18.63	15.50-21.00	14.99	45.73	32.79
15.	Length of cooked rice	8.82	8.08-9.21	1.14	4.17	27.35
16.	Breadth of cooked rice	2.77	2.58 -3.05	1.15	4.04	28.57
17.	L/B ratio of cooked rice	3.20	2.91-3.49	0.84	3.60	23.47
18.	Elongation ratio	1.41	1.27-1.50	0.30	1.20	25.45
19.	Elongation index	1.14	0.94 -1.32	1.31	4.39	30.00
20.	Imbibitions ratio	4.05	3.40 -5.00	5.90	18.00	32.83
21.	Water absorption	171.13	143.00 -217.00	6.80	20.43	33.30
22.	Amylose (%)	24.69	22.07-28.10	23.81	71.76	33.20
23.	Protein (%)	9.00	7.30-10.00	10.01	31.04	32.25

Table 13. Analysis of variance (ANOVA) for different quality traits in rice hybrids

Sl No.	Characters	d.f		Mean sum of square	
		Genotypes	Error	Genotypes	Error
1	Hulling (%)	7	14	37.999**	4.349
2	Milling outturn (%)	7	14	11.34**	0.95
3	HRR	7	14	78.273**	0.140
4	Length of rough rice (mm)	7	14	1.35**	0.05
5	Breadth of rough rice (mm)	7	14	0.0129*	0.026
6	L/B ratio of rough rice	7	14	0.257**	0.066
7	Length of uncooked rice(mm)	7	14	0.183	0.260
8	Breadth of uncooked rice (mm)	7	14	0.232**	0.014
9	L/B ratio of uncooked rice	7	14	0.158**	0.030
10	Length of cooked rice (mm)	7	14	0.37**	0.07
11	Breadth of cooked rice (mm)	7	14	0.11**	0.02
12	L/B ratio of cooked rice	7	14	0.12*	0.03
13	Alkali spreading value	7	14	2.12**	0.01
14	Cooking time (minute)	7	14	8.52**	0.14
15	Kernel elongation ratio	7	14	0.017*	0.004
16	Elongation Index	7	14	0.050**	0.005
16	Volume expansion (%)	7	14	0.73**	0.01
17	Water absorption (%)	7	14	3495.80**	4.78
18	Amylose (%)	7	14	17.72**	0.07
19	Protein (%)	7	14	2.79**	0.09

4.15. STUDY OF MILLING AND GRAIN APPEARANCE OF THE HYBRIDS

When rice is threshed, the hull (lemma and palea) remains intact - this is known as 'rough rice'. The hull is removed (about 20% of the kernel weight) to produce brown rice. Further milling removes the bran (the seed coat, embryo, and some endosperm) to produce milled rice. A milled rice grain contains approximately 85% starch and 5% protein. The quality of rice is determined by grain appearance, cooking quality and nutritional value. The grain is important for farmers as it determines the market price and to consumers as it determines their acceptability. Quality in rice is a combination of several physico-chemical characters of the grain. The physical properties of the rice grain are determined by grain color, shape and size, grain weight, hardness of the endosperm, appearance of the milled kernels, hulling and milling recovery. Starch, Proteins, minerals and vitamins constitute the chemical components of the rice grain. The market quality depends on physical attributes, while consumer's preference (cooking, eating and nutritive value) depends on chemical traits. Interestingly, both are inter-dependent. The results on mean performance of the hybrids and checks of present study are presented characterwise in table 14.

4.15.1 Hulling (%)

The hulling percentage (brown rice recovery) incase of hybrids ranged from 79.25% in BRRI hybrid dhan1 and Heera to 80.50% in BRRI dhan28 and Sonarbangla-1, with mean being 79.79%. The hulling percentage recorded for other hybrids was 79.75 and 80.25 percent in successive order. Between the checks BRRI dhan28 had higher hulling percentage (80.50%) than BRRI dhan29 (77.75%). Five hybrids show lower mean performance with respect to hulling percent as comparison to check BRRI dhan28 (80.50%) whereas Sonarbangla-1 showed similar result as compared to BRRI dhan28 and all hybrids showed higher hulling percentage compared to check BRRI dhan29 (77.75%). The similar range of hulling percentage was also reported by Sandeep (2003) during characterization of 20 new plant type genotypes in rice.

Table 14. Mean performance of quality characteristics in different hybrids (uncooked rice)

Sl. No.	Hybrids/ Checks	Hulling (%)	Milling (%)	HRR (%)	Rough rice			Brown rice			Milled rice (uncooked rice)		
					Length (mm)	Breadth (mm)	L/B ratio	Length (mm)	Breadth (mm)	L/B ratio	Length (mm)	Breadth (mm)	L/B ratio
1	Sonarbangla-1	80.50	73.00	48.25	10.16	3.00	3.39	7.80	2.89	2.70	6.80	2.20	3.09
2	Jagoron	80.25	72.00	61.00	9.07	2.97	3.05	7.20	2.80	2.57	6.20	2.17	2.56
3	Heera	79.25	72.00	62.75	8.61	3.30	2.61	7.40	2.84	2.61	6.20	2.00	3.10
4	Aloron	79.75	73.00	61.75	8.61	2.78	3.10	7.10	2.68	2.65	6.50	2.30	2.83
5	Richer	79.75	74.00	63.60	9.92	2.95	3.36	6.80	2.61	2.61	6.20	2.40	2.58
6	BRRI hybrid dhan1	79.25	68.50	61.55	10.11	3.44	2.94	7.10	2.95	2.41	6.00	2.50	2.40
	Mean	**79.79**	**71.95**	**59.81**	**9.41**	**3.07**	**3.08**	**7.23**	**2.80**	**2.59**	**6.32**	**2.26**	**2.76**
7	BRRI Dhan29	77.75	69.00	60.50	8.70	3.21	2.71	7.30	2.96	2.47	6.20	2.50	2.48
8	BRRI Dhan28	80.50	72.00	63.65	9.18	3.00	3.06	7.50	2.85	2.63	6.70	2.20	3.05
	Mean	**79.13**	**70.50**	**62.08**	**8.94**	**3.11**	**2.89**	**7.40**	**2.91**	**2.55**	**6.45**	**2.35**	**2.77**
	Grand mean	**79.63**	**71.69**	**60.49**	**9.30**	**3.08**	**3.03**	**7.28**	**2.82**	**2.58**	**6.35**	**2.28**	**2.76**
	SEd±	1.70	0.80	0.305	0.18	0.13	0.21	0.24	0.01	0.26	0.81	0.07	0.08
	CV (%)	2.59	1.36	0.62	2.33	5.29	2.56	6.98	0.94	0.90	1.59	3.90	3.49
	CD (5%)	3.65	1.70	0.67	0.38	0.28	0.45	0.43	0.06	0.06	0.17	0.16	0.17

L/B= Length/Breadth ratio, HRR= Head Rice Recovery, SEd= Standard Error difference, CV= Coefficient of Variation, CD= Critical Difference

