VARIETAL CHARACTERIZATION AND YIELD EVALUATION OF SIX RICE HYBRIDS (*Oryza sativa* L.) GROWN IN BANGLADESH

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Beloved Parents

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CERTIFICATE

This is to certify that the thesis entitled, "Varietal characterization and yield evaluation of six rice hybrids (Oryza sativa L.) grown 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 AND PLANT BREEDING,*** *embodies the result of a bona fide research work carried out by* ***MD. SAMSUZZAMAN,*** *Registration No 00395, under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2007

……..…………………………………

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ABSTRACT

A field experiment was conducted with six hybrids cultivated in Bangladesh and two modern check varieties of rice (*Oryza sativa L.*) at Sher-e-Bangla Agricultural University experimental farm, to perform varietal characterization and to carry out of yield evaluation based on different morphological characters during the period of January 2006 to May 2006. The experiment was laid out in a randomized complete block design with three replications. In the experiment plant height for BRRI dhan 28 was highest (101.5 cm) and lowest for hybrid Richer (82.5 cm). For days to 50% flowering BRRI dhan 29 required maximum days (116.3 days) and BRRI dhan 28 required lowest days (95 days) but hybrid showed intermediate. For number of effective tillers, Hira showed maximum performance (17.7) and Sonarbangla 1 showed lowest performance (13.3). For days to maturity, Sonarbangla 1 required lowest days (118 days) and BRRI dhan 29, highest days (148 days). In panicle length status, Richer showed maximum performance (27.7 cm) and for BRRI dhan 28 (26 cm) was the lowest. Number of filled grains was the highest for BRRI dhan 29 (163.3) whereas, Jagoron only 118. Number of total grains was highest in BRRI dhan 29 (201.7) and for Jagoron it was only 133.7. On the other hand, for 1000-grain weight, Aloron was the best than others (28.8 g). In biological yield/plant (g), BRRI dhan showed highest yield (49.6 g) and Hira only 18 g. For harvest index, Jagoron was the best (64%) and for BRRI dhan 28 only 38%. For grain yield/plant Aloron expressed highest performance (47.87 g), whereas, BRRI dhan 28 it was only 30.45 g. Grain yield/plot, Aloron was the best than others. For grain yield/ha, Aloron was the best (7.4 t) than others. In yield advantage for plot basis Aloron was the best (54.45%) over BRRI dhan 28 and 24.75% over BRRI dhan 29, respectively. Maturity was also earlier for Aloron than other hybrids. Among the all hybrids, Aloron was the best in terms of grain yield/ha. High heritability was found for days to maturity (99.93%). The maximum variation was found in biological yield per plant (12-81 g). In correlation analysis a highly significant positive association were found for plant height, days to maturity, days to 50% flowering, panicle length and filled grains per panicle with grains/panicle, grain yield/ha.

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LIST OF ABBREVIATIONS AND SYMBOLS

Full word	**Abbreviations**
Agro Ecological Zone	AEZ
Bangladesh Rice Research Institute	BRRI
Centimeter	cm
Degree centigrade	^{0}C
Gram (s)	g
Muriate of Potash	MP
Triple Super Phosphate	TSP
Number	no.
Randomized Complete Block Design	RCBD
Ton/hectare	t/ha
Percent	%
Degrees of freedom	df
Co-efficient of Variation	CV
Standard Error	SE
Kilogram	kg
Kilogram/hectare	kg/ha
Parts Per Million	ppm
Concentration of Hydrogen Ions	pH
Cation Exchange Capacity	CEC
Hour	hr
Millimeter	mm
Harvest Index	HI
Least Significant Difference	LSD
And others	*et al.*,
Bangladesh Bureau of Statistics	BBS
International Rice Research Institute	IRRI
Analysis of Variance	ANOVA

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important crop of tropical world. It is the major sources of food for approximately half of the world population and hence the most important crop on the earth (Goff, 1999). Rice is cultivated in about 152.04 mha and contributes 585.59 million tons of grains (FAO, 2002). Above 90% of total rice is produced and consumed in Asia-Pacific region. Rice provides 20-80% dietary energy and near about 12-17% of dietary protein for Asians (Azeez, 1986). In China, hybrid rice grows well and produce higher yield than modern cultivar and attracts farmer's attention (Lin and Yuan, 1980). Out side of China, India is the first country to develop and commercially exploit the hybrid technology and 17 hybrids have been released (Hossain, 2004).

In 1971, the total production of rice in Bangladesh was 10.59 million metric tons (mMt). At that time the population of the country was about 70.88 million. During 1970-1975, the share of amount of rice was below 455g/head per day. During 2000-2003, the share of rice/head per day increased more than 500g although the rice land/capita per year decreased remarkably. This scenario indicates that the country produces enough rice to feed its huge population. This becomes possible because of the cultivation of modern rice varieties in 66% rice land and total rice production increased to 25.18 mMt.

However, the total rice area in 1970-2003 remained almost similar to 10.5 million ha. It is estimated that the population will gradually increases to 161 million in 2020 although the population growth rate will be much lower than that in 1991. Growth rate of population in 1991 was 2.17, which was reduced to 1.48 in 2001. Population predicted for 2020 will require 27.26 mMt. During this time, the total rice area will shrink from 10.71 to 10.28 million ha and the hectare rice will be needed to increase from 2.74 tons to 3.74 per capita.

Rice area will gradually shrink to only 0.149 acre in 2020 and the required rice/head per day will be decreased from 528g in 2001 to 463g in 2020 due to the increase of population. This indicates a decreasing trend of daily requirement of rice. Thus for maintaining the adequate level of rice yield required for the estimated population in the years to come rice research should continually develop improved and cost effective technologies (Anon, 2005).

In Bangladesh total rice growing area was 90,83,138.87 ha. Among the total area, hybrid growing area was only 1,88,274.493 ha during the year 2005 (Anon, 2005). The population of Bangladesh is growing consequently and the country has to produce additional rice for about 2.2 million mouths every year. The country suffers an annual deficit of 2-3 million tons with annual addition of 0.45 million tons. In the year 2020, the country production of milled rice have to be increased 26.797 to 35 million tons (Anon, 2005) and the average yield of milled rice has to be doubled (i.e. 3.39t/ha) from the present level of 1.8 t/ha. To feed the fast increasing global population, the worlds annual rice production must be increase from 520 million tons of 1994 to 760 million tons by the year 2020 (Kundu and Ladha, 1995)

The International Rice Research Institute (IRRI) took the initiative in 1979 to explore potential and problems of developing this technology for countries outside China. Learning from Chinese experience, nearly 20 countries are currently involved in development and use of this technology and many of them work collaborate with IRRI. Among the countries outside china, India is the first country, where hybrid rice technology has become a commercial reality. The annual growth rate in global rice production was only 1.8% during the 1985 to 1992 compared to 2.8% during 1975 to 1985 and 3.6% during 1965 to 1975. Over the years, there has been a gradual decline in the annual growth rate of global rice production. This world requires 60% increase in rice production (Khush, 1996).

According to Swaminathan (1998), we need a minimum annual growth rate of 2.5% in rice production to maintain the self-reliance. While shrinking land area with expanding urbanization and industrialization as well as plateuing of yield level on the other hand, this production increase must be achieved on less land, with less labor, less water and fewer chemicals.

The challenged faced by the rice scientist are to developed technologies to break the genetic yield barrier(s) and make quantum yield increase to meet the required food needs of the country beyond 2000AD. During the last 25 years, an additional 300 mt of rice was produced through the adaptation of hybrid rice on large scale in China. Hybrids rice through its enhanced productivity enabled China to spare around four million hectare rice area annually for the production of other high value crops (Ahmed *et al.*, 2001). Rice grows in a wide range of complex environments, such as dry and flooded conditions, low to high temperatures and in a wide range of soil type (Swaminathan, 1989). Approximately, 78% of the Worlds rice is grown under irrigated or rainfed lowland conditions (Anon, 1997). Although rice is adapted to low land, complete submergence for more than 2-3 days killed most of the rice cultivars (Mishra *et al.*, 1996).

Type of damage would be rather serious for dwarf and semi dwarf varieties, which cause total crop losses. A good crop of hybrid has the potential of yielding 14-28% more than the best-inbred or pure line variety grown under similar environmental conditions (Siddiq, 1993). Many research works on hybrid rice technology have been conducted in various countries. Some commercial companies of Bangladesh are marketing hybrid seed imported from different countries like China and India. But the field performances of those varieties are not up to the mark as described by their marketing authorities. As a result, farmers are losing their interest in cultivating hybrid rice varieties. Along with variety and climatic factors, improved cultural practices can play an important role in augmenting yield of rice.

In the commercial production of hybrids optimum plant density ensures the plants to grow properly with their aerial and underground parts by utilizing more solar radiation and soil nutrients (Miah *et al*., 1990). Hybrid rice the highest yielding inbred check varieties of similar duration. Adoption of hybrids on large scale can contribute to increase production and productivity (Mishra, 2001). F_1 rice hybrid produced more grain yield than semi dwarf inbred cultivars (Lin and Yuan, 1980: Virmani *et al.*, 1982).

Yield is the product of yield components i.e. panicle no., grain no., and grain weight in rice (Yoshida, 1981). Yield of rice is a function of genotype and environment. For increasing yield, a good number of varieties with high yield potential have been developed (Hossain *et al*. 1990). However, variation of yield may occur due to inability of choosing appropriate variety for an appropriate environment. Environment includes both climatic and management variables. All the modern varieties of rice do not suit similar climatic variables; thus season-specific recommendations are made for season(s) other than they are recommended for all seasons (Hossain *et al.*, 1987).

In Bangladesh, development of high yield potential variety is one of the ways to satisfy the future demand. Irrigated modern rice contributes 41% of the total rice production in Bangladesh (Anon, 2000). Rice production in Indian sub-continent has shown remarkable increase in the past two decades due to spread of high yielding modern varieties. Among the many genetic approaches being explored to break the yield barrier in rice, hybrid rice technology appears to be the most feasible and readily adopted one.

In China average yield of hybrid rice is 6.67 t/ha (Lin, 1980). Therefore, to increase rice yield, development of hybrid rice is one of the modern technologies that can be used. Also the climate of Bangladesh is favorable for both the hybrid rice seed production and hybrid rice cultivation (Araki, 1988).

Development of hybrid rice has brought a great hope and aspiration to meet the challenging demand of food deficits of the 21st century. China successfully developed hybrid rice in 1994 and by 1991 had expanded its cultivated area to 17.3 million hectares (Yuan and Fu, 1996).

Hybrid rice has about a 30% yield advantages over the conventional pure line varieties (Yuan, 1998). Rice is grown in Bangladesh in three distinct seasons namely Aus, Aman and Boro. Rice is grown in 11.025 million hectares of land with a production of 26.796 million tons (Anon, 2004). Anonymous, (2005) reported that the yield of Aus was 1.43 t/ha, Aman 1.82.07 t/ha and Boro was 3.35 t/ha respectively (Anon, 2005). But the yield of hybrid rice was higher i.e. near doubled (4t/ha) from the average yield 2.15t/ha (Anon, 2001).

In Bangladesh hybrid rice has a good prospect but very little research work has been done for the development of hybrid. Only one rice hybrid variety named BRRI hybrid 1 has been released for commercial cultivation by Bangladesh Rice Research Institute (BRRI). Few seed companies have imported hybrid seeds of different varieties, which are also cultivated in farmer’s field. However, the farmers are confusing about the growth characteristics and genetically yield potential of these hybrids in comparison with high yielding varieties locally cultivated in Bangladesh.

Since emergence in 1972, the BRRI has earned international standard of agricultural research and heritage status developing over 46 numbers of modern/high yielding (including one hybrid) varieties of rice. The performance of two Boro rice varieties of BRRI dhan 28 and BRRI dhan 29 are highly commendable. These two inbred HYV rice varieties are internationally competitive and considered to be super rice varieties. The potential and cultivable commercial yields of BRRI dhan 28 is 6 to 6.5 ton per hectare and BRRI dhan 29 is 7 to 7.5 ton per hectare (Anon, 2004).

The hybrid varieties mostly cultivated in Bangladesh are imported from China by private seed companies and only one hybrid varieties BRRI hybrid 1 has developed by Bangladesh Rice Research Institute and potentiality of this hybrid is 8.5 ton per hectare (Anon, 2004). 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, though their yield advantage were 23% and 5% higher than that of HYVs, respectively. Greater emphasis is being given for increasing yield of hybrid rice during development or imported from other countries.

The population of Bangladesh is increasing day by day and that is why horizontal expansion of rice area is not possible due to high population pressure on land, to ensure the food security for her increasing population. Therefore, it is an urgent need of the time to increase rice production through increasing yield. Proper practices are the most effective means for increasing yield of rice at farmers level using inbred and hybrid varieties (Alauddin, 2004).

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

Objectives:

1. Characterization of cultivated commercial hybrids
2. Evaluation of yield and identification of potential hybrids

REVIEW OF LITERATURE

The International Rice Research Institute (IRRI) took the initiative in1979 to explore potential and problems of developing this technology for countries outside China. Learning from Chinese experience, nearly 20 countries are currently involved in development and use of this technology and many of them work collaborate with IRRI. The annual growth rate in global rice production was only 1.8% during the 1985 to 1992 compared to 2.8% during 1975 to 1985 and 3.6% during 1965 to 1975. Over the years, there has been a gradual decline in the annual growth rate of global rice production. This world requires 60% increase in rice production (Khush, 1996).

According to Swaminathan (1998), we need a minimum annual growth rate of 2.5% in rice production to maintain the self-reliance, and to have sufficient rice production to maintain the self-reliance, and to have sufficient rice for both home consumption and export. Of the various short and long term approaches contemplated for rising further the yield threshold of rice, exploiting of hybrid vigor is considered the most feasible and readily practicable approaches. Hybrids rice through its enhanced productivity enabled China to spare around four million hectare rice area annually for the production of other high value crops (Ahmed *et al.,* 2001).