4.15.2 Milling Outturn (%)

The milling percentage for hybrids ranged from 68.50 to 74.00 percent. The highest value was recorded for Richer and the lowest value was recorded for BRRI hybrid dhan1. The grand mean value for milling percentage was 71.69. The other hybrids showing high milling recovery were Sonatbangla-1 (73.00) and Aloron (73.00), while lower value was recorded for Jagoron (72.00) and Heera (72.00). Between the checks higher milling percentage was recorded for BRRI dhan28 (72.00) and lower for BRRI dhan29 (69.00). Five hybrids showed high percentage of milled rice recovery than both the checks and as many as four hybrids to check BRRI dhan28 (72.00%). One hybrid (Aloron) gave similar result as compared to the check BRRI dhan28 (72.00%). BRRI hybrid dhan1 (68.50) performed lower for milling percentage compared to both the checks. The highest hulling percent was found for hybrid Sonarbangla-1 (80.50%) while the highest milling percent highest mean was found for hybrid Richer (74.00%). This result indicated that higher hulling percent always did not give the higher milling percent. The similar results were also recorded by Hariprasanna (1998) and Sandeep (2003). Mishra (2003) studied milling percentage of some related hybrids in India and checks and concluded range of 60.50 to 72.60%. In the present study, the milling percentage for hybrids ranged from 68.50 to 74.00 percent which was higher than the *indica/japonica* hybrids studied by Hariprasanna (1998).

4.15.3 Head Rice Recovery (HRR %)

The head rice recovery for the hybrids ranged from 48.25 to 63.65%. The maximum value of 63.65 % was recorded for BRRI dhan28, while the minimum value of 48.25% was recorded for Sonarbangla-1 with a grand mean of 60.49 %. Three hybrids namely, Jagoron, BRRI hybrid dhan1 and Aloron showed recovery of 61.00, 61.55 and 61.75% respectively which was relatively low. Between the checks, BRRI dhan28 gave 63.65% head rice recovery while BRRI dhan29 gave the lower value of 60.50% with a mean of 62.08%. For the commercial success of a rice hybrid it must possess high total milled rice and whole kernel (HRR) turnout. If a hybrid 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). Viraktamath (1987) and Yadav and Singh (1989) reported an inverse relationship between HRR% and grain L/B ratio. In the present study, all the hybrids except Sonarbangla-1 (48.25%) are superior to the check BRRI dhan29 (60.50%) for the trait HRR percent. Five hybrids showed lower HRR than the check BRRI dhan28 (63.65%), while one hybrid (Heera) perform similar result (63.60%). Shobha Rani (2003) reported HRR of nine released hybrids of India during Kharif 2000 and reported their range as 46.20% to 59.60%. In the present study, the head rice recovery for the hybrids ranged from 48.25 to 63.65, these results clearly indicate them to be of good for HRR as compared to the released hybrids in India.

4.15. 4 Kernel length of rough rice (Paddy)

The mean value of kernel length of rough rice for hybrids ranged from 8.61 to 10.16mm. The longest kernels were observed for Sonarbangla-1 and shortest kernels were observed for Heera and Aloron. The grand mean value for kernel length of rough rice was observed as 9.30 mm. The next higher mean value for kernel length of this trait was for BRRI hybrid dhan1, Richer and Jagoron, were 10.11, 9.92 and 9.07 mm, respectively. The lower mean value (8.61mm) for kernel length for this trait was observed in Aloron and Heera. Between the checks, BRRI dhan28 had the longest kernels value (9.18mm) and BRRI dhan29 had the shortest kernels value (8.70mm) with a mean value of 8.94mm (Plate 10). Shobha 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 yields of head rice. Khan *et al.* (2000) reported that length of grain ranged from 9.50 to 10.99mm.

4.15.5 Kernel breadth of rough rice (Paddy)

The mean value of kernel breadth of rough rice for hybrids ranged from 2.78 to 3.44 mm. The broadest kernels were observed for BRRI hybrid dhan1 and lower value of kernels breadth was observed for Aloron with grand mean 3.08mm. The lower mean value for kernel breadth for this trait were 2.78mm (Aloron), 2.95mm (Richer) and 2.97mm (Jagoron), respectively. Between the checks, BRRI dhan29 had broader kernels (3.21mm) than that of BRRI dhan28 (3.00mm) with a mean value of 3.11mm (Plate 10). Vraktamth (1987) observed that kernel breadth enhanced the milling output and HRR was strongly associated with milling percentage. Hybrid Richer has comparatively higher milling percent and HRR%, hence the higher milling and HRR percent of Richer could be attributed to the increased kernel breadth but highest breadth of rough rice (3.44mm) was obtained for BRRI hybrid dhan1. As many as four hybrids (Aloron, Richer, Jagoron and Sonarbangla-1) showed lower breadth than the check BRRI dhan29 (3.21mm). Two hybrids (BRRI hybrid dhan1 and Heera) showed higher breadth than the check BRRI dhan28 (3.00mm) and one (Sonarbangla-1) gave similar result (3.00mm) (Table14).

4.15.6 Kernel Length/breadth ratio of rough rice (L_r/B_r)

The range for kernel L/B ratio varied from 2.61 in Heera to 3.39 in Sonarbangla-1. The grand mean value of grain shape was 3.03. The values for this trait in other hybrids were recorded as 2.94 (BRRI hybrid dhan1), 3.10 (Aloron), 3.18 (Jagoron) and 3.36 (Richer), with a mean of 3.08. Between the checks, BRRI dhan28 had the higher L/B ratio (3.06) than BRRI dhan29 (2.71) with a mean of 2.89. Five hybrids showed higher length breadth ratio than the check BRRI dhan29 (2.71) and one showed lower value (2.61). As many as three hybrids showed more than the check BRRI dhan28 (3.06) and three showed lower value. Hossain (2004) found the range for length/breadth ratio of rough rice varied from 3.22 to 4.56.

4.15.7 Kernel length of brown rice (L_b)

The mean value of kernel length of brown rice for hybrids ranged from 6.80 to 7.80 mm. The longest kernels were observed for Sonarbangla-1 and shortest kernels were observed for Richer. The grand mean value for kernel length of brown rice was observed as 7.28 mm. The next higher mean value for kernel length for this trait for Heera and Jagoron were 7.40 mm and 7.20 mm, respectively. The lower mean value for kernel length for this trait for Richer, BRRI hybrid dhan1 and Aloron were 6.80, 7.10 and 7.10mm, respectively. Between the checks, BRRI dhan28 had the longest kernels value (7.50 mm) and BRRI dhan29 had the shortest kernels value (7.30 mm). Hybrid Sonarbangla-1 gave higher length in rough rice and it also gave slightly higher length (7.80mm) incases of brown rice. The hybrid Richer showed lower length (6.80mm) in both cases. As many as five hybrids show higher length than the check BRRI dhan28 (7.50mm) while four hybrids than the check BRRI dhan29 (7.30mm). Hossain (2004) showed grain length of brown rice ranged from 6.33mm to 7.57mm. Some hybrids found higher length in rough rice but gave slightly less length in brown rice which was agreed with the findings of Hossain (2004).