Yield of rice is a function of genotype and environment. For increasing yield, a good number of varieties with high yield potential have been developed (Hossain *et al.,* 1990). Environment includes both climatic and management variables.

Not all the modern varieties of rice suit similar climatic variables; thus, season-specific recommendations are made for season(s) other than they are recommended for all seasons (Hossain *et al.*, 1987).

Yield is the product of yield components i.e. panicle no., grain no., and grain weight in rice (Yoshida, 1981). Response to selection depends on many factors, such as interrelationship of the character. Therefore, knowledge of the relationship between yield and yield components is desirable to know the magnitude and direction of changes expected during selection.

The available literatures under the heads of the objectives of the study were also reviewed in the following paragraphs.

2.1 Plant height (cm)

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

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

Young and Virmani (1990) reported that the hybrids were superior to their parents in yields were taller than the parents.

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

Saha Ray *et al.,* (1993). Marekar, R.V and Siddiqui, M.A (1996) stated that positive and significant correlations were observed between yield per plot and plant height, length of panicle, days to maturity, 1000-grain weight, length of grain and L/B ratio.

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

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

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

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

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

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

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

Oka, M and Saito, Y (1999) experimented that among F_1 there were relationships plant height; panicle length and number of grains/panicle were higher in the hybrid MH2005.

Pruneddu, G and Spanu, A (1999) conducted that plant height ranged from <65 cm in Mirto, Tejo, Gladio, Lamone and Timo, to 80-85 cm. Nine hybrid rice cultivars were resistant to lodging.

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

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

Mrityunjay, G (2001) concluded hybrids, in general, gave higher values for plant height at harvest, panicle length and number of filled grains per panicle, performed better compared to the others in terms of yield and yield components.

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

De, D.K *et al.,* (2002) experimented that plant height ranged from 80.00 to 132.00 cm, whereas panicle length ranged from 22.00 to 29.00 cm. which is responsible for grain yield per plant.

2.2 Days to 50% flowering

Most Scientists indicated that days to 50% flowering has direct and indirect effect on yield, grains/panicle and also tillering height.

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

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

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.

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

Endo, R. M *et al.*, (2000) said that flowering occurred 88 days after seedling emergence.

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

2.3 No. of effective tillers per plant

Ghose and Ghatge (1960) stated that tiller number, panicle length contributed to yield. Effective tillers/plant, number of grains/panicle and grain weight as the major contributing characters for grain yield were reported by Ghosh and Hossain (1988) and grain yield had positive correlations with number of productive tillers/plant (Paramasivam, 1986; Tahir *et al.*, 1988).

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

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

Mishra, D *et al.,* (1996) concluded that number of tillers per hill and number of grains per panicle exhibited positively high significant correlation with yield.

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

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

Nehru, S. D *et al.,* (1999) suggested that increased yield might be due to increased numbers of tillers and spikelets fertility percentage and test weight.

Thakur, S.K *et al.,* (1999) studied genetic variability and correlations among grain yield and its attributing traits, in an F_2 population in hybrid rice. Correlation studies suggested that tillers per plant, had a positive association with grain yield, plant height, panicle weight, biological yield and harvest index.

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

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

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

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

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

Laza, M.R.C *et al.,* (2001) concluded that the early vigour of hybrid rice (Oryza sativa) developed in temperate areas has been mainly attributed to its higher tillering rate. However, the tillering rate of hybrids was significantly lower than or equal to that of conventional varieties.

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

2.4 Days to maturity

Lin and Yuan (1980) reported that most hybrids had longer growth duration, however, Xu and Wang (1980) observed that days to maturity depended on the restorer.

Yu, H.Y *et al.,* (1995) concluded that hybrid variety was bred from the cross II32A/Hui 92 in the Zhejiang province of China it reaches a height of 90 cm and has a growth period of 122-125 days.

He, F.Y *et al.,* (1998) studied that hybrid the growth period is 136 days. The hybrid combinations Lexiang 202xMinghui-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).

Pruneddu, G and Spanu, A (1999) conducted that earliest hybrid rice cultivar Ebro, reaching maturity 114 days after sowing, and Balilla, Tejo and Thaibonnet were the latest, reaching maturity 128 days after sowing.

Yang, Z.F (1998) examined that Chao Chan 1 a hybrid rice cultivar. The growth period is 145 days. Conversely, Ponnuthurai *et al.,* (1984) reported that hybrid growth duration similar to that of the shorter duration parent.

Wang, H.L (2000) experimented that in plot trials in 1998 and 1999, growth period of early hybrid rice cv. Zhe 9516 was 116 and 117 days, respectively.

Ma, G.H *et al.,* (2001) experimented that ADTRH1 is a rice hybrid. This hybrid is semidwarf and matures in 115 days. Huang, N.R *et al.,* (1999) studied the morphological and physiological characteristics of Yueza 122. The results showed that it was an early maturity hybrid combination with duration of 83 days from sowing to heading in the early cropping season.

Parvez, M. M *et al.,* (2003) observed that shorter field duration was observed in Sonarbangla-1 than the control. Ma, G.H *et al.,* (2001) studied a comparative performance of 8 rice hybrids. All hybrids showed shorter growth duration (97-107 days) than the controls (110-116 days).

Wei, W.Q *et al.*, (2004) concluded that Yueza 122 was bred by crossing GD-IS with Guanghui 122. It shows wide adaptability, high and stable grain yield, moderate growth period, and fine grain quality, high resistance to rice blast and medium resistance to bacterial blight.

2.5 Panicle length (cm)

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

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

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

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

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

Oka, M and Saito, Y (1999) said that there were relationships with parental values for panicle length, grain number/panicle and panicle emergence date. The hybrid MH2005 gave a yield of 6.09 t/ha compared with 4.36 t/ha from cv. Hitomebore.

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

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

Ganesan, K. N (2001) conducted that panicle length (0.167) had the highest significant positive direct effect on yield/plant followed by number of tillers/plant (0.688), panicle exsertion (0.172), and plant height (0.149).

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

Zhang, Q *et al.*, (2005) indicates that the panicles length had a positive correlation with the yield; while the spikelets per panicle had negative correlation with the yield.

2.6 Filled grain per panicle

Mahajan, C.R (1993) indicated that filled grains/panicle, grain yield/plant was positively and significantly correlated with straw yield/plant.

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

Yang, C.D and Song, Q.X (1994) observed that heterosis was highest for number of effective panicles (59.06%) and high for total filled grain number/main panicle (42.44%). Number of effective grains/ panicles was correlated with 100-grain weight and 10-grain length.

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

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

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

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

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

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

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

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

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

Oka, M and Saito, Y (1999) experimented that among F_1 hybrids from crosses of rice cv. Sasanishiki with other cultivars there were relationships with parental values for grain number/panicle, panicle length, and panicle emergence date.

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

Mrityunjay, G (2001) to study the performance of 4 rice hybrids and 4 high yielding rice cultivars. Hybrids, in general, gave higher values for number of filled grains per panicle, plant height at harvest, panicle length compared to the others.

Ganesan, K. N (2001) conducted that an experiment of 48 rice hybrids. Filled grains/panicle (0.895) had the highest significant positive direct effect on yield/plant followed by number of tillers/plant (0.688, panicle length (0.167) and plant height (0.149).

Liu, J.F and Yuan, L.P (2002) studied the relationships between high-yielding potential and yielding traits. Filled grains per panicle was positively correlated with biomass, harvest index and grain weight per plant.

Parvez, M. M *et al.,* (2003) studied the yield advantage for the hybrid rice was mainly due the proportion of filled grains per panicle, heavier grain weight (35%) and increased values than the control (28%).

Chaudhary, M and Motiramani, N.K (2003) filled grain yield per panicle showed significant positive correlation with effective tillers per plant, spikelets density and biological yield per plant.

Yuan, J.C *et al.,* (2005) the variation in fertile grain percentage/panicle in indica was greater than that in japonica

2.7 Total grains per panicle

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

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

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

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

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

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

Oka, M and Saito, Y (1999) experimented that among F_1 hybrids crosses with rice cv. Sasanishiki. Plant height, panicle length and number of grains/panicle were higher in the hybrid than in Sasanishiki, but the 1000-grain weight was lower.

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

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

According to Zhang, Q *et al.,* (2005) the result indicates that the grain/ panicles had a positive correlation with the yield; while the spikelets per panicle had negative correlation with the yield.

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

2.8 1000-grain weight (gm)

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

Kumar et al. (1994) stated that grain weight was highly correlated to grain size, which is product of grain length and width that are inherited independently and this independent inheritance lead to variation in F_1 grain weights.

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

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

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

Yang, Z.F (1998) studied that Chao Chan1 hybrid rice was 1000-seed weight is 28 g. which is directly related with yield.

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

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

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

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

2.9 Biological yield (gm)

A positive significant correlation between biological yields also been reported by no. of workers in rice (Siddiq and Reddy, 1984; Malik *et al.,* 1988; Ganesan and Subramaniam, 1990). High yielding hybrids also showed significant heterosis and heterobeltiosis for total dry matter and harvest index (Ponnuthurai *et al.*, 1984; Kim, 1985).

Kim and Rutger (1988) noted that hybrids that gave high grain yields also produced high biomass. In addition, biomass yield at different growth stages showed different patterns for hybrid rice and conventional rice. Hybrid rice has more dry matter accumulation in the early and middle growth stages.

Hybrid rice also accumulates more total dry matter than conventional rice (Zhende, 1988). Qiu, D.J *et al.,* (1994) experimented that the higher the biological yield, the higher was the economic yield (the regression equation is given). Results suggested that enhancing biological yields by increasing plant height would be effective in improving hybrid yields.

Geetha, S (1993) indicated that straw yield and harvest index were all correlated positively with grain yield.

Ramesha, M. S *et al.,* (1998) conducted that the superior yielding ability of the hybrids over the controls resulted from increased total biomass and increased panicle weight, with almost the same level of harvest index.

Peng, S *et al.,* (2000) concluded that the increasing trend in yield of cultivars due to the improvement in harvest index (HI), while an increase in total biomass was associated with yield trends for cultivars-lines. High genotypic co-efficient of variation and broad sense heritability with respect to biological yield in rice has been reported by Vinaya Rai and Murty (1979).

2.10 Harvest index

Geetha, S (1993) indicated that harvest index, number of ear-bearing tillers, filled spikelets per panicle, percentage filled spikelets, test weight, straw yield and were all correlated positively with grain yield.

Jiang, L.G *et al.,* (1995) compared 10 varieties for yield components. The yield increase of dwarf over tall varieties mainly resulted from higher harvest index, while the yield increase of hybrid rice over the dwarf varieties was mainly from higher biomass production.

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, M. S *et al.,* (1998) conducted that hybrids showed heterosis for dry matter accumulation at many growth stages.

Sathya, A *et al.,* (1999) reported that productive tillers per plant was the principal character responsible for grain yield per plant followed by 100-grain weight, days to 50% flowering, plant height and harvest index as they had positive and significant association with yield.

Peng, S *et al.,* (2000) concluded that the increasing trend in yield of cultivars released before 1980 was mainly due to the improvement in harvest index (HI), while an increase in total biomass was associated with yield trends for cultivars-lines developed after 1980.

Kiniry, J. R *et al.,* (2001) concluded that yield differences among cultivars were due to HI values. The mean HI was 0.32 for all four cultivars over the two harvests in each of the 2 years.

Chaudhary, M and Motiramani, N.K (2003) observed that broad-sense heritability was very high for all characters, except harvest index.

2.11 Grain yield/plant

Mahajan, C.R (1993) indicated that grain yield/plant was positively and significantly correlated with straw yield/plant and filled grains/panicle.

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

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

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

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

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

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

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

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

Oka, M and Saito, Y (1999) experimented that among F_1 hybrids from crosses of rice cv. Sasanishiki. The hybrid MH2005 gave a yield of 6.09 t/ha compared with 4.36 t/ha from cv. Hitomebore. Plant height, panicle length and number of grains/plant were higher in the hybrid than in Hitomebore, but the 1000-grain weight was lower.

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

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

Mohammad, T *et al.,* (2002) conducted that phenotypic and genotypic coefficients of variation (PCV and GCV) were of comparable magnitudes except grain yield/plant and grains per panicle where the environmental coefficient of variation (ECV) contributed more to the PCV than GCV.

Chaudhary, M and Motiramani, N.K (2003) reported that grain yield per plant showed significant positive correlation with effective tillers per plant, spikelets density and biological yield per plant. Almost all characters exhibited high heritability coupled with high genetic advance, except harvest index.

2.12 Yield Potential of Hybrid

Prior to the breeding of hybrids, yield potential of *indica-japonica* hybrids in Hunan Province, China, and Korea were evaluated with the assumption that the yield potential could be estimated by compensating for yield losses due to hybrid sterility.

Araki et al. (1990) noted that two experimental *indica/japonica* hybrids, Kanto Kou 1 and Ouu Kou 1. Ouu Kou 1 gave an average yield increase of 22% at six sites, excluding the one affected by cold weather in 1991.

Yuan (1990) reported that an experiment *indica/japonica* hybrid, Erjiuqing indica (TGMS)/DT13 (japonica WC variety) was conducted at the Hunan Hybrid Rice Research Centre in 1989. This hybrid gave a yield increase of 47% against an *indica* hybrid V-You-6.

Khush *et al.*, (1994) reported that the yield potential of modern high yielding varieties grown under the best tropical conditions is 9-10 t/ha. Tropical rice hybrids under similar condition have shown about 12 t/ha.

Khush *et al.*, (1998) also noted that if these new plant cultivars will be used to produce hybrid rice, which is expected to have a yield potential of 13 t/ha.

Ramana, MV *et al.*, (1998) observed the mean grain yield of the best performing rice hybrids was 37.7% higher than the conventional cv. IR-64 during 1993, while in 1995 the maximum yield of rice hybrid MTUHR 2037 was 10.3, 17.4 and 31.1% higher than that of comparison cultivars Chaitanya, BPT 5204 and Tellahamsa, respectively. The mean grain yield of rice hybrids during 1996 was 23.7 and 26.0% higher than BPT 5204 and Tellahamsa, respectively.