4.15.8 Kernel breadth of brown rice (B_b)

The mean value of kernel breadth of brown rice for hybrids ranged from 2.61mm to 2.95mm. The broadest kernels were observed for BRRI hybrid dhan1 and lower value of kernel breadth was observed for Richer. The grand mean value for kernel breadth of brown rice was observed as 2.82mm. The next higher mean value for kernel breadth of this trait for Sonarbangla-1, Heera and Jagoron were 2.89mm, 2.84mm and 2.80mm, respectively. The lower mean values for kernel breadth for this trait were 2.61mm (Richer) and 2.68mm (Aloron). Between the checks, BRRI dhan29 had broader kernels (2.96mm) than that of BRRI dhan28 (2.85mm) with a mean value of 2.91mm. Hossain (2004) found grain breadth of brown rice ranged from 1.73mm to 2.35mm. In present study, two hybrids showed higher breadth than the check BRRI dhan28 and four showed lower value whereas all hybrids showed lower breadth as compared to BRRI dhan29.

4.15.9 Length/breadth ratio of brown rice (L_b/B_b)

The length/breadth ratio of brown rice among the hybrids studied ranged from 2.41 in BRRI hybrid dhan1 to 2.70 in Sonarbangla-1. The grand mean value of grain shape was 2.58. The hybrids showing L/B ratio of higher order were Sonarbangla-1 (2.70) and Aloron (2.65). Between the checks, lower L/B ratio of 2.47 was recorded for BRRI dhan29 and higher 2.63 were recorded for BRRI dhan28. Five hybrids showed higher length breadth ratio than check BRRI dhan29 (2.47). But four hybrids showed lower than the check BRRI dhan28 (2.63). The highest L/B ratio of brown rice showed highest value in L/B ratio of rough rice. Lower L/B ratio of rough rice (Heera) did not show lower value in L/B ratio incase of brown rice, indicating less relationship from rough rice to brown rice recovery. Hossain (2004) showed length/breadth ratio of brown rice is highest like length/breadth ratio of rough rice but it is not same for lowest ratio.

4.15.10 Kernel length of uncooked rice (L_0)

The mean value of kernel length of milled rice for hybrids ranged from 6.00 to 6.80 mm. The longest kernels were observed for Sonarbangla-1 and shortest kernels were observed for BRRI hybrid dhan1. The grand mean value for kernel length of milled rice was observed as 6.35mm. The next higher mean value for kernel length for this trait was 6.50mm (Heera). The lower mean value for kernel length for this trait for BRRI hybrid dhan1, Aloron, Richer and Jagoron were 6.00, 6.20, 6.20 and 6.20mm, respectively. Between the checks, BRRI dhan28 had the longer milled rice (6.70mm) than that of BRRI dhan29 (6.20mm) (Plate 10). Hossain (2004) observed the grain length of milled rice of hybrids ranged from 5.35mm to 7.30mm and eight hybrids were superior for grain length in comparison to basmati rice hybrids. Soroush *et al.* (1995) showed kernel length before cooking 7.14 to 8.06mm whereas Khan *et al.* (2000) reported that kernel length before cooking ranged from 6.80 to 7.68mm.

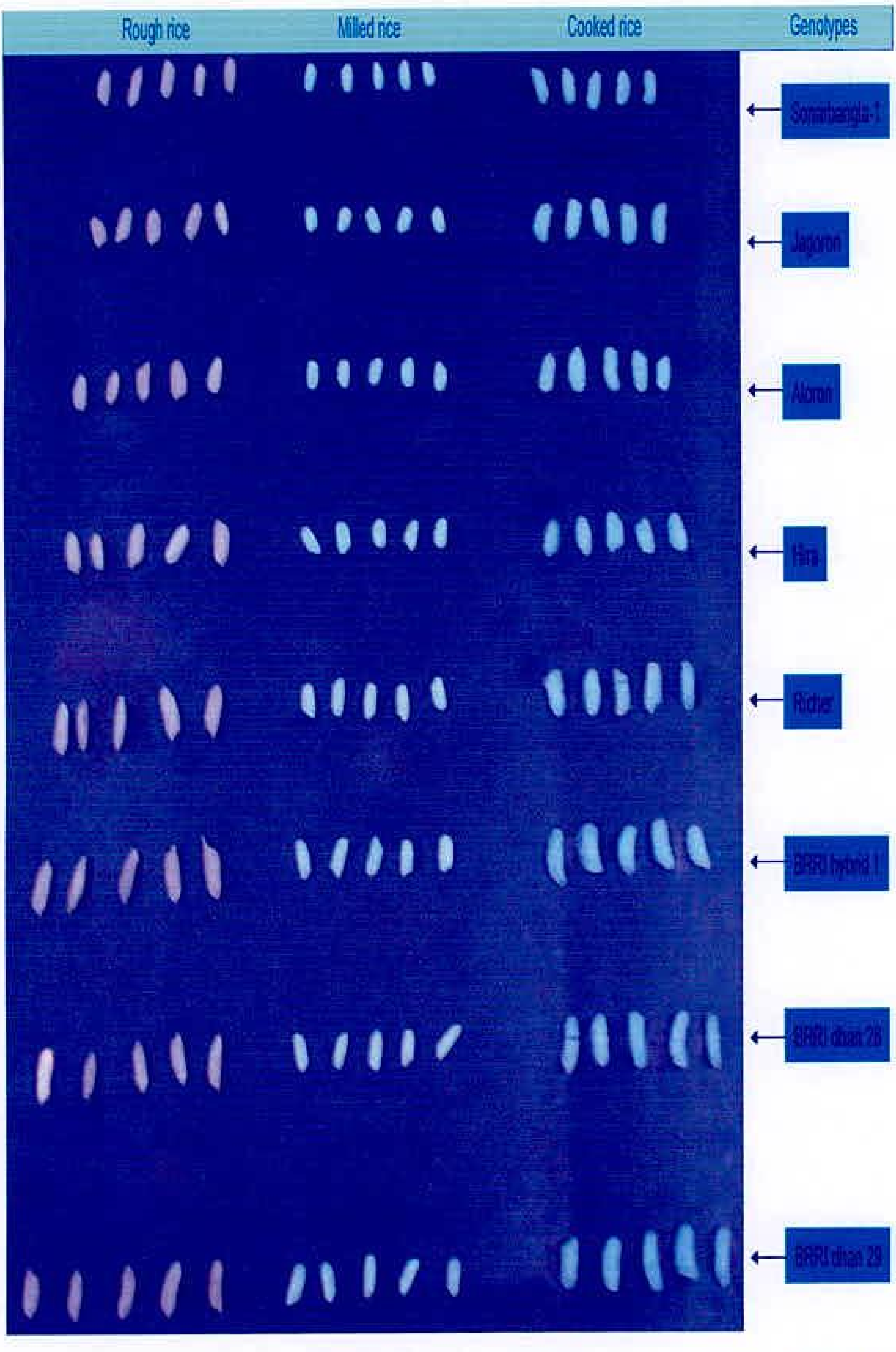

Plate 11. Comparative view of rough rice, milled rice and cooked rice of hybrids and checks

4.15.11 Kernel breadth of uncooked rice (B_0)

The mean value of kernel breadth of milled rice for hybrids ranged from 2.00mm to 2.50mm. BRRI hybrid dhan1 gave highest and Aloron gave the lowest value. The grand mean value for this trait was 2.28mm. The other with successive higher mean value for kernel breadth of milled rice were Richer and Aloron showing values 2.40 and 2.30 mm, in respective order. The hybrids Jagoron and Sonarbangla-1 showed lower values 2.17 and 2.20mm, respectively. Between the checks, BRRI dhan29 showed broader milled rice (2.50mm) than that of BRRI dhan28 (2.20mm). Yadaw *et al.* (2004) found kernel breadth of milled rice ranged from 2.9mm to 3.3mm before cooking whereas Soroush *et al.* (1995) showed width before cooking 1.86 to 2.04mm. Khan *et al.* (2000) reported that width before cooking ranged from 1.72 to 1.83mm.

4.15.12 Kernel Length/breadth ratio of uncooked rice

Kernel length/breadth ratio which is a measure of shape of kernel, gave a range of 2.40 for BRRI hybrid dhan1 to 3.10 for Heera the hybrids with a grand mean value of 2.76. The other hybrids showing relatively high values it was recorded as Sonarbangla-1 (3.09) and Aloron (2.83). The rest two (Jagoron & Richer) showed lower ratio of 2.56 & 2.58, respectively. Between the checks, BRRI dhan28 showed higher ratio (3.05) than BRRI dhan29 (2.48) with a mean value of 2.77. Classification of hybrids are presented in Table 14 revealed that hybrid ranging from long slender to long bold. Among the hybrids, two hybrids were grouped as long slender type (Sonarbangla-1 and Heera) and three hybrids (Richer, Aloron and Jagoron) into medium slender and one hybrid (BRRI hybrid dhan1) in long bold group. Between the checks, BRRI dhan28 was found to long slender and BRRI dhan29 was long bold type. 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 for commercial production (Adair *et al*,. 1966). Some ethnic groups prefer short bold grains, while medium and long slender grains are by others. In general, medium to long grains are preferred in the Indian subcontinent.

Table 15. Classification of grain types of rice hybrids and checks

Classification group				
Long Slender (LS) (Length 6 mm & above L/B ratio 3 & above)	**Short Slender (SS)** (Length less than 6 mm L/B ratio 3 & 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)	**Short bold (SB)** (Length less than 6 mm L/B ratio less than 2.5)
Hira	-	-	-	-
Sonarbangla-1	-	-	-	-
BRRI dhan28	-	-	-	-
-	-	Richer	-	-
-	-	Aloron	-	-
-	-	Jagoron	-	-
-	-	-	BRRI hybrid dhan1	-
-	-	-	BRRI dhan29	-

4.15.13 Endosperm translucency and chalkiness

Among the six hybrids, all showed clear-cut endosperm appearance. Between the checks, both of the two varieties also showed translucent grain. The endosperm appearance of all hybrids was more or less good. Grain appearance is largely determined by endosperm opacity, the amount of chalkiness. Khush *et al.* (1986) classified the endosperm of rice based on endosperm opacity as waxy or non waxy. Waxy rice devoid of or have only trace of amylose content and are opaque. Non waxy rices have varying amylose level (2.1 to 32%) and are dull, hazy or translucent. Dull and hazy kernels have amylose content ranging from 3-9%, while translucent kernels have an amylose content ranging from 10-32%. Kumar and Khush (1988) reported that if the parents vary in endosperm appearance the F_2 grains show clear segregation and may pose a problem in hybrids. Khush *et al.* (1986) reported that mixture of different endosperm appearance grains (due to varying level of amylose percent) does not seem to reduce cooking and eating qualities, but the consumers of india prefer only translucent grain which fetch as high premium in the market.

It is therefore very important to choose those parental lines having similar endosperm appearance. Earlier workers (Khush *et al* 1986; Virmani, 1994) also suggested the same. Chalkiness is undesirable in all segments of the rice industry. Breeders select intensively for clear, vitreous kernels. Environmental factors such as harvesting at high moisture content can also affect chalkiness. Chalky kernels will break easily, reducing milling yields. The nature of endosperm appearance of hybrids and the checks has been presented in table 16.

Table 16 Endosperm appearances in hybrids and check varieties

Sl. No.	Hybrids/ Checks	Endosperm appearance in hybrids and checks
1	Sonarbangla-1	Translucent
2	BRRI hybrid dhan1	Translucent
3	Aloron	Translucent
4	Heera	Translucent
5	Richer	Translucent
6	Jagoron	Translucent
7	BRRI dhan28	Translucent
8	BRRI dhan29	Translucent

4.16. COOKING AND EATING CHARACTERISTICS OF THE GRAIN.

Cooking and eating qualities of rice present a major problem in many rice producing areas. The traits which greatly affect eating and cooking qualities of rice are amylose content (AC), gelatinization temperature (GT) and gel consistency (GC). Varieties that are high in amylose and lower in amylopectin tend to have drier (not so sticky) grains when cooked (Tan *et al.* 1999, Yan *et al.* 2001).

4.16.1 Kernel length of cooked rice (L_1)

The maximum kernel length recorded after cooking of milled rice was 9.31mm of Sonarbangla-1 and minimum was 8.08mm of BRRI dhan29. The grand mean value for this trait was 8.82mm (Table 17). The other hybrids showing values of high magnitude BRRI hybrid dhan1, Richer and Aloron with values 9.08, 8.95 and 8.89mm, in respective order. The hybrids Jagoron and Heera showed lower values as 8.71 and 8.65 mm, respectively. Between the checks, BRRI dhan28 had longer length after cooking (9.01 mm) than that of BRRI dhan29 (8.08 mm) (Plate 11). During cooking rice grains absorb water and increase in volume through increase in length or breadth alone or length and breadth both. Breadth wise splitting is not desirable whereas length wise splitting (grain elongation) on cooking without increase in girth is considered as desirable treat in high quality premium rices such as basmati, which elongate almost 100 percent on cooking (Khush *et al.,* 1979; Sidhu, 1989). Some rices show extreme elongation on cooking particularly in presoaked grains while in most varieties the expansion is relatively more breath wise (Azeez and Shafi, 1986; Juliano, 1972 and Sadhukhan and Chattopadhyay, 2001). In the present study, entire hybrids show higher kernel length than the check BRRI dhan29 (8.08mm). Except Sonarbangla-1 and BRRI hybrid dhan1 as many as four hybrids showed lower length then the check BRRI dhan28, while Sonarbangla-1 showed excellent kernel elongation being more than the check BRRI dhan29 and BRRI dhan28. Shobha rani (2003) reported kernel length after cooking of nine released hybrids of India ranging from 10.2 to 12.4mm. Soroush *et al.* (1995) showed cooked kernel length 10.62 to 12.32mm.