Khan, M.N.A *et al.*, (1998) hybrids produced a higher grain yield/plant than the respective mid-parents in both F_1 cross-combinations. Average heterosis value for yield was 1.14.

Ma, G.H *et al.*, (2001) studied a comparative performance of 8 rice hybrids and the control cultivars PS02 and PTT1. The hybrids possessed more leaves (12-15.9) than the local cultivars (15.1-15.3) as well as higher yield.

NN49 produced the highest yield (7.142 t/ha) which was 58.78 and 26.52% higher than those of PS02 and PTT1.

Ma, G.H *et al.*, (2001) experimented that ADTRH1 is a rice hybrid in different trials, ADTRH1 showed 26.9 and 24.5% higher yield over CORH1 and ASD18, respectively, with an average yield of 6.6 t/ha. The hybrid recorded the highest grain yield 11.4 t/ha. The highest yield of the control in these trials was 9.6 t/ha.

Parvez, M. M *et al.*, (2003) conducted a comparative study to evaluate four imported hybrid rice cultivars with a high yielding variety (BRRI Dhan-29).The Chinese cultivar, Sonarbangla-1, performed best in terms of all the parameters considered. The other three Indian cultivars (Amarsiri-1, Aalok and Loknath) had lower performance than the control. Sonarbangla-1 produced a 20% higher rice yield (7.55 t/ha) than the control (6.26 t/ha). Yield advantage for the hybrid rice was mainly due to heavier grain weight (35%).

MATERIALS AND METHODS

The 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. This chapter deals with a brief description on experimental site, climate, soil, land preparation, planting materials, layout of the experimental design, land preparation, fertilizer application, irrigation and drainage, intercultural operation, data recording and their analysis, days to 50% flowering, no. of effective tillers per plant, days to maturity, panicle length, no. of filled spikelets per plant, no. of unfilled spikelets per panicle, total no. of filled spikelets per panicle, 1000-grain weight, biological yield per plant, grain yield per plant, grain yield per plot, grain yield per hectare, harvest index.

3.1 Site description

The experiment was conducted in the Sher-e-Bangla Agricultural University research farm, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28 during the period from January 2006 to May 2006. The experimental site was located at 8.45m elevation above sea level with latitude of $23^{0}46^{'}$ and longitude of $90^{0}23^{'}$. For better understanding about the experimental site is shown in the AEZ Map of Bangladesh in Appendix ii.

3.2 Soil

The experiment was carried out in a typical rice growing soil belongs to the Modhupur Tract (UNDP, 1988). Soil was sandy loam in texture. The land was well drained with good irrigation facilities. The nutritional status of the experimental soil of farm area determined in the SRDI, the Soil Testing Laboratory, Khamarbari, Dhaka have been presented in appendix iv.The experimental site was a medium high land and pH of the soil was 5.6. The morphological characters of soil of the experimental plots as indicated by FAO (1988). Soil series: Tejgaon ,General soil: Non calcarious dark grey.

3.3 Climate

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

3.4 Planting materials

Five hybrid rice varieties from different private seed companies, one hybrid and two check varieties from Bangladesh Rice Research Institute were used for this experiment.

Varieties are:

V_1=Sonarbangla-1	V_2= Jagoron
V_3= Hira	V_4= Aloron
V_5= Richer	V_6= BRRI hybrid 1
V_7= BRRI dhan 28(Check)	V_8= BRRI dhan 29(Check)

Table 3.4 List of the genotypes used in the experiment with their origin

Varieties	Origin	Imported by
Sonarbangla-1	Imported from China	Mollica seed company
Jagoron (GB 4)	Imported from China	BRAC
Aloron	Imported from China	BRAC
Hira	Imported from China	Surreme seed company
Richer 101	Imported from China	Chens crop science
BRRI hybrid-1	Released by BRRI	
BRRI dhan-28	Released by BRRI	
BRRI dhan-29	Released by BRRI	

3.5 Seed Sprouting

Healthy seeds were selected following standard method. Seeds were immersed in water for 24 hours. These were then capped in tightly and shady areas. The seeds started sprouting after 48 hours, which were suitable for sowing in 72 hours.

3.6 Raising of seedling

A common procedure was followed in raising of seedlings in the seedbeds. The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation was gently provided to the bed as and when needed.

3.7 Layout of the experimental design

The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. There were eight treatment combinations. The total no. of unit plots was 24. The size of unit plot is 3m x 2m. The distance between plot to plot and replication were 1m.

3.8 Land preparation

The experimental plot was prepared by three successive plowing ploughings and cross ploughings. Each ploughings was followed by laddering to have a good puddled field. All kinds of weeds and residues of previous crop were removed from final ploughing. Individual plots were cleaned and finally leveled.

3.9 Transplantation

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

3.10 Fertilizer Management

At the time of final land preparation total P and K were used as basal dose and total N splitted into three installments. The experimental plot was fertilized with 60:40:40 kg/ha N, P and K respectively. The first one third of N 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 and Zn at the rate 60 kg and 10 kg/ha as basal dose.

3.11 Irrigation and Drainage

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

3.12 Intercultural operation

3.12.1 Gap filling

After one week of transplanting gap filing was done whenever it was necessary using the seedling from the previous source.

3.12.2 Weeding

First weeding was done at 20 days after seedling planting followed by second weeding at 15 days after first weeding.

3.12.3 Application of irrigation water

Irrigation water was added to each plot according to the needs. All the plots were kept irrigated as per treatment. Before ripening, the field was kept dry for all the treatments. Irrigation was given at a regular interval to maintain 2-3 cm depth up to hard dough stage of rice.

3.12.4 Plant protection measures

Plants were infested with rice stem borer, leafhopper, and rice hispa, rice bug to some extent, which was successfully controlled by application of insecticides such as Diazinon, and Ripcord @ 10 ml/ 10 liter of water for 5 decimal lands. Crop was protected from birds and rats during the grain-filling period. Field trap and phostoxin poisonous bait was used to control the rat. For controlling the birds, watching was done properly, especially during morning and afternoon.

3.12.5 Harvesting and post harvest operation

Maturity of crop was determined when 90% of the grains become golden yellow in color. Ten pre selected hills per plot from which different data were collected, separately harvested and bundled properly tagged and then brought to the threshing floor for recording grain and straw yield.

Threshing was done using by pedal thresher. The grains were cleaned and sun dried to moisture content of 14%. Straw was also sun dried properly. Finally grain and straw yield per plot were recorded and converted to t/ha.

3.13 Recording observations

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

3.13.1 Plant height:

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

3.13.2 Days to 50% flowering:

No. of days required for 50% of the plants to show panicle emergence, from the date of showing were recorded.

3.13.3 No. of effective tillers per plant:

Total no. of panicle bearing tillers in a plant counted at the time of harvesting.

3.13.4 Days to maturity:

No. of days required from sowing to physical maturity was recorded.

3.13.5 Panicle length:

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

3.13.6 No. of filled grains per panicle:

No. of filled grains present on the main panicle was recorded.

3.13.7 Spikelets fertility (%):

At the harvesting, five panicles were harvested at maturity from five randomly chosen plants in each of the hybrids and the no. of filled, unfilled and total spikelets was counted. Spikelets fertility percentage was then computed as

$$\text{Spikelets fertility (\%)} = \frac{\text{No. of filled spikelets in the panicle}}{\text{Total no. of spikelets in the panicle}} \times 100$$

3.13.8 1000-grain weight:

1000 grains were counted from a random sample drawn from bulk produce and weight in gm was recorded at 14% moisture level.

3.13.9 Biological yield per plant:

The plants harvested at maturity stage were sun dried uniformly till constant moisture level was attained and weight in gm.

3.13.10 Grain yield per plant:

Grain yield in gm plant^{-1} was taken after harvesting, threshing, cleaning and drying the produce to 14% moisture level.

3.13.11 Grain yield/plot:

Grain in gm plant^{-1} ten plants of each replication was taken after harvesting, threshing, cleaning and drying the produce to 14% moisture level and calculated for 3m x 2m = 6m^2 in kg.

3.13.12 Grain yield/ha:

Grain yield plot^{-1} was converted into grain yield ha^{-1} in kg.

3.13.13 Harvest index (HI):

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

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

3.14 LSD analysis:

Mean comparisons were done by LSD (Least Significant Difference)Test method.

3.15 Identification of potential hybrids for commercial cultivation.

3.16 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 the 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 3.16 The structure of Analysis of Variance (ANOVA)

Sources of variation	**df**	**MSS**	**Expected MSS**	***F-value***
Replication	(r-1)	Mr	$\sigma_e^2+g\sigma_r^2$	
Treatment/genotype/hybrids/ parents/checks	(g-1)	Mg	$\sigma_e^2+r\sigma_g^2$	*Mg/Me*
Error	(r-1)(g-1)	Me	σ_e^2	
Total	*(rg-1)*			

Where, r = No. of replication

g = No. of genotypes (treatments)

Mr, Mg and Me = Mean sum of squares due to replications, genotypes and error respectively

σ_e^2 = Error variance = Me

σ_g^2= Genotypic variance = (Mg – Me)/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.

3.17 Estimation of mean, range, standard error and critical difference:

Mean value of each character was worked out by dividing the total with corresponding no. 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 degrees 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± x 't'value (5% or 1%) at error d.f.

Coefficient of variation was calculated as follows in percent.

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

3.18 Assessment of genetic differences among yield contributing characteristics of hybrids.

3.18.1 The Genotypic variance $= \frac{\text{Treatment MSS} - \text{Error MSS}}{\text{No. of replications}}$

3.18.2 The phenotypic variances

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

$$\sigma_p^2 = \sigma_e^2 + \sigma_g^2$$

3.18.3 Genotypic and phenotypic coefficient of variation:

Genotypic and phenotypic coefficient of variation were estimated by using the following formula given by Johnson *et al.* (1955).

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

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

3.18.4 Heritability (h^2):

Heritability in broad sense was calculated as follows:

$$\text{Heritability } (h^2_b)\ (\%) = \frac{\sigma_g^2}{\sigma_p^2} \times 100$$

Where, σ_g^2 = Genotypic variance

σ_p^2=Phenotypic variance

LIST OF PLATES

Plates I.Field view of the experimental plots at a glance

Plates II. Field view of the experimental plots where showed plant height varied among the different varieties

Plates III.Field view of the experimental plots at vegetative growth stage

RESULTS AND DISCUSSION

The experimental results obtained from the investigation on "Varietal characterization and yield evaluation of six rice hybrids (*Oryza sativa* L) grown in Bangladesh" are presented here under the following heads:-

1 Characterization of cultivated commercial hybrids

2 Evaluation of yield and identification of potential hybrids

4.1 Characterization of cultivated commercial hybrids:

In the present study, six hybrids collected from different seed companies and from research organization have been evaluated for their performance of yield and yield contributing traits, interrelationships of these traits for commercial cultivation of ones. Generally, a breeder aims at accumulating favorable genes from diverse resources in a particular genotype, which would largely depend upon the availability of genetic variability in the germplasm in respect of any particular character and evaluate that character for better use of human beings.

4.2 Mean performance

The discussions on mean performance of yield and yield components of the hybrids and check varieties have been presented here under (Table 1).

4.2.1 Plant height (cm)

In the present study plant height of the hybrids ranged from 82.46 cm in Richer to 100.31 cm in BRRI dhan 28 with a mean of 89.58 cm.

Table 1. Mean performance of hybrids and checks for varietal characters

Sl No	Variety	PH (cm)	DFF	NET/p	DTM	PL (cm)	FG/p	TG/p	TGW (g)	BY/p (g)	HI (%)
1	Sonarbangla 1	89.52	97.66	13.33	118.00	27.47	145.40	166.50	28.28	29.58	60.43
2	Jagoron	85.80	97.00	15.33	123.00	27.34	118.00	133.66	28.24	26.02	63.97
3	Hira	87.67	96.00	17.66	125.00	27.53	135.66	153.33	25.82	28.00	51.49
4	Aloron	91.73	120.33	16.33	135.00	28.57	120.00	148.33	28.82	40.41	63.09
5	BRRI hybrid 1	100.31	123.00	16.00	148.66	27.60	148.66	213.33	27.90	46.45	48.00
6	Richer	82.46	118.00	15.66	135.00	27.73	118.06	137.66	26.98	32.88	57.64
Mean		89.58	108.66	15.72	130.77	27.70	130.96	158.83	27.67	33.89	57.43
7	BRRI dhan 28 (check)	101.54	95.00	16.33	123.00	25.96	124.66	145.33	20.31	31.01	38.00
8	BRRI dhan 29 (check)	97.50	116.33	16.33	148.00	27.50	163.33	201.66	20.92	49.61	54.32
Mean		99.52	105.66	16.33	135.50	26.73	144.00	173.50	20.61	40.31	46.16
Grand mean		92.06	107.91	15.87	131.95	27.46	134.22	162.50	25.91	35.49	54.61
SEd		2.82	0.40	1.86	0.16	0.85	13.59	9.51	1.46	4.31	2.57
CV%		3.76	0.46	14.38	0.15	3.83	12.40	7.17	6.94	14.90	5.78
CD%		6.05	0.86	3.99	0.35	1.84	29.15	20.39	3.14	9.24	5.52

PH=Plant height, DFF=Days to 50% flowering, NET/p=No. of effective tillers/plant, DTM=Days to maturity, PL=Panicle length, FG/p=Filled grains/panicle, TG/p=Total grains/panicle, BY/p=Biological yield/plant, HI=Harvest index, TGW=1000-grain weight

For the checks the value ranged from 97.5 cm (BRRI dhan 29) to 101.5 cm (BRRI dhan 28), with a mean of 99.52 cm. Plant height of hybrids was lower than the checks. Among the 8 genotypes, BRRI dhan 28 showed a maximum plant height of 101.5 cm and Richer showed a minimum plant height of 82.5 cm. The grand mean value for this trait was 92.06 cm. The group of genotypes that showed higher plant height was constituted by BRRI dhan 28 (101.5 cm), BRRI hybrid 1 (100.3 cm) and BRRI dhan 29 (97.5 cm). The group of genotypes that showed lower plant height was constituted by BRRI dhan 28 (82.5 cm) and Jagoron (85.5 cm) respectively (Table 1). A comparative view of the same has been depicted diagrammatically in Fig 1. Here, Richer (82.5 cm) is lower in response of plant height and BRRI dhan 28 (101.5 cm) is higher for plant then compairing with others. Khush (1999) reported that short stature reduces the susceptibility of rice crop to lodging and leads to higher harvest index. A plant height of 90-100cm is considered ideal for maximum yield. Yu, H.Y *et al.,* (1995) concluded that hybrid where it reaches a height of 90 cm and proved resistant to Magnaporthe grisea and Nilaparvata lugens. Wang, H.L (2000) reported that plant height was 88-89 cm directly related to yields. Pruneddu, G and Spanu, A (1999) conducted that plant height ranged from <65 cm in Mirto, Tejo, Gladio, Lamone and Timo, to 80-85 cm. Nine hybrid rice cultivars were resistant to lodging. Yang, Z.F (1998) reported that plant height is 95-98 cm. Patnaik *et al.,* (1990) found that hybrids with intermediate to tall plant height. Young and Virmani (1990) reported that the hybrids were superior to their parents in yields were taller than the parents. Ponnuthurai *et al.,* (1984) reported that taller plants might have better plant canopy for photosynthesis. De, D.K *et al.,* (2002) experimented that plant height ranged from 80.00 to 132.00 cm. The average plant height of the hybrids (89.58 cm) studied in the present study is also smaller than checks (99.52 cm), which agree with the findings of Khush (1999), but no hybrids show lodging behavior. Considering all of them that short stature is effective for rice yield.