Table 17 Mean performance of quality characteristics in different hybrids of cooked rice

Sl. No.	Hybrids/ Checks	Cooked rice			Kernel el. Ratio	Kernel el. Index	Water uptake (%)	Volume expansion (%)	ASV	Amylose (%)	Protein (%)	Cooking time (minute)
		Length (mm)	Breadth (mm)	L/B ratio								
1	Sonarbangla-1	9.31	2.99	3.11	1.37	1.00	178.00	5.00	5.10	26.01	10.01	19.00
2	Jagoron	8.71	2.61	3.34	1.39	1.13	143.00	3.40	3.00	23.00	10.00	18.00
3	Heera	8.65	2.79	3.10	1.34	0.94	125.00	4.00	4.80	23.01	8.70	19.50
4	Aloron	8.89	3.05	2.91	1.45	1.07	180.00	4.30	3.80	22.07	8.90	21.00
5	Richer	8.95	2.61	3.43	1.47	1.32	217.00	3.70	3.20	22.08	8.80	20.00
6	BRRI hybrid dhan1	9.08	2.90	3.13	1.50	1.25	182.00	3.70	5.00	26.00	10.00	18.50
Mean		**8.96**	**2.83**	**3.17**	**1.47**	**1.12**	**170.83**	**4.02**	**4.15**	**23.67**	**9.40**	**19.17**
7	BRRI dhan29	8.08	2.61	3.10	1.27	1.24	210.00	4.30	4.70	28.10	7.30	17.50
8	BRRI dhan28	9.01	2.58	3.49	1.36	1.13	134.00	4.00	4.80	27.30	8.30	15.50
Mean		**8.55**	**2.60**	**3.30**	**1.32**	**1.19**	**172.00**	**4.15**	**4.75**	**27.65**	**7.80**	**16.50**
Grand mean		**8.82**	**2.77**	**3.20**	**1.41**	**1.14**	**171.13**	**4.05**	**4.30**	**24.69**	**9.00**	**18.63**
SEd±		0.21	0.10	0.15	0.52	0.06	1.79	0.09	0.06	0.21	0.24	0.320
CV (%)		2.91	4.51	5.75	4.54	6.08	1.28	2.58	2.47	1.05	3.33	1.99
CD (5%)		0.45	0.22	0.32	0.11	0.12	3.84	0.18	0.18	0.45	0.52	0.647

L/B= Length/Breadth ratio, el. = Elongation, ASV= Alkali Spreading Value, SEd= Standard Error difference, CV= Coefficient of Variation, CD= Critical Difference

4.16.2 Kernel breadth of cooked rice (B_1)

The mean value of kernel breadth of milled rice for hybrids ranged from 2.61 mm to 3.05 mm. Aloron gave highest and Richer & Jaoron gave the lowest value. The grand mean value for this trait was 2.77mm. The other with successive higher mean value for kernel breadth of milled rice was Sonarbangla-1, BRRI hybrid dhan1 and Heera showing values 2.99, 2.90, and 2.79mm, in respective order. The other hybrids Jagoron and Richer showed values 2.61 and 2.61mm, respectively. Between the checks, BRRI dhan29 showed higher breadth (2.61mm) than BRRI dhan28 (2.58mm). The maximum breadth of cooked kernel has been recorded for Aloron (3.05mm) and lowest for BRRI dhan28 (2.58mm). All the hybrids showed higher breadth than the check BRRI dhan28. As many as four hybrids namely Heera, Sonarbangla-1, BRRI hybrid dhan1 and Aloron showed more increase in breadth than the check BRRI dhan29 and other two hybrid (Richer & Jagoron) showed same result with compared to the check BRRI dhan29 (Table 17). Khan *et al.* (2000) reported boiled kernel width 2.20 to 2.32mm.

4.16.3 Kernel Length/breadth ratio of cooked rice (L_1/B_1)

The mean value for length/ breadth ratio of cooked kernel ranged from 2.91 in Aloron to 3.49 in BRRI dhan28. The grand mean value of L_1/B_1 after cooking was 3.20. The mean value of high magnitude recorded in other for this trait hybrids were 3.43 (Richer), 3.34 (Jagoron), 3.13 (BRRI hybrid dhan1) and 3.11 (Sonarbangla-1). The mean value of low magnitude were 3.1 (Heera) and 2.91(Aloron). Between the checks, BRRI dhan28 (3.49) showed higher ratio than BRRI dhan29 (3.10) with a mean of 3.30. Four hybrids have higher L/B ratio than the check BRRI dhan29 and one showed similar value while no hybrids than the check BRRI dhan28. 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. The low value of Aloron is mainly due to less length wise expansion and more breadth wise expansion, such behavior indicates of poor cooking quality.

4. 16. 4 Kernel elongation ratios (L_1/L_0)

Elongation ratio, which is very important cooking index, ranged from 1.34 to 1.50 for the hybrids. The highest value was recorded for BRRI hybrid dhan1 and lowest was recorded for Heera. The grand mean value of this trait was 1.41. The hybrids BRRI hybrid dhan1, Richer, Aloron and Jagoron recorded higher value of magnitude 1.50, 1.47, 1.45 and 1.39, respectively. Where as, in remaining hybrids it was recorded as 1.34 (Heera) and Sonarbangla-1 (1.37). Between the checks, BRRI dhan28 showed higher ratio (1.36) than BRRI dhan29 (1.27) with a mean of 1.32. Elongation ratio 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). In the present study, the hybrids had moderate to high degree of kernel elongation ratio. The entire hybrids under the study showed higher elongation ratio than the check BRRI dhan28 and as well as the check BRRI dhan29 except Heera (1.34). Kernel elongation was primarily influenced by kernel shape and size. Therefore, elongation ratio which indicates length wise elongation will be a better measure of cooking quality than elongation ratio which indicates both length and breadth wise elongations. Similar conclusion was also done by Singh (1990).

4.16.5 Kernel elongation index (L_1/B_1)/ (L_0/B_0)

Among the all hybrids, Richer had the maximum mean value of 1.32 and Heera had minimum mean value of 0.94 for kernel elongation index with a grand mean of 1.14. The values showing relatively high magnitude for this trait was Richer, BRRI hybrid dhan1 and BRRI dhan29 with values of 1.32, 1.25 and 1.24, respectively. Other hybrids Heera (0.94), Aloron (1.07) and Jagoron (1.13) showed lower magnitude of kernel elongation index. Between the checks, BRRI dhan29 showed higher value of 1.24 kernel elongation index than BRRI dhan28 (1.13). Kumar (1989) concluded that elongation index was more reliable measure of kernel elongation. In the present study, three hybrids gave higher elongation index than the check BRRI dhan28. As many as two hybrids showed higher elongation index than the check BRRI dhan29. Sandeep (2003) reported the kernel elongation ratio ranged from 1.32 to 1.72 in 20 new plant type genotypes. The present set of hybrids showed quite lower range than the finding by Sandeep (2003).

4.16.6 Water uptake (%)

Richer scored highest value 217.00% for this character, while Heera scored lowest value 125.00% among the hybrids with a grand mean of 171.13%. Between the checks, BRRI dhan29 had higher score of 210.00% than that of BRRI dhan28 (134.00%) with a mean of 172.00%. 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 extant 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 short and medium grain varieties of the USA have high water absorption as compared to long grain types. The present study, out of six hybrids, five hybrids showed higher water uptake than the checks BRRI dhan28 and one hybrid showed higher water uptake than BRRI dhan29. Working with a longer number of scented basmati varieties Sood and Siddiq (1980) have reported still wider range (174.00-439.00%) of variation for this character. The mean water absorption of 170.83% of the hybrids under the present study indicated that majority of the hybrids had moderate to high water absorption capacity. Zaman (1981) reported that the good cooking rice varieties have water absorption value ranging between 174.00% and 225.00%, whereas majority of these showing pasty appearance have value high as from 300 to 570%. He concluded that high water absorption is relatively less desirable character and it would be desirable to select a variety of hybrid with moderate water absorption.

Table 18. Classification of rice hybrids and checks on the basis of Alkali spreading score, Alkali Spreading Value and GT types

Sl.No.	Hybrids/ Checks	Alkali spreading value	Range	Alkali digestion	GT Types
1	Sonarbangla-1	5.10	4.83-5.66	Intermediate	Intermediate
2	BRRI hybrid dhan1	5.00	4.83-5.66	Intermediate	Intermediate
3	Hira	4.80	4.17-5.33	Intermediate	Intermediate
4	Aloron	3.80	3.8-4.17	Intermediate	Intermediate
5	Richer	3.20	2.17-3.5	Low	High
6	Jagoron	3.00	2.17-3.5	Low	High
7	BRRI dhan28	4.80	4.17-5.33	Intermediate	Intermediate
8	BRRI dhan29	4.70	4.17-5.33	Intermediate	Intermediate

GT=Gelatinization temperature

Table 19.Classification of rice hybrids and check varieties on the basis of amylose percent

Classification Groups of amylose content				
Waxy (0-2%)	**Very low amylose (3-9%)**	**Very low amylose (10-19%)**	**Intermediate amylase (20-25%)**	**High amylose (>25%)**
-	-	-	Richer (22.08)	Sonarbangla-1 (26.01)
-	-	-	Aloron (22.07)	BRRI hybrid dhan1 (26.00)
-	-	-	Jagoron (23.00)	BRRI dhan29 (28.10)
-	-	-	Heera (23.01)	BRRI dhan28 (27.30)

4.16.8 Volume expansion (%)

The maximum volume expansion was found 5.00 percent in Sonarbangla-1, while minimum was 3.40 percent in Jagoron with a grand mean value of 4.05%. The other higher mean values of this trait were 4.30 (Aloron), 4.3 (BRRI dhan29), 4.0 (BRRI dhan28) and 3.10 (Heera). The lower mean values of this trait were 3.40 (Jagoron), 3.70 (BRRI hybrid dhan1) and 3.70 (Richer). Between the checks, BRRI dhan29 showed higher values (4.30) than that of BRRI dhan28 (4.00) (Table 17). Volume expansion of kernels on cooking is considered another important measure of consumer preference. More volume of cooked rice from a given quantity of rice is a matter of great satisfaction to an average rice consumer irrespective of the fact weather the increased volume is due to length wise or breadth wise expansion (Zaman, 1981). In comparison with check BRRI dhan28 two hybrids showed higher value of this trait. One hybrid showed higher value (4.30) than the check BRRI dhan29 and one showed similar result. The mean value of volume expansion was 4.02% indicated that majority of hybrids included in the study were of low to medium volume expansion. Zaman (1981) reported that the varieties which tend to show high volume expansion are sticky and give a pasty appearance on cooking. Invariably all the pasty cooking types have been found to be associated with higher water absorption. He concluded that pasty cooking closely related to high water absorption. Therefore, hybrids with low water absorption and high volume expansion are more desirable.

4.16.9 Alkali spreading value (ASV)

Alkali spreading value was used as an estimate of gelatinization temperature of the starch. The mean alkali spreading score for the hybrids ranged from 3.00 in Jagoron to 5.10 in Sonarbangla-1. The grand mean of this trait was 4.30. The other hybrids recorded ASV value as 5.00 (BRRI hybrid dhan1) and 4.80 (Heera). The rest of the hybrids had values 3.80 (Aloron), 3.20 (Richer) and 3.00 (Jagoron). Between the checks, BRRI dhan28 showed higher value (4.80) than BRRI dhan29 (4.70) with a mean of 4.75 (Table 17). Among the hybrids, Jagoron and Richer showed both low value for alkali digestion and high GT types, while rest of four hybrids showed intermediate alkali digestion and GT types. The gelatinization temperature (GT) is considered to be to be yet another major index of cooking quality of rice. 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). Study of world collection of rice at IRRI reveals that traditional tropical rice varieties, in general, are of intermediate GT with the exception of Bulk and Waxy rices that are characterized with low GT (IRRI Annual Report, 1977). Islam (1983) also observed that GT of rice hybrids was intermediate between the parents or similar to the parents, depending on whether or not parents differed in this trait.

4.16.10 Amylose (%)

In case of hybrids amylose content ranged from 22.07% in Aloron to 26.01% in Sonarbangla-1 with a grand mean of 24.69%. Between the checks, BRRI dhan29 had the higher amylose percent than BRRI dhan28 which were 28.10 and 27.30 percent, respectively, with a mean of 27.65%. Two hybrids (Sonarbangla-1 & BRRI hybrid dhan1) showed high amylose (26.01 & 26.00%) percent and four hybrids (Richer, Aloron, Jagoron & Heera) showed intermediate amylose (23.01, 23.00, 22.08 and 22.07) percent. The checks, BRRI dhan28 and BRRI dhan29 show high amylose content (27.30 and 28.10) considered to be the best from cooking point of view. Shobha Rani (2003) estimated amylose content of nine released hybrids in India and reported their range as low as 20.90% (KRH-2) to as high as 27.80% (APRH-2). Amylose content (AC) is considered to be the most important parameter of cooking quality as it determines the indices like water absorption, volume expansion, stickiness, gloss, colour and firmness when cooked (Sanjiva Rao *et al.*, 1952; Williams *et al.*, 1958). Screening of world germplasm collection at IRRI and other Rice Research Centre has revealed the amylose content in rice to range from 0% to 35%. Study of a representative collection of population and highly preferred varieties for amylose content has suggested the range of amylose content to vary between 20.90 to 27.50% (IRRI, 1966). Amylose is almost absent from the waxy (glutinous) rices. Such rices do not expanded in volume, are glossy and sticky and remain firm when cooked (Juliano, 1979). These rices are the staple food of people in Northern and North eastern Thailand and

Laos. Varieties grown in Philippines, Malaysia and Indonesia have intermediate amylose content which cook moist and tender and do not become hard upon cooking. High amylose rices cook dry, less tender and hard on cooking, show high volume expansion and high degree of flakiness. Juliano (1971) after an extensive study of rice varieties from different parts of the world and concluded that all japonica varieties of temperate region have low amylose and they are preferred in Japan and South Korea for their stickiness, tenderness, gloss and taste. Rice varieties of Vietnam, Thailand, India, Bangladesh, Philippines, Malaysia and Indonesia on the other hand have high to intermediate amylose (IRRI, 1971; Khush *et al.,* 1979). In India though majority of the varieties have high amylose, the most preferred varieties have intermediate amylose. Preference for intermediate amylose types is true with majority of the South and Southeast Asian countries as well. Classification of hybrids on the basis of amylose content is given in Table 19.