4.2.2 Days to 50% flowering

The number of days taken for 50% flowering ranged from 96.0 days in case of Hira to 123.0 days in BRRI hybrid 1, with a mean being 108.66 days. Among the checks BRRI dhan 28 showed earlier flowering range 95.0 days and BRRI dhan 29 showed latest flowering (116.3 days), with a mean of 105.66 days. Hybrids showed maximum days to flowering then the checks. Among all the genotypes, it ranged from 96.0 days for Hira to 123.0 days for BRRI hybrid 1. The grand mean for days to 50% flower of all genotypes was 107.91 days. The group of genotypes that showed maximum days to flowering was constituted by BRRI dhan 29 (116.3 days), Richer (118.0 days), Aloron (120.3 days), and BRRI hybrid 1 (123.0 days). The group of genotypes that took minimum days to flowering was constituted by BRRI dhan 28 (95.0 days), Hira (96.0 days), Jagoron (97.0 days) and Sonarbangla 1 (97.7 days), respectively (Table 1). A comparative view of the same has been depicted diagrammatically in Fig 2. The tall hybrids BRRI hybrid 1 take exceptionally long duration for 50% flowering (123 days), which would be difficult to fit in presently practiced cropping system, but it would fit well in deep water and ill drainage condition where any other crop can not be grown. Endo, R. M *et al.,* (2000) said that flowering occurred 88 days after seedling emergence of hybrid. Considering all of them that BRRI dhan 28 (95.0 days) is superior then others and BRRI hybrid 1 is inferior considering with others varieties/genotypes.

4.2.3 No. of effective tillers

Among all the genotypes, Hira showed highest no. of effective tillers (17.7) and Sonarbangla 1 showed least no. of effective tillers (13.3) with a grand mean of 15.87. The group of genotypes that showed higher no. effective tillers per plant was constituted by Aloron (16.3) and Hira (17.7). The group of genotypes which showed least number of effective tillers perplant was constituted by Sonarbangla 1 (13.3) and Jagoron (15.3), respectively (Table 1).

In the present study, hybrids have moderate number of effective tillers per plant. The relative performance has been depicted diagrammatically in Fig 3. Here, Hira (17.7) is better in accordance with no. of effective per plant and Sonarbangla 1 (13.3) is less preferable in their effective tillers. Earlier many workers reported that higher no. of productive tillers are responsible for higher yield (Pandey *et al.*,1995; Reddy and Nerker, 1995 Padmavathi *et al.*,1996 Rao *et al.*,1996a). Reduced tillering facilities synchronous flowering, maturity and more uniform panicle size. Genotypes with lower tiller no. are also reported to produce a larger proportion of heavier grains (Padmaja, R 1987). Ghose and Ghatge (1960) stated that tiller number, panicle length contributed to yield. Effective tillers/plant, number of grains/panicle and grain weight as the major contributing characters for grain yield were reported by Ghosh and Hossain (1988). Paramasivam, (1986); Tahir *et al.*, (1988); Padmavathi *et al.*, (1996) and Jiang *et al.*, (2000) observed the importance of number of tillers/plant which influencing yield. Ma, G.H. *et al.*, (2001) experimented that ADTRH1 is a rice hybrid. It tillers profusely (12-15 productive tillers per hill) with each panicle 27.5-cm long, producing 142 grains. Nuruzzaman, M *et al.*, (2000) experimented that tiller number varied widely among the varieties and the number of tillers per plant at the maximum tiller number stage ranged between 14.3, 39.5, and 12.2, 34.6.

4.2.4 Days to maturity

The days to maturity among hybrids ranged from 118.0 days for Sonarbangla 1 to 148.7 days for BRRI hybrid 1 with a mean of 130.77 days. In case of checks BRRI dhan 28 mature earlier (123.0) than both the checks, with a mean of 135.90 days. The ranged for days to maturity among all the genotypes varied from 118.0 days (Sonarbangla 1) to 148.7 days (BRRI hybrid 1). The grand mean for days to maturity of all the genotypes was 131.95 days.

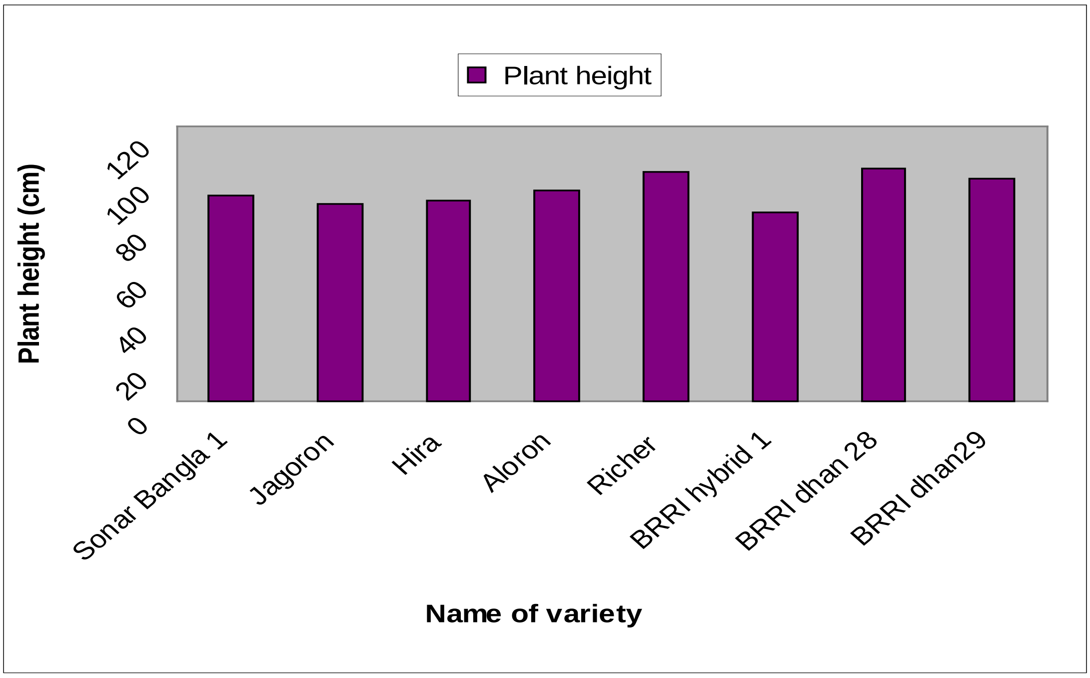

Figure 1. Relative performance of hybrids and ckecks for plant height

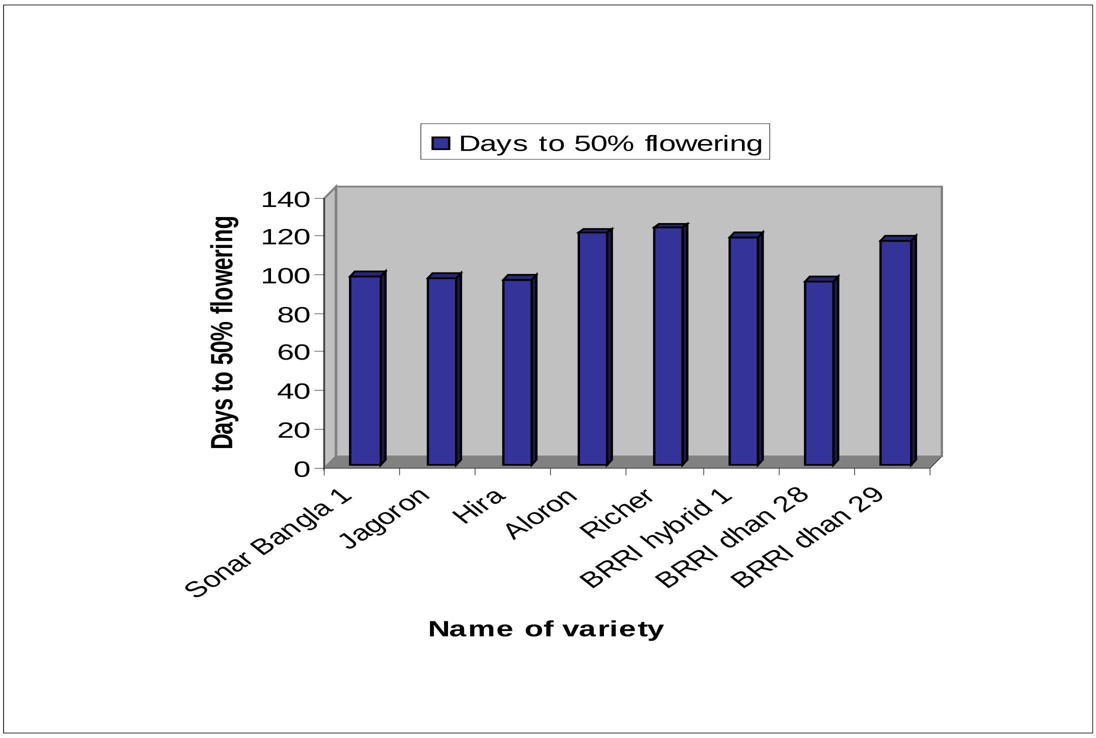

Figure 2. Relative performance of hybrids and ckecks for days to 50% flowering

The group of genotypes that showed maximum days to maturity was constituted by BRRI dhan 29 (148.0 days) and BRRI hybrid 1 (148.7 days). The group of genotypes which showed least no. of days to maturity was constituted by Sonarbangla 1 (118.0 days) and Jagoron (123.01days) respectively (Table 1). A comparative depiction of days to maturity has been made in Fig 4. In the present study, most of the hybrids took moderate days to maturity except BRRI hybrid 1. He, F.Y *et al.*, (1998) said that Xie You 914 is a new hybrid the growth period is 136 days. The hybrid combinations Lexiang 202xMinghui-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). Subbaiah (2003) reviewed the growth duration of seventeen released hybrids ranged from 105 days (HRI-120) to 135 days (KRH-2 and PHB-71). Five hybrids of the present study (118 to 135 days) fall I the dame ranged noted by Subbaiah (2003) and only one hybrid show longer duration which only maturing in (149 days) of 118 days in the best grain yielder. Pruneddu, G and Spanu, A (1999) conducted that Ebro was the earliest hybrid rice cultivar, reaching maturity 114 days after sowing, and Balilla, Tejo and Thaibonnet were the latest, reaching maturity 128 days after sowing. Yang, Z.F (1998) examined that Chao Chan 1 a hybrid the growth period is 145 days. Parvez, M. M *et al.,* (2003) observed that shorter field duration was observed in Sonarbangla-1 than the control. Ma, G.H *et al.,* (2001) studied of 8 rice hybrids. All hybrids showed shorter growth duration (97-107 days) than the controls (110-116 days). Ma, G.H *et al.,* (2001) experimented that ADTRH1 is a rice hybrid. This hybrid is semidwarf and matures in 115 days. Huang, N.R *et al.*, (1999) studied the morphological and physiological characteristics of Yueza 122. The results showed that it was an early maturity hybrid combination with duration of 83 days from sowing to heading in the early cropping season. Conversely, Ponnuthurai *et al.,* (1984) reported that hybrid growth duration similar to that of the shorter duration parent. Rice hybrids have large panicle and more spikelets than conventional varieties.

4.2.5 Panicle length (cm)

Among the hybrids, the length of main panicle ranged from 27.3 cm in Jagoron to 28.6 cm in Aloron, with a mean of 27.70 cm. In case of checks the panicle length ranged from 26.0 (BRRI dhan 28) to 27.5 (BRRI dhan 29), with a mean of 26.73 cm. The mean value of panicle length for all the genotypes ranged from 26.0 cm (BRRI dhan 28) to 28.6 cm (Aloron). The grand mean value for this trait was 27.46 cm. The group of genotypes that showed longer panicle length was constituted by Richer (27.7 cm) and Aloron (28.6 cm). The group of genotypes which showed shorter panicle length was BRRI dhan 28 (26.0 cm) and Jagoron (27.3 cm) are in Table 1. In the present study, hybrids showed longer panicle length than the checks. A diagrammatic depiction of the results has been made in Fig 4. Wang *et al*. (1991) reported that the length of panicle varied from 26.30 cm to 27.00 cm among the *indica/japonica* hybrids. But in the present study the range of panicle length of hybrids is from 27.30 to 28.6 cm.