4.16.11 Protein (%)

In case of hybrids protein content ranged from 8.70 in Heera to 10.0 in Sonarbangla-1 with a mean of 9.40. Three hybrids showed values of high protein content *viz* Sonarbangla-1(10.01), Jagoron (10.00) and BRRI hybrid dhan1(10.00). As many as three hybrids had values of intermediate protein content with values 8.90 (Aloron), 8.80 (Richer), and 8.70 (Heera). Between the checks, BRRI dhan28 (8.30) had higher protein than that of BRRI dhan29 (7.30) with a mean of 7.80% (Table 17). High protein content was significantly correlated with light grains, early heading, and short stature. The nutritional value depends on the total quantity and quality of protein. However, the protein content of the milled rice is relatively low (mean of 9 per cent). The milled rice proteins consist of at least 8.0 per cent or more of glutalin, 10 percent globulin, 5 percent prolamin (Irshad, 2001).

4.16.7 Cooking time

The cooking time of the cultivars varied from 15.50 minutes in BRRI dhan28 to 21.00 minutes in Aloron with a grand mean value of 18.65 minutes when cooked in 100^{0}C. Maximum cooking time was found in Aloron (21.00

minutes) and the minimum cooking time in BRRI dhan28 (15.50 minutes). Between the checks BRRI dhan29 (17.50 minutes) took more time of cooking than BRRI dhan28 (15.50 minutes) with a mean of 16.50 minutes. The color and gloss of the grain was also intensively correlated to the exposure of microwave heating (Anuja *et al.*, 2003). Brown rice required 35-45 minutes of cooking to make it soft enough to eat (Board, 1998). Cooking time depends on the chemical composition, rice variety and the length of the storage before the rice is cooked. The linear kernel elongation after cooking is compared with the original length of kernel before cooking (Irshad, 2001).

Chapter 5

Summary and Conclusion

SUMMARY AND CONCLUSION

Rice is the world's most important food crop and a primary source of food for more than half of the world's population. Heterosis or hybrid vigour as well as quality characters are manifested as most important for hybrids to the consumers. For general consumer acceptance, it is essential that the hybrids developed possess good quality characteristics as well as high yield potential. Therefore, the hybrids included in trials and parental lines have been critically screened for various quality parameters. The present investigation was carried out with the following objectives:-

- ❖ Estimation of standard heterosis in cultivated rice hybrids.
- ❖ Assessment of genetic variation of important grain characters among the hybrids.
- ❖ Study of the grain appearance and milling of the hybrids.
- ❖ Determination of cooking and eating characteristics of the grain.

Field experiment was conducted at the central research farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from January 2006 to June 2006. Five hybrid rice varieties imported by different private seed companies, one hybrid released by BRRI and two check varieties also released by BRRI were used for this experiment. The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. The out come of the investigations is summarized as under:

Estimation of standard heterosis in cultivated rice hybrids:

- Analysis of variance revealed highly significant variation present among the hybrids and checks for the characters studied. Existing of significant level of variation present in the materials indicated the possibility of improving genetic yield potential via exploitation of heterosis.

- All the hybrids were superior to best yielding check BRRI dhan29 in mean performance with respect to grain yield per plant, grain weight per meter square, 1000-grain weight and harvest index.
- The selected hybrids were of early to late maturity period and had semi dwarf to tall plant stature.

Positive and significant standard heterosis over BRRI dhan28 was observed in-

- Three hybrids for days to 50% flowering and five hybrids for days to maturity
- Four hybrids for panicle length
- Five hybrids for grain yield per plant
- Two hybrids for total spikelets per panicle
- Two hybrids for biological yield
- All the hybrids for harvest index, 1000-grain weight, grain yield per square meter and yield per plant

Positive and significant standard heterosis over BRRI dhan29 was observed in-

- Four hybrids for days to maturity
- All the hybrids for grain yield per plant and 1000-grain weigh and
- Four hybrids for harvest index and grain yield per square meter

Significant and negative standard heterosis over BRRI dhan29 was observed in-

- Five hybrids for 50% days to flowering and days to maturity,
- Five hybrids for total number of spikelets per panicle
- All for biomass yield for plant
- One for harvest index
- All the hybrids showed higher grain yield per hectare than the checks on plot harvest basis. The yield advantages of hybrids over BRRI dhan 28 ranged from 11.82 to 35.45 and 2.50 to 24.17% over BRRI dhan29 on yield per hectare basis. In general yield was strongly and positively related with 1000-grain weigh, grain yield per plant and harvest index. Aloron gave highest yield among the hybrids and checks as it gave highest 1000-grain weight among the hybrids and checks

Assessment of genetic variation of important grain characters among the hybrids

- The study revealed existence of variability in respect to grain traits. This offers a scope for exploitation of quality traits of hybrids
- Genotypic and Phenotypic coefficient of variation ranged from 1.20 to 129.40 and 0.30 to 43.07 percent
- The highest GCV & PCV was found in percent head rice recovery (HRR%) and lowest in elongation ratio
- The broad sense heritability ranged from 22.01 for breadth of rough rice to 33.30 for water absorption
- A wide range of variation is observed for characters like alkali spreading value (ASV), kernel elongation index, volume expansion , amylose percent, percent water uptake, L/B ratio of rough rice, L/B ratio of milled rice, and percent head rice recovery (HRR%)

Study of grain appearance and milling of the hybrids

- Maximum hybrids showed higher hulling percent, and milling percent than check BRRI dhan28 and BRRI dhan29 but BRRI hybrid dhan1 showed lower milling percentage than the check BRRI dhan29
- Most of the hybrids showed lower head rice recovery than the check BRRI dhan28 but higher head rice recovery than the check BRRI dhan29.
- Sonarbangla-1 showed lowest head rice recovery because of its breakage during milling due to long grain
- Out of 6 hybrids two had long slender grains and three belonged to medium slender and one belonged to long bold grain. No hybrid was found to short slender, and short bold type

Determination the cooking and eating characteristics of the grain

- Superior cooking performance over BRRI dhan29 was observed in-
  - All the hybrids for length of cooked rice elongation
  - All the hybrids for kernel elongation ratio
  - All the hybrids for kernel elongation index and
  - One hybrid for volume expansion.