4.2.6 No. of filled grains /panicle

The mean of hybrids for no. of filled grains/panicle was 130.96, with the range being 118.0 (Jagoron) to 148.7 (BRRI hybrid 1). For the checks, the number ranged from 124.7 (BRRI dhan 28) to 163.3 (BRRI dhan 29), with a mean of 144.00. Among all the genotypes, the no. of filled grains/panicle varied from 118.0 (Jagoron) and 148.7 (BRRI hybrid 1), with a grand mean of 134.22. The group of genotypes that showed higher no. of filled grains/panicle was constituted by Sonarbangla 1 (145.4), BRRI hybrid 1 (148.7) and BRRI Dhan 29 (163.3). The group which showed least no. of filled grains/panicle included Jagoron (118.0) and BRRI Dhan 28 (118.1) respectively (Table 1). A comparative view with checks has been presented in Fig 5.

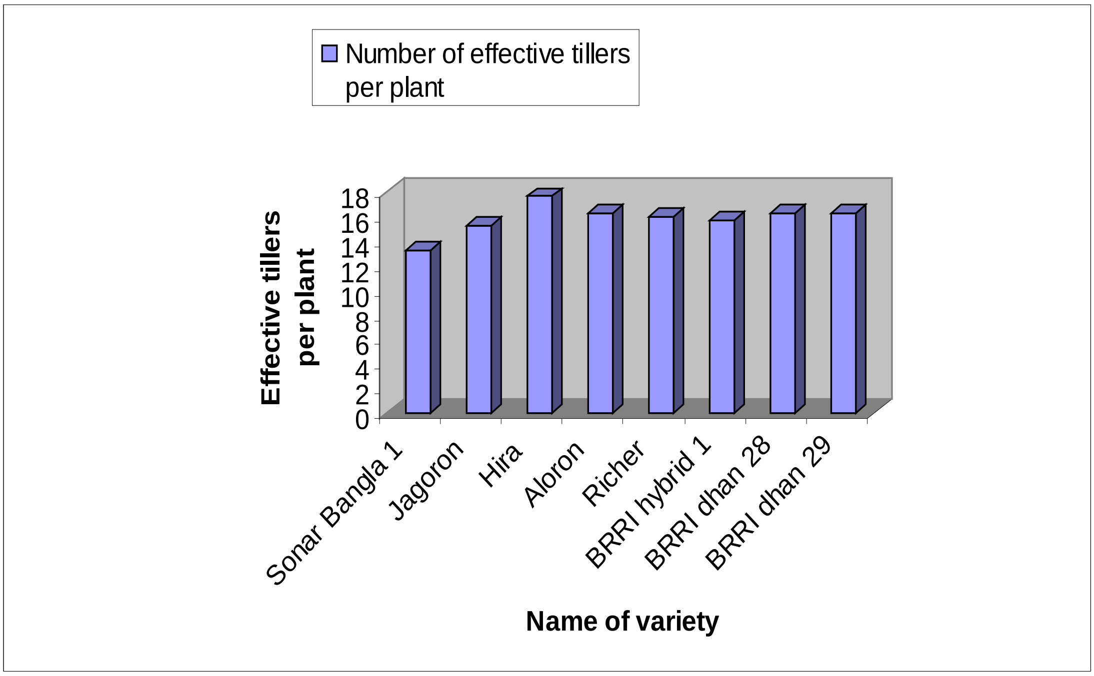

Figure 3. Relative performance of hybrids and ckecks for number of effective tillers per panicle

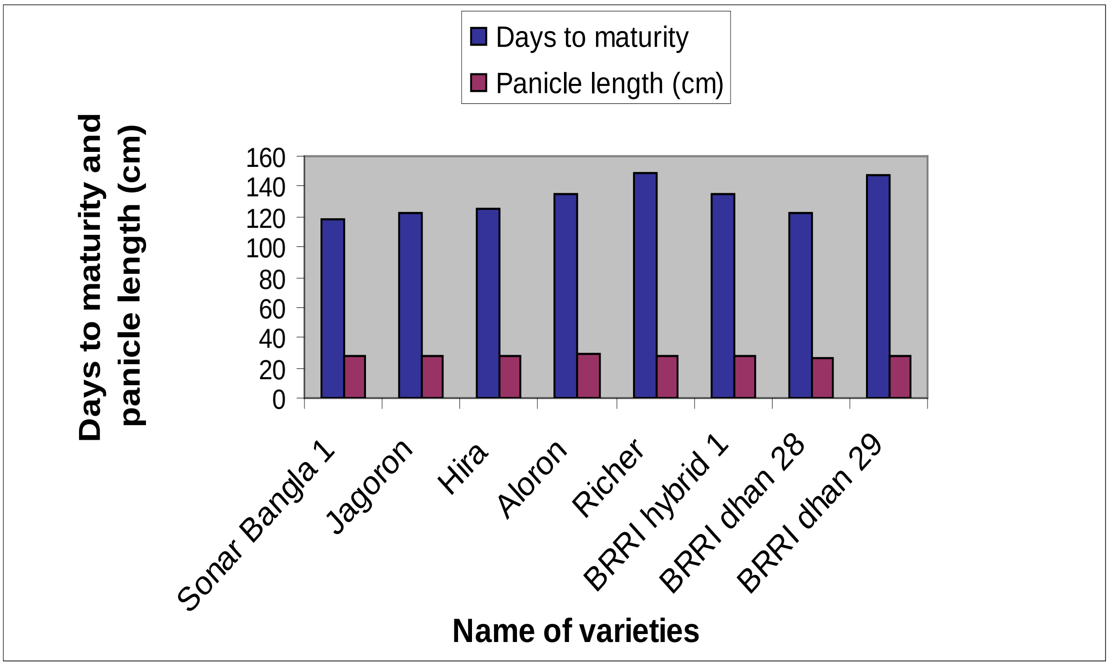

Figure 4. Relative performance of hybrids and ckecks for days to maturity and panicle length (cm)

Most variation was observed for filled grain/panicle, number of fertile spikelets and grain yield/plant. Mrityunjay, G (2001) studied the performance of 4 rice hybrids and 4 high yielding rice cultivars. Hybrids, in general, gave higher values for number of filled grains per panicle. Ramana, MV *et al.,* (1998) observed that hybrids produced more panicles m^{-2} and filled grains per panicle than conventional cultivars. Parvez, M. M *et al.,* (2003) said that yield advantage for the hybrid rice mainly due the proportion of filled grains per panicle, heavier grain weight (35%) and increased values than the control (28%).

4.2.7 No. of total grains/panicle

The mean of hybrids for this character was 158.83 with the range being 133.7 (Jagoron) to 213.3 (BRRI hybrid 1). For the checks, the number ranged from 145.3 (BRRI dhan 28) to 201.7 (BRRI dhan 29) with a mean of 173.50. Among all the genotypes, the no. of total grains/panicle varied from 133.7 (Jagoron) and 213.3 (BRRI hybrid 1), with a grand mean of 162.50. The group of genotypes that showed higher no. of total grains/panicle was constituted by BRRI dhan 29 (201.7) and BRRI hybrid 1 (213.3). The group which showed least no. of total grains/panicle included Jagoron (133.7) and Richer (137.7), respectively (Table 1). In the present study, hybrids showed higher grains then their checks. A comparative view with checks has been presented in Fig 6. Wey, J and Traore, S. G (1998) analyses of yield components revealed that plant densities were low, and that the most important components were the number of panicles per plant and the number of grains per panicle. Lin, T.F (1995) studied the percentage of filled grains was the most important factor affecting grain yield. Yuan, J.C *et al.,* (2005) studied the variation in the yield components of 75 high-quality rice cultivars. Among the yield components, the greatest variation was recorded for number of grains per panicle in indica rice, and number of panicles in japonica rice.

Dhananjaya, M.V *et al.,* (1998) observed that most variation was for productive tillers/plant, number of fertile spikelets and total grain yield/plant. It was concluded that, BRRI hybrid 1 (213.3) is superior then others.

4.2.8 1000-grain weight (g)

The highest thousand-grain weight was observed in Aloron (28.82 g) and the lowest in Hira (25.82 g) among the hybrids, with a mean of 27.67 g. Among the checks, the range was from 20.3 g (BRRI dhan 28) to 20.9 g (BRRI dhan 29) with a mean of 20.61g. Among all the genotypes Aloron showed highest 1000-grain weight (28.8 g) and BRRI dhan 28 showed lowest weight (20.3 g), with a grand mean of 25.91 g. The highly performing group was constituted by the genotypes Jagoron (28.24 g), Sonarbangla (28.28 g), and Aloron (28.82 g). The group which showed lowest 1000-grain weight was BRRI dhan 28 (20.31 g), BRRI dhan 29 (20.92 g) and Hira (25.82 g), respectively (Table 1). The relative performance has been depicted in Fig 7. In the experiment, all the hybrids are superior then thecks. Yang, Z.F (1998) studied that Chao Chan1 hybrid rice was 1000-seed weight was 28 g. which is directly related with yield. Ma, G.H *et al.,* (2001) experimented that ADTRH1 a rice hybrid, 1000-grain weight was23.8 g. In different trials, ADTRH1 showed 26.9 and 24.5% higher yield over CORH1 and ASD18.

4.2.9 Biological yield per plant

Among the hybrids, biological yield per plant ranged from 28.0 g in Hira to 46.45g in BRRI dhan 29, with a mean value of 33.89 g. In case of checks, BRRI dhan 28 showed lowest values (31.01 g) and BRRI dhan 29 showed highest values (49.61 g), with a mean value of 40.31 g. The hybrids showed lowest biological yield per plant than the checks. Among all the genotypes, BRRI dhan 29 showed maximum biological yield per plant (49.61 g) and Hira showed minimum biological yield per plant (28.0 g), with a grand mean of 35.49 g.

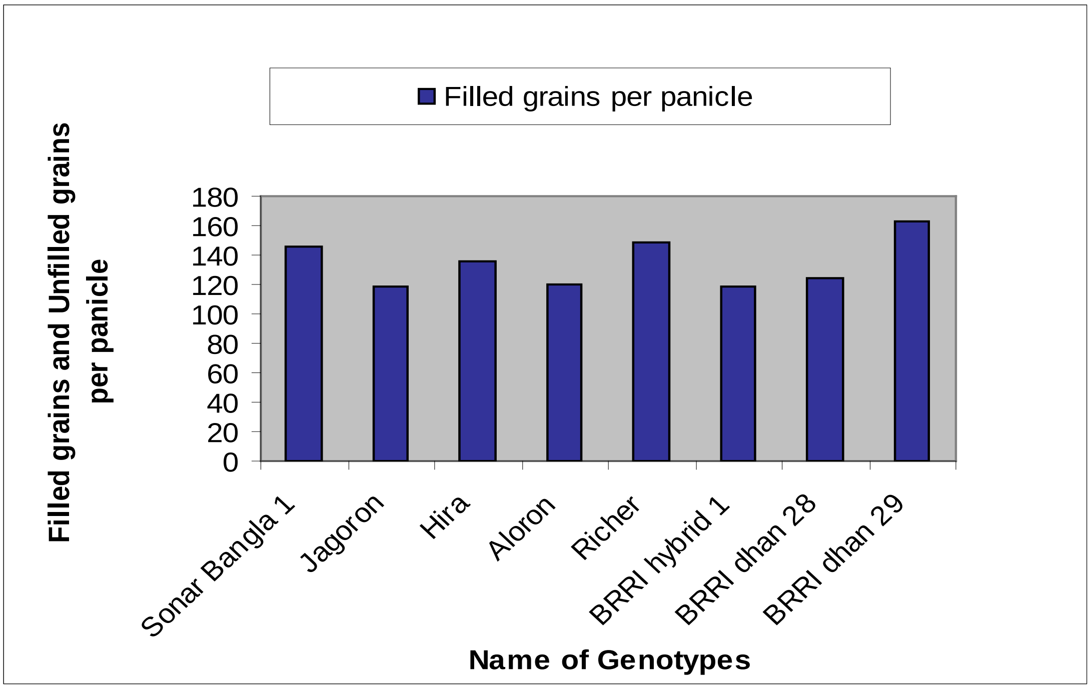

Figure 5. Relative performance of hybrids and ckecks for filled grains per panicle

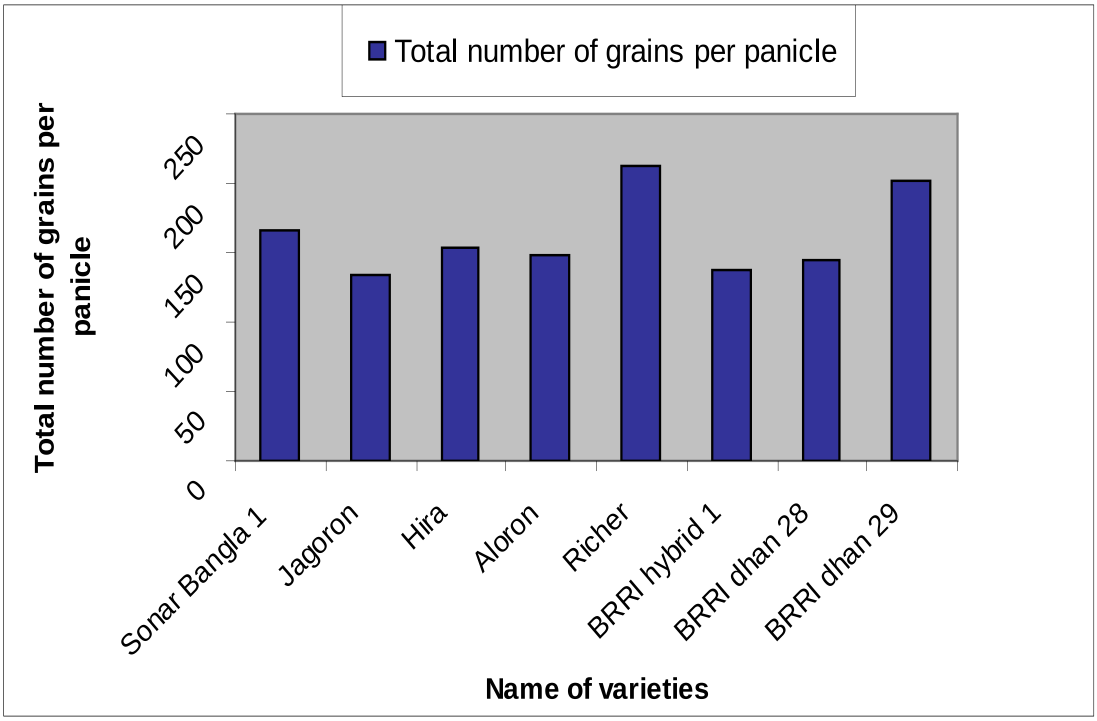

Figure 6. Relative performance of hybrids and ckecks for total number of grains per panicle

The highly performing groups of hybrids included Aloron (40.41 g) and BRRI dhan 1 (46.45 g,) respectively (Table 1). A comparative view of the results has been presented in Fig 8. In the present study, the variety BRRI dhan 29 (49.61 g) is betters then others. High genotypic co-efficient of variation and broad sense heritability with respect to biological yield in rice has been reported by Vinaya Rai and Murty (1979). Kim and Rutger (1988) noted that hybrids that gave high grain yields also produced high biomass. Qiu, D.J *et al.,* (1994) experimented that the higher the biological yield, the higher the economic yield. Ramesha, M. S *et al.,* (1998) conducted that superior yielding of hybrids over the controls resulted from increased total biomass and increased panicle weight, with almost the same level of harvest index. Hybrid rice also accumulates more total dry matter than conventional rice (Zhende, 1988).