- Superior cooking performance over BRRI dhan28 was observed in-
    - Two hybrids for length of cooked rice elongation
    - All the hybrids for kernel elongation ratio
    - Two hybrids for kernel elongation index
    - Three hybrids for water uptake and
    - Two hybrids for volume expansion one perform same.
- Maximum hybrids showed intermediate GT and intermediate amylase content which is preferred by the consumers but lower than the checks.
- The study revealed that high amylase grains had low protein, while low and very low amylose types had high protein.
- All hybrids showed translucent grains most of the hybrids had intermediate amylase content and intermediate alkali spreading value (ASV) & GT type
- Two hybrids Richer & Jagoron showed intermediate amylose with low alkali spreading value (ASV) & high GT type.
- All the hybrids were identified having acceptable grain quality with translucent endosperm appearance with yield ranging from 6.15 t/ha to 7.45 t/ha but inspite of their high yield grain quality in relation to amylose content is intermediate.
- It had been estimated that most of the hybrids had higher protein contents than both the inbred checks
- BRRI hybrid dhan1 and Sonarbangla-1 showed appropriate amylose content with highest protein content but BRRI hybrid dhan1 perform lower yield potential compared to other hybrids.
- Lowest amylose with intermediate protein content obtained from superior yielding Aloron
- The experiment showed significant positive association between-
    - Hulling and milling outturn
    - Head rice recovery and grain breadth of rough rice, length of milled rice, length of cooked rice and L/B ratio of cooked rice.

- Kernel elongation index and grain breadth of rough rice, grain breadth of milled rice, grain length of cooked rice and L/B ratio of cooked rice.
- Water uptake and L/B ratio of milled rice and grain length of cooked rice and between alkali spreading value and grain length breadth ratio of cooked rice

Considering overall performance hybrid Aloron can be cultivated for high yield potential and BRRI hybrid dhan1 can be cultivated for better grain quality.

Future suggestions:

Based on the above findings following suggestions are made for further evaluation, improvement and utilization of materials:

- Inspite of higher heterosis most of the hybrids show poor grain quality. It is suggested that further improvement of grain quality would help enhance potentiality of these hybrids.
- Promising hybrids with high level and good grain quality may further be evaluated in multilocation trial for recommended and commercial cultivation.
- Keeping in view the market acceptability of the hybrids should be further improved to have high amylose content, high protein content with high alkali spreading value grains through intensive breeding.

In Bangladesh there are many local rice cultivars which are going to be extinct because of their low yield potentiality but having high protein content along with other desirable traits. Therefore, it is essential to collect and evaluate the local cultivars in order to incorporate the desirable characters in the breeding program in commercial high yielding hybrid varieties. Future opportunities include the development of hybrids possessing stronger heterosis and more stable yield performance, improved grain quality with higher yield potential. Efforts have begun at IRRI, BRRI and other centers to critically analyze the quality characteristics of all available CMS lines, maintainers, restorers, and their hybrids. Emphasis must be placed on the improvement of cooking and eating quality to satisfy consumer preference.

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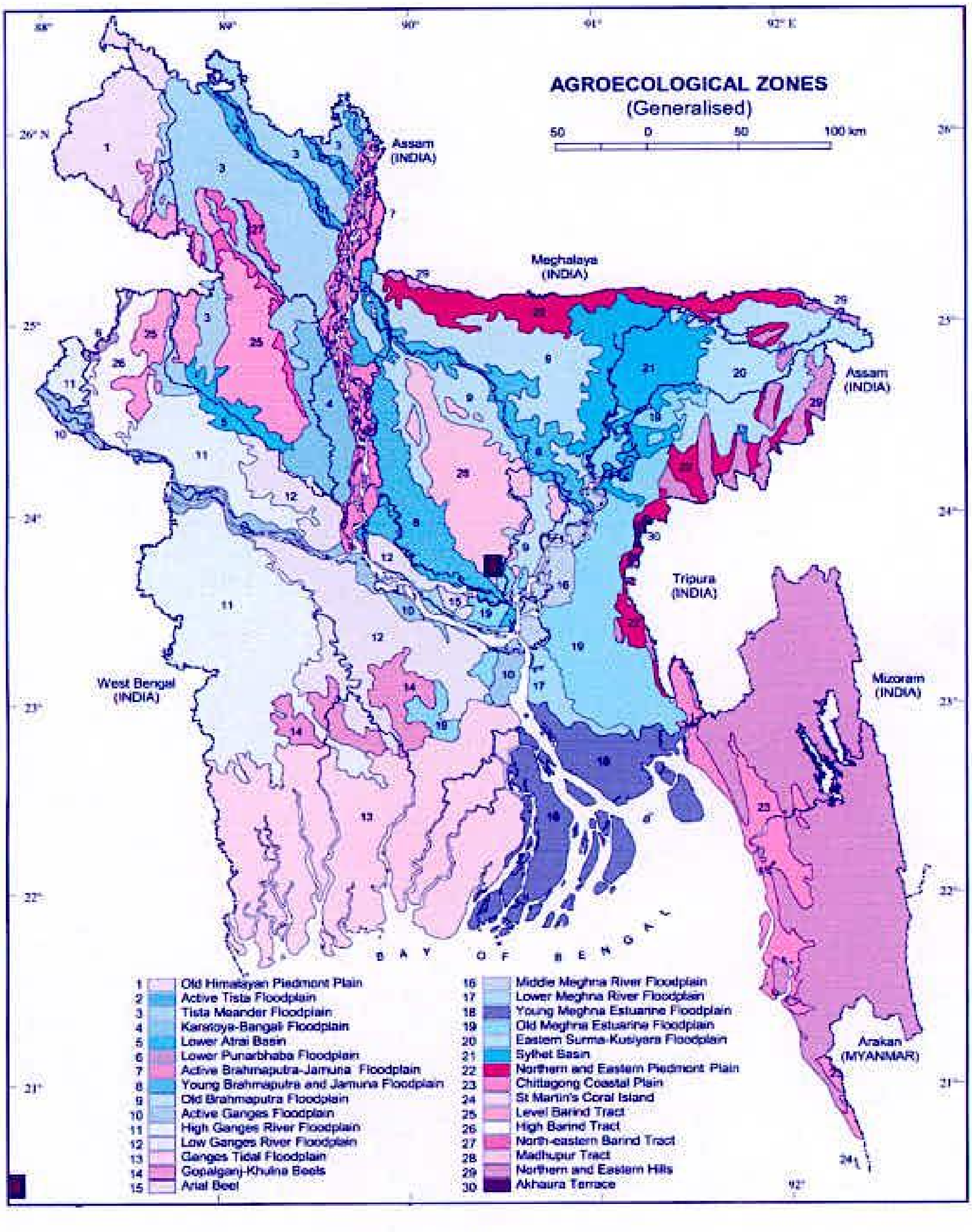
Appendices

Appendix I. Map showing the experimental sites under study



Appendix II. Physico-chemical properties of soil in the study area.

Characteristics	Value/concentration
Particle size analysis.	
% Sand	26
% Silt	45
% Clay	29
Textural class	Silty-clay
pH	6.3
Organic matter (%)	1.8
Total N (%)	.09
Phosphorus microgram/gm soil	13.1
Potassium (ml equivalent/100 g soil	0.19

Appendix III. Monthly average of temperature, relative humidity, total rainfall and sunshine hour of the experiment site during the period from January 2006 to May 2006

Year	Month	Air temperature (^{0}C)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2006	January	24.50	13.90	19.2	68.50	4.00	194.1
	February	28.90	18.00	23.4	61.00	3.00	221.5
	March	32.20	21.80	27.00	66.69	66.70	155.0
	April	34.44	23.96	29.20	68.08	90.01	253.0
	May	33.23	24.11	28.67	96.13	297.9	96.0

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.