4.2.10 Harvest index

The mean harvest index of the hybrids was recorded 57.43 percent and range varied from 48.0 percent (BRRI hybrid 1) to 64.0 percent Lagoron, in case of hybrids. Whereas, the range of harvest index percent among the checks varied from 38.0% (BRRI dhan 28) to 54.3% (BRRI dhan 29), with a mean value of 46.16 percent. Among all the genotypes, Jagoron showed maximum harvest index (64.0%), with a grand mean of 54.61%. The highly performing group included Sonarbangla 1 (60.4%), Aloron (63.1%) and Jagoron (64.0%). Moreover, the group with least performance for this character was constituted by the genotypes BRRI dhan 28 (38.0%), BRRI hybrid 1 (48.0%) and Jagoron (51.5%), respectively (Table1). A comparative view of results of this trait has been presented in Fig 8. In the present study, the variety Jagoron (64.0%) is superior then to all. Jiang, L.G *et al.*, (1995) compared 10 varieties for yield components. The yield increase of dwarf over tall varieties mainly resulted from higher harvest index, while the yield increase of hybrid rice over the dwarf varieties was mainly from higher biomass production.

Sitaramaiah *et al.,* (1998) observed that high yielding hybrids also recorded higher harvest index and higher biomass yield. Kiniry, J. R *et al.,* (2001) concluded that yield differences among cultivars were due to HI. The superiority of hybrids for biomass over conventional varieties is reported widely. Blanco *et al.,* (1990) observed 10-20% superiority of hybrids for total biological yield and grain yield.

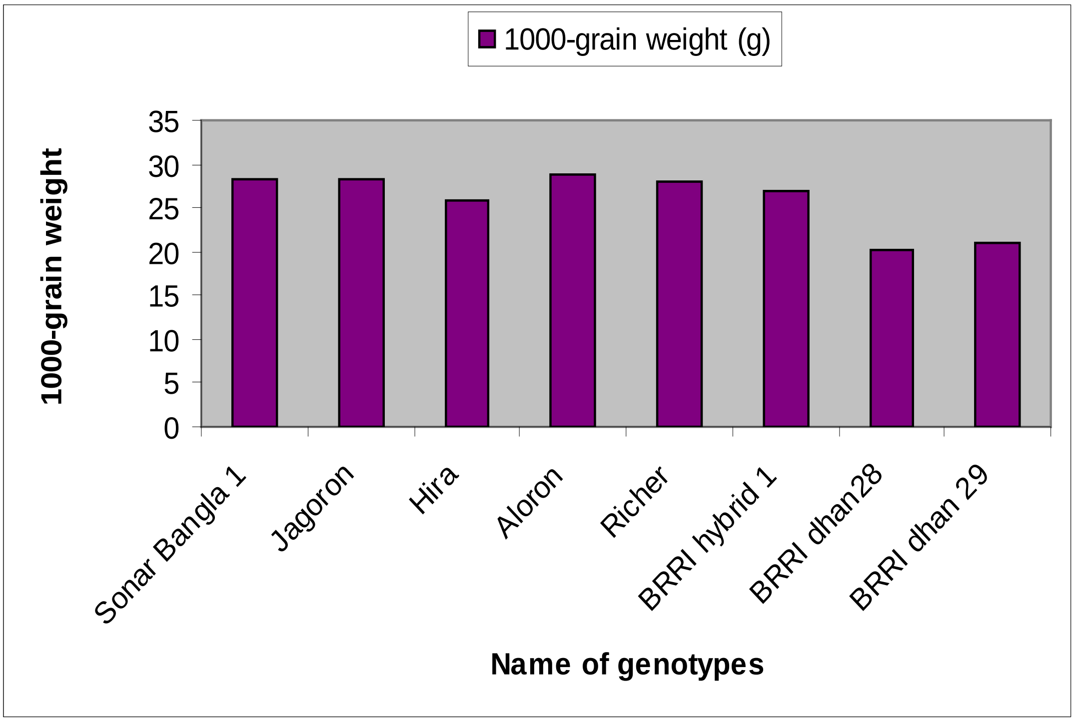

Figure 7. Relative performance of hybrids and ckecks for 1000-grain weight

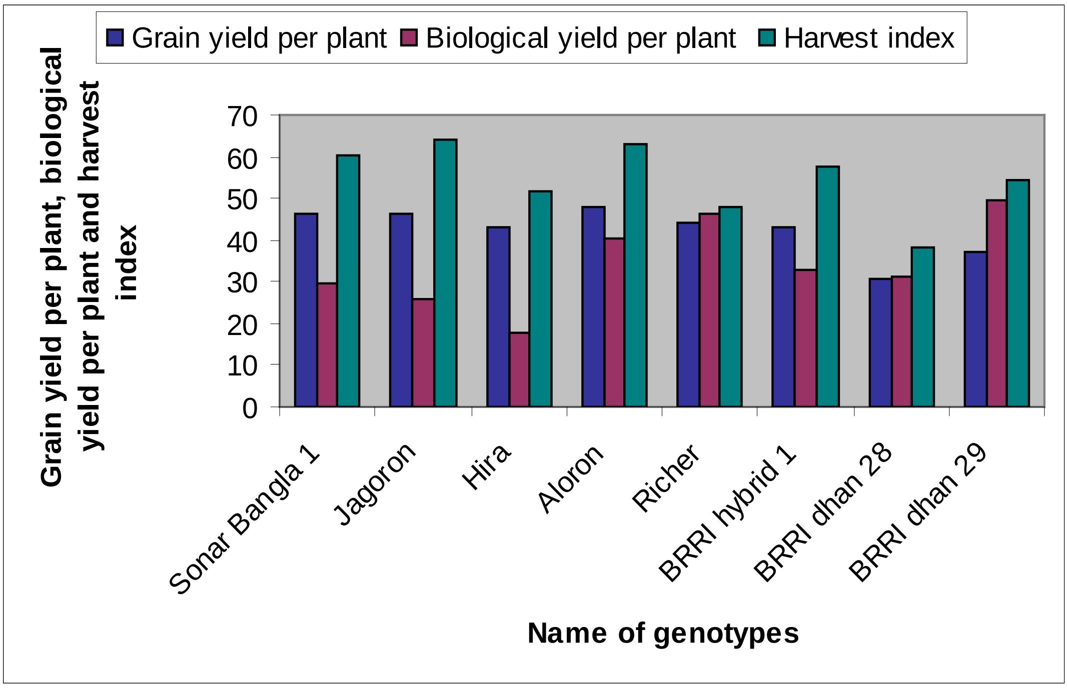

Figure 8. Relative performance of hybrids and ckecks for grain yield per plant, biological yield per plant and harvest index

5.1 Evaluation of yield and identification of potential hybrids

Yield is the product of yield components i.e. panicle no., grain no., and grain weight in rice (Yoshida, 1981). On the other hand Hossain *et al*. (1990) said that yield of rice is a function of genotype and environment. For increasing yield, a good number of varieties with high yield potential have been developed However, variation of yield may occur due to inability of choosing appropriate variety for an appropriate environment.

5.2 Analysis of variance

Analysis of variance was carried out and the mean sum of squares for various characters was presented in Table 2. 'F' test revealed highly significant variation among eight genotypes for all the characters studied. The analysis of variance (ANOVA) presented in Table 2. Showed significant variation for all the yield and yield components studied.

5.3 Analysis of Variability and heritability

The materials used in present study, show wide degree of variability maximum variation was found in unfilled grain/panicle (12.0-81.0, 575%), followed by biological yield per plant (23.21-56.19, 142.09%), harvest index (35.00-66.10, 88.85%), filled grain per panicle (104.0-190.0, 82.69%), total grain per panicle (126.0-225.0, 78.57%), 1000-grain weight (18.01-30.10, 67.12%), grain yield per plant (29.45-48.87, 65.96%), respectively (Table 3). A wide range of variation has been reported by several workers in the rice germplasm. Sarkar, K.K *et al.,* (2005) said that the highest heritability value was registered for 1000-grain weight, followed by brown kernel length and grain length. Grain weight and gain no. per panicle (Kandhola and Panwar, 1991 and Chauhan, 2000), tillers no. per plant (Amirthadenarathinam, 1983; and murugesan and subramaniam, 2001), plant height (Maurya *et al.,* 1986) and harvest index (Kim, 1985; Ponnuthurai *et al.*, 1984; Virmani *et al.,* 1981a and Peng *et al.,* 2000).

Table 2. 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)	8.039	147.707**	11.970
2	Days to 50% flowering	0.292	465.976**	0.244
3	No of effective tillers/plant	4.875	4.565**	5.208
4	Days to maturity	0.042	410.899**	0.042
5	Panicle length	0.452	1.542*	1.109
6	Filled grain/panicle	136.115	857.516**	277.045
7	Total grains/panicle	28.500	2641.238**	135.738
8	Grain yield/plant	0.001	102.154**	2.857
9	Biological yield	25.661	236.276**	27.981
10	Harvest index	4.542	228.006**	9.970
11	1000 grain weight	2.088	34.666**	3.230
12	Grain yield/plot	0.001	0.720*	0.001
13	Grain yield/ha	0.003	1.992*	0.004

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

Table 3. Estimates of range, grand mean and heritability (broad sense) for yield and its related characters in hybrids and checks

Sl No.	Characters	GM	Range	% of Variation	h^2 (%) (bs)
1	Plant height (cm)	92.069	77.40-106.61	38.27	79.07
2	Days to 50% flowering	107.917	95.00-123.00	29.47	99.84
3	No. of effective tillers/plant	15.875	13.00-18.00	38.46	50.71
4	Days to maturity	131.958	118.00-149.00	26.27	99.93
5	Panicle length	27.463	23.80-29.57	24.24	11.49
6	Filled grain/ panicle	134.225	104.00-190.00	82.69	41.20
7	Total grain/ panicle	162.500	126.00-225.00	78.57	86.01
8	Grain yield/plant (g)	42.425	29.45-48.87	65.94	92.04
9	Biological yield//plant (g)	35.498	23.21-56.19	142.09	71.27
10	Harvest index	54.618	35.00-66.10	88.85	87.44
11	1000-grain weight (g)	25.911	18.01-30.10	67.12	76.48
12	Grain yield/plot (kg)	3.823	2.88-4.47	54.88	99.58
13	Grain yield/ha (t)	6.376	4.81-7.50	55.92	99.39

Broad sense heritability (h^2b) ranged from 99.93% for days to maturity to 11.49% for panicle length. High estimates of Broad sense heritability (h^2b) was revealed by characters like 99.93% for days to maturity, 99.84% for days to 50% flowering, 99.58% for grain yield per plot, 99.39% for grain yield per hectare, 92.04% for grain yield per plant, 91.70% for grain yield per square meter, 87.44% for harvest index, 96.01% for total grain per panicle , 80.36% for no. of filled spikelets per panicle, 79.07% for plant height and 76.48% for 1000-grain weight, respectively (Table 2).

High estimates of broad sense heritability were also reported by some workers for character like days to 50% flowering, maturity and no. of productive tillers per plant (Maurya 1986 and Yadav, 1992), biomass yield (Vinaya Rai and Murty, 1979), plant height and spikelets per panicle (Mehetre, 1996 and Choudhury and Das, 1997), 1000-grain yield (Govindarasu and Natarajan, 1995), yield per plant and harvest index (Yadav, 1992). Chaudhary, M and Motiramani, N.K (2003) said that broad-sense heritability was very high for all characters, except harvest index. Mani, S.C *et al.*, (1997 observed that high estimate of heritability coupled with high genetic advance for number of filled grains/panicle suggested the predominance of additive gene action for this character. Saravanan, R and Senthil, N (1997) said that high heritability estimates were observed for productive tillers/plant Mishra, D *et al.*, (1996) estimates high heritability for all characters of hybrid rice except number of tillers per plant, panicle length and number of chaffs per panicle. Number of tillers per plant and number of grains per panicle exhibited positively high significant correlation with yield. High genotypic co-efficient of variation and broad sense heritability with respect to biological yield in rice has been reported by Vinaya Rai and Murty (1979).

5.4 Mean performance

The discussions on mean performance of yield and yield components of the hybrids and check varieties have been presented here under (Table 4).

5.4.1 Grain yield per plant (g)

The performance of any hybrid or variety is finally estimated on the basis of the grain yield. Among the hybrids, grain yield/plant ranged from 42.88 g in Richer to 47.87 g in Aloron, with a mean of 45.10. Whereas, the range of the checks varied from 30.45 g (BRRI dhan 28) to 36.87 g (BRRI dhan 29), with a mean of 33.66. Among all the genotypes grain yield/plant ranged from 30.45 g (BRRI dhan 28) to 47.87 g (Aloron), with a grand mean value of 42.24. The group of high grain yield/plant was constituted by the genotypes of Jagoron (46.22 g), Sonarbangla 1 (46.47 g) and Aloron (47.87g). The genotype BRRI dhan 28 (30.45 g) and BRRI dhan 29 (36.87g) constituted the group with low grain yield/plant (Table 4). Diagrammatic representation of grain yield/ha and per plant has been made in Fig 8. In the present study, it is summarised that, all the hybrids were superior then their corresponding checks. Oka, M and Saito, Y (1999) experimented that among F_1 hybrids from crosses of rice cv. Sasanishiki. The hybrid MH2005 gave a yield of 6.09 t/ha. Geetha, S *et al.,* (1994) studied that six hybrids were studied for grain characters. Hybrid ADRH4 was the highest yielding (19.7 g/plant) due to a higher number of grains per plant. Sitaramaiah *et al.,* (1998) observed that high yielding hybrids had higher biomass and harvest index. In the present study, all the hybrids show higher grain yield (40.88 to 48.87 g per plant) than the checks (29.45 to 37.87 g per plant).

5.4.2 Grain yield per plot (kg)

Among the hybrids, grain yield/plot ranged from 3.69 in BRRI hybrid 1 to 4.47 in Aloron, with a mean of 4.01. Whereas, the range of the checks varied from 2.89 in BRRI dhan 28 to 3.58 in BRRI dhan 29, with a mean of 3.23.

Table 4. Mean performances of hybrids and checks for yield related characters

Sl No	**Variety**	**GY/p**	**GY/pl**	**GY/h (t)**
1	Sonarbangla 1	46.47	4.35	7.25
2	Jagoron	46.22	3.99	6.66
3	Hira	42.90	3.72	6.20
4	Aloron	47.87	4.47	7.45
5	BRRI hybrid 1	44.30	3.69	6.15
6	Richer	42.88	3.87	6.48
Mean		45.10	4.01	6.70
7	BRRI dhan 28 (check)	30.45	2.89	4.83
8	BRRI dhan 29 (check)	36.87	3.58	5.97
Mean		33.66	3.23	5.40
Grand mean		42.24	3.82	6.37
SEd		1.38	0.02	0.05
CV%		4.00	0.97	1.03
CD%		2.96	0.05	0.10

GY/pl=Grain yield/plot, GY/h=Grain yield/ha. GY/p=Grain yield/plant, Among all the genotypes grain yield/ha ranged from 2.89 BRRI dhan 28 to 4.47 Aloron with a grand mean value of 3.82. The group of high grain yield/plot was constituted by the genotypes of Jagoron (3.99), Sonarbangla 1 (4.35) and Aloron (4.47). The genotypes BRRI dhan 28, 2.89 and BRRI dhan 29, 3.58 constituted the group with low grain yield/plot (Table 4). Diagrammatic representation of grain yield/plot has been made in Fig 9. In present study, the variety Aloron was superior to all.

5.4.3 Grain yield/ha (t)

The performance of any hybrid or variety is finally estimated on the basis of the grain yield. Among the hybrids, grain yield/ha ranged from 6.2 in Hira to 7.4 in Aloron with a mean of 6.70. Whereas, the range of the checks varied from 4.8 BRRI dhan 28to 6.0 BRRI dhan 29 with a mean of 5.40. Among all the genotypes grain yield/ha ranged from 4.8 BRRI dhan 28 to 7.4 Aloron, with a grand mean value of 6.37. The group of high grain yield/ha was constituted by the genotypes of Jagoron, 6.7, Sonarbangla 1, 7.3 and Aloron, 7.4 respectively. The genotypes BRRI dhan 28, 4.8 and BRRI dhan 29, 5.97 constituted the group with low grain yield/ha (Table 4). Diagrammatic representation of grain yield/ha and per plant has been made in Fig 9. In present study, the variety Aloron was superior to all.

6.1 Yield advantages over checks (%) at plot basis

Based on LSD test of mean yield per plot, all the hybrids and the checks were given ranking Table 5. The means having a common letters are non significant at 5% level of significance and were ranked into same group. The ranged for grain yield per plot for hybrids from 3.690 kg in BRRI hybrid 1 to 4.470 kg in Aloron with a mean of 4.01kg per plot. Among the checks, BRRI dhan 28 showed least yield (2.894 kg) and BRRI dhan 29 showed highest yield (3.583 kg) per plot, with a mean yield of 3.23 kg per plot.

Table 5. Yield performance of selected hybrids and check varieties at plot basis

Sl. No	Name of hybrids	Mean yield/plot (kg) (3m x 2m = $6m^2$)	Yield (kg/ha)	Yield advantage over checks (%)	
				BRRI dhan 29	BRRI dhan 28
1	Aloron	4.470	7450.00	24.75*	54.45*
2	Sonarbangla – 1	4.352	7255.00	21.46*	50.38*
3	Jagoron	3.998	6666.60	11.58*	38.14*
4	Richer	3.876	6480.00	8.177*	33.93*
5	Hira	3.720	6200.00	3.82*	28.54*
6	BRRI hybrid 1	3.690	6154.40	2.92*	27.50*
Mean		4.017	6701.01	-	-
Checks					
7	BRRI dhan 29	3.583	5973.66	00.00	-19.22*
8	BRRI dhan 28	2.894	4832.33	23.80*	00.00
Mean		3.238	5402.99		
Grand mean	6376.00				
Me		0.001	-	-	-
SEd±		0.025	-	-	-
CV (%)		0.974	-	-	-
CD (%)		0.1108	-	-	-

* Significant at 5% level,

Me = Error mean sum of square

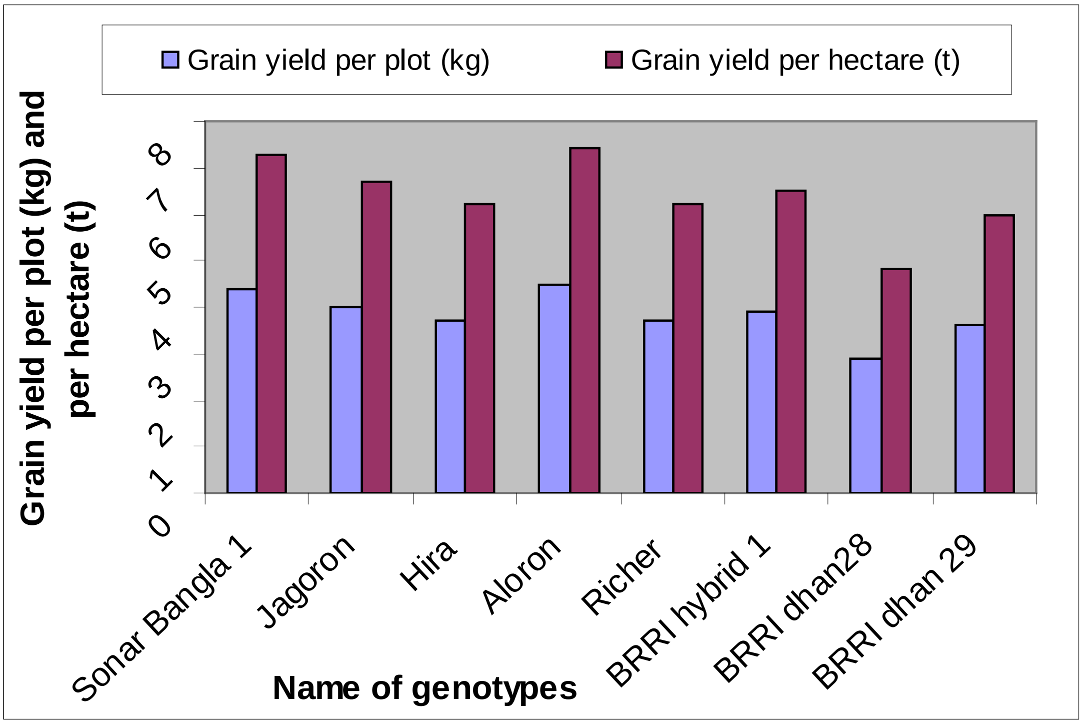

Figure 9. Relative performance of hybrids and checks for grain yield/plot (kg) and grain yield/hectare (t)

The high performing groups were Aloron (4.470 kg) and Sonarbangla 1 (4.352 kg), but there were no significant difference between them. The groups of hybrids that showed lower yield per plot were BRRI hybrid 1 (3.690 kg) and Hira (3.720 kg) but inspite of their lower yield, the entire lower group showed higher yield per plot then all the checks. The yield per hectare for hybrids ranged from 6050 kg (BRRI hybrid 1) to 7500 kg (Aloron), with a mean of 6681.66 kg. The yield advantage for hybrids over checks ranged from 2.98% (BRRI hybrid 1) to 24.75% (Aloron) over (BRRI dhan 29) and 27.50 (BRRI hybrid 1) to 54.45% (Aloron) over BRRI dhan 28 and 2.98% (BRRI hybrid 1) to 27.50 %(BRRI hybrid 1) showed lowest yield advantage and Aloron showed highest yield advantage over both the checks 24.75%, Aloron 27.50to 54.45%. For this trait all the hybrids showed highly significant positive yield advantage over the checks except BRRI hybrid 1 (2.98%) which showed simple significant positive yield advantage incase of check BRRI dhan 29. A comparative performance of yield advantage over the checks and grain yield/kg per plot has been graphically presented in Fig 10 and in Table 5. The present range of yield advantage is fairly higher than the earlier reports. Yuan *et al.* (1989) reported that *indica* hybrids showing yield increases of 38.46% against an improved inbred variety in Jiangsu province of China. Yuan (1990) further reported that an experimental *indica/japonica* hybrid gave a yield advantage of 47% against an indica/indica hybrid V-You-6. Peng (1994) found that hybrids developed from *indica/japonica* derived lines in Sichuan, China yielded 18.8-24% more than the best inbreds with a maximum yield of 11.7 t/ha. Mishra (2003) reported 18% to 44.9% yield advantage of 17 released indica hybrids over standard checks from on farm evaluation experiment in India.

6.2 Maturity group wise per day productivity

It is important to know the duration of maturity along with duration wise yield potential of newly identified any rice hybrids of varieties for acceptance by farmers for suitability to cropping pattern of the target region.

Generally, it is believed that short duration for varieties are low yielding and only along duration varies give high yield in view of varies report strong correlation between crop duration and yield (Deng, Y. 1980; Lin and Yuan, 1980; Tian *et al.*, 1980; Wu *et al.*, 1980; Gomathinayagam *et al.*, 1988; Chandra *et al.*, 1992; Yadav, 1992; Kadoo, 1997). Based on days to maturity, collected six hybrids are classified into different maturity group (table 6.). Of all the hybrids, 3 hybrids (Sonarbangla 1, Jagoron, and Hira) into medium early, 2 hybrids (Aloron and Richer) into medium and only 1 hybrids (BRRI hybrid 1) into late duration type. Among the checks, 1 variety (BRRI dhan 28) was placed into medium early group and 1 variety (BRRI dhan 29) was grouped with late duration group. The productivity per day was calibered individually as well as group. The medium early group hybrid had per day productivity of 55.00 kg/ha with a ranged from 49.60 kg/ha to 61.22 kg/ha. In case of medium duration group hybrid per day productivity was 51.59 kg/ha ranging from 48.00 kg to 55.18 kg/ha. The late maturing group included only 1 hybrid which had per day productivity of 41.30 kg/ha. The checks BRRI dhan 28 and BRRI dhan 29 showed per dayproductivity to be 39.28 kg/ha and 40.02 kg/ha, respectively being in medium early maturity group and late in respective order. It is interestingly to note that medium group and medium early maturing group hybrids have same level of per day productivity. The range of per day productivity within the group is more or less similar in both maturity groups. The level seems to be high in medium group as compared to medium early and late maturity group has shown per day productivity (61.22kg/ha) as high of the best hybrid (Sonarbangla 1) of the medium group. This suggests that the hybrids of medium duration group are likely to be much superior to hybrids of early and medium early maturity group. A comparative study of maturity of hybrids with their per day productivity was shown in Table 6and Fig 11.

Table 6. Classification of hybrids on the basis of days to maturity and their per day productivity

Classification of hybrids on the basis of duration					
Medium early (116 – 130 days)		Medium (135 – 145 days)		Late (more than 145 days)	
Name of hybrids	Per day productivity	Name of hybrids	Per day productivity	Name of hybrids	Per day productivity
Sonarbangla 1	61.22	Aloron	55.18	BRRI hybrid 1	41.30
Jagoron	54.20	Richer	48.00		
Hira	49.60				
Mean	55.00		51.59		
Checks					
BRRI dhan 28	39.28			BRRI dhan 29	40.02

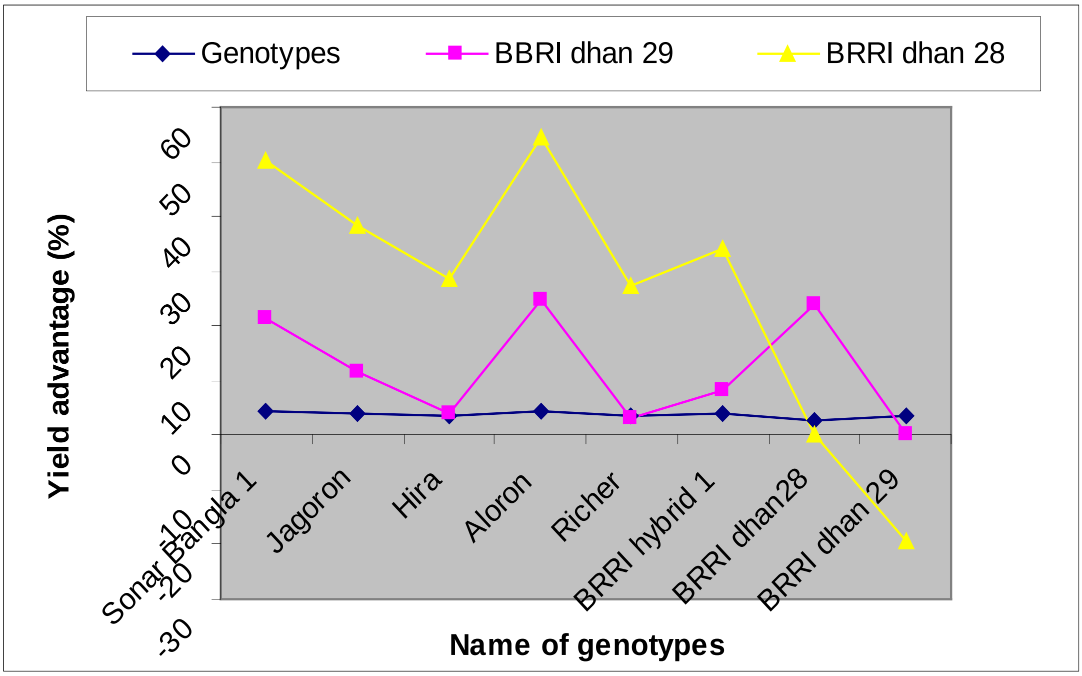

Figure 10. Yield advantage (%) of different hybrids over checks

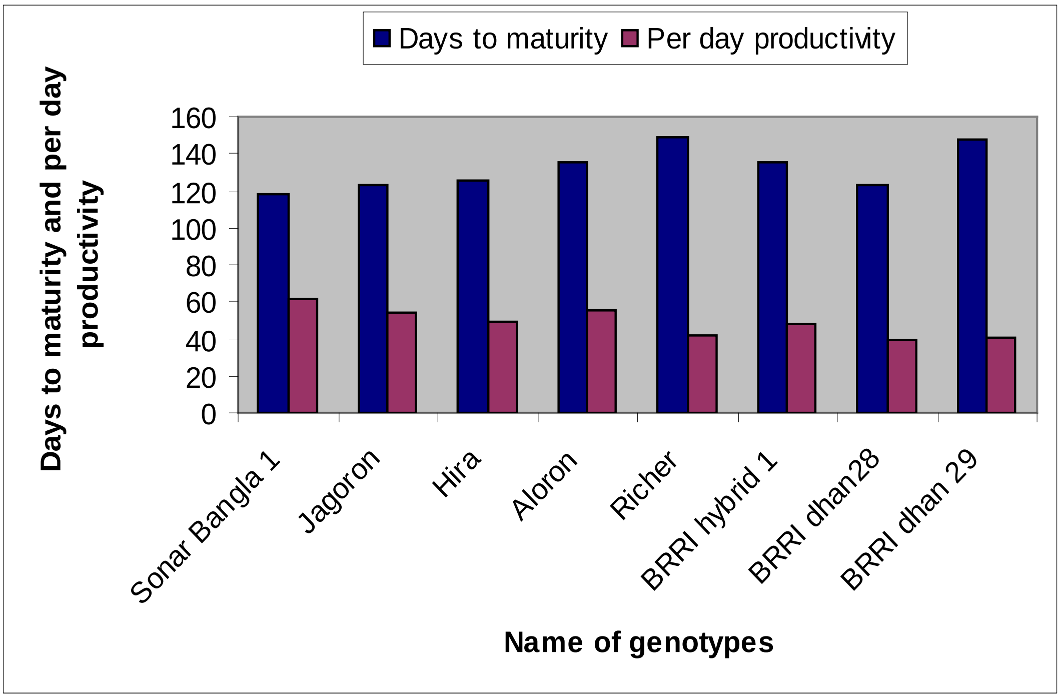

Figure 11. Relative studies of maturity group wise per day productivity of hybrids and checks

This suggests the possibility of identifying hybrid in medium group, breaking the positive correlation between long duration and yield. Similar observations of combining high yield and early maturity in rice hybrids were noted earlier by Virmani, (1999). Medium early duration hybrids (Aloron) also showed nearly same level of per day productivity (55.18kg/ha) as it is in medium groups. The level of maturity group is much higher than any other group.

6.3 Correlation analysis

The relationship between grain yield, biological yield, harvest index, plant height, panicle length, no. of filled and unfilled spikelets etc are varied from variety to variety. As revealed by table 7. the results of association between pairs of yield components among the hybrids revealed that plant height had highly significant positive correlation with total grain per panicle (0.592), grain yield per plant (0.544), harvest index (0.622), grain yield per plot (0.539), grain yield per square meter (0.539), grain yield per hectare (0.539) and significant positive correlation with unfilled grain per panicle (0.487), filled grain per panicle (0.431), biological yield per plant (0.462). On the other hand a significant negative correlation with 1000-grain weight (-0.448). Negative association betweevn plant height and grain yield has been reported by Amirthadevarathinam (1983) and Sukanya and Rathinam (1986) while in contrast several workers reported positive correlation between plant height and grain yield (Chauhan *et al.,* 1986, Janagale *et al.,* 1987 and Gomathinayagam *et al.,* 1988). In the present study grain yield is significantly correlated with plant height. Haque *et al.,* (1991) reported positive association of plant height with yield per plant but negative association with panicle per plant in modern varieties. Ganesan, K. N (2001) reported that plant height, days to flowering, number of tillers/plant, and productive tillers/plant had both positive and negative indirect effects on yield.

Table 7. Estimates of simple correlation coefficients for yield and yield components in hybrids and checks

Variables	Plant Height	Days to 50% flowering	No of effective tillers/plant	Days to maturity	Panicle length	Filled grain/panicle	Total grain/panicle	Grain yield/plant	Biological yield	Harvest index	1000 grain weight	Grain yield/plot	Grain yield/ha
Plant Height	-												
Days to 50% flowering	.252	-											
No of effective tillers/plant	.127	-.089	-										
Days to maturity	.370	.344	.180	-									
Panicle length	-.251	.237	.090	.223	-								
Filled grain/panicle	.431(*)	-.038	-.056	.385	-.148	-							
Total grain/panicle	.592(**)	.335	-.009	.694(**)	-.014	.811(**)	-						
Grain yield/plant	-.544(**)	.105	-.148	-.056	.523(**)	-.133	-.058	-					
Biological yield	.462(*)	.265	.139	.825(**)	.273	.504(*)	.674(**)	-.112	-				
Harvest index	-.622(**)	-.139	-.362	-.098	.471(*)	-.101	-.213	.780(**)	-.084	-			
1000 grain weight	-.448(*)	.232	-.087	-.141	.526(**)	-.205	-.143	.894(**)	-.139	.624(**)	-		
Grain yield/plot	-.539(**)	-.048	-.237	-.096	.532(**)	-.118	-.128	.896(**)	-.064	.862(**)	.771(**)	-	
Grain yield/ha	-.539(**)	-.048	-.237	-.096	.532(**)	-.118	-.128	.896(**)	-.064	.862(**)	.771(**)	1.000(**)	-
Grain yield/m^2	-.539(**)	-.048	-.237	-.096	.532(**)	-.118	-.128	.896(**)	-.064	.862(**)	.771(**)	1.000(**)	1.000(**)

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

Cristo, E *et al.,* (2000) observed that highest correlation was between the final height and panicle length, and full grains per panicle and yield. Oka, M and Saito, Y (1999) experimented that among F_1 there were relationships plant height; panicle length and number of grains/panicle were higher in the hybrid MH2005. Sathya, A *et al.,* (1999) utilized 24 hybrids and 11 parents. Plant height, productive tillers per plant, and harvest index are the principal character, which is responsible for grain yield per plant as they had also positive and significant association with yield. Saha, R *et al.,* (1993). Marekar, R.V and Siddiqui, M.A (1996) said that a positive and significant correlation were observed between yield per plot and plant height, length of panicle, days to maturity and 1000-grain weight. Padmavathi, N *et al.,* (1996) stated that high positive direct effects of plant height, number of panicles/plant and panicle length on grain yield. Choudhury and Das (1997) observed similar significant positive correlation for days to maturity, days to 50% flowering, plant height, grains per panicle and panicle length with yield. Paul and Sarmah (1997) also noted that yield was positively correlated with days to maturity, plant height and filled grains/panicle.

Days to 50% flowering was found to have highly significant and positive correlation with unfilled grain per panicle (0.614) showed Table 7. Most Scientists said that days to 50% flowering has direct and indirect effect on yield, grains/panicle and also tillering height. Ganesan, K. N (2001) said that plant height, days to flowering, number of tillers/plant, and productive tillers/plant had both positive and negative indirect effects on yield. Sathya, A *et al.,* (1999) studied 24 hybrids and 11 parents. Days to 50% flowering was the principal character responsible for grain yield per plant followed by 1000-grain weight, plant height and harvest index as they had positive and significant association with yield.

Days to maturity showed highly significant and possible correlation with unfilled grain per panicle (0.715), total grain per panicle (0.694) and with biological yield per plant (0.825) in Table 7.

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

In case of panicle length, highly positive correlation was observed with grain yield per plant (0.523), 1000-grain weight (0.526), and grain yield per plot (0.532), grain yield per square meter (0.532) and grain yield per hectare (0.532). A significant positive correlation with harvest index (0.471) in Table 7. Sukanya and Rathinam (1986) reported negative correlation between panicle length and grain yield. Ganesan, K. N (2001) conducted that panicle length (0.167) had the highest significant positive direct effect on yield/plant followed by number of tillers/plant (0.688), panicle exsertion (0.172), and plant height (0.149). Cristo, E *et al.,* (2000) observed that highest correlation was between the final height and panicle length, and full grains per panicle and yield. Marekar, R.V and Siddiqui, M.A (1996) concluded that positive and significant correlations were observed between yield per plot and plant height, length of panicle, days to maturity, 1000-grain weight, length of grain and L/B ratio. Sawant, D.S *et al.,* (1995) concluded that panicle length was negatively correlated with flowering time and positively correlated with tiller height. Padmavathi, N *et al.,* (1996) concluded that number of tillers/plant, number of panicles/plant, panicle length and 1000-grain weight was positively associated with grain yield. Ganapathy, S *et al.,* (1994) reported that the number of productive tillers per hill, panicle length and grains/panicle had a significant and positive association with grain yield. Ramalingam, J *et al.,* (1994) concluded that varieties with long panicles, a greater number of filled grains and more primary rachis would be suitable for selection because these characters have high positive association with grain yield and are correlated among themselves. Zhang, Q *et al.,* (2005) indicates that the panicles length had a positive correlation with the yield; while the spikelets per panicle had negative correlation with the yield. Laza, M.R.C *et al.,* (2004) measured yield-related traits, panicle size had the most consistent and closest positive correlation with grain yield.

Grain yield per plant had highly significant positive correlation with plant height (0.544), panicle length (0.523), 1000-grain weight (0.894), harvest index (0.780), grain yield per plot (0.896), and grain yield per square meter (0.896) and with grain yield per hectare (0.896). Similarly, grain yield per plot had highly significant positive correlation with plant height (0.539), panicle length (0.532), grain yield per plant (0.896), harvest index (0.862), 1000-grain weight (0.771) and with grain yield per square meter (1.000).

Also grain yield per hectare had highly significant positive correlation with plant height (0.539), panicle length 0.532), grain yield per plant (0.896), harvest index (0.862) in Table 7. Yamaguchi *et al.,* (1985) did not find positive correlation between grain yield and harvest index. A significant positive correlation with grain yield and biological yield have been reported by Siddiq and Reddy (1984), Ganesan and Subramaniam (1990). A no. of workers has reported positive association between grain yield and this trait (Chauhan *et al.,* 1986, Janagale *et al.,* 1987 and Jagdish, 1987). Ganesan, K. N (2001) concluded that grains/plant had the least significant positive direct effect on number of tillers/plant (0.688), panicle exsertion (0.172), panicle length (0.167) and plant height (0.149). Geetha, S *et al.,* (1994) studied that six hybrids were studied for grain characters. Correlation analysis revealed that only grains per plant had a strong positive association with grain yield. Dhananjaya, M.V *et al.,* (1998) evaluated that grain yield was positively correlated with harvest index, panicle density, number of fertile spikelets, 1000-grain weight, number of productive tillers and plant height. Chauhan, J.S *et al.,* (1999) said that grain yield was positively associated with dry matter at 50% flowering, biological yield and harvest index. Leaf area index, dry matter accumulation of 50% flowering, biological yield and harvest index seemed to be important in improving grain yield. Paul, S.K and Sarmah, A.K (1997) said that yield was negatively correlated with false grains/panicle days to maturity, plant height and filled grains/panicle.

Ashvani, P *et al.,* (1997) examined that grain yield/plant showed significant and positive correlation at genotypic and phenotypic levels with number of effective tillers/plant, grain yield/panicle, 1000 grain weight and total biological yield/plant. Ganapathy, S *et al.,* (1994) concluded that the number of productive tillers per hill, panicle length and grains/panicle had a significant and positive association with grain yield. Mahajan, C.R (1993) indicated that grain yield/plant was positively and significantly correlated with straw yield/plant and filled grains/panicle. Chaudhary, M and Motiramani, N.K (2003) reported that grain yield per plant showed significant positive correlation with effective tillers per plant, spikelets density and biological yield per plant. Almost all characters exhibited high heritability coupled with high genetic advance, except harvest index.

For filled grains per panicle a highly significant positive correlation with total grains per panicle (0.811), no. of filled spikelets per panicle (0.523) and had a positive correlation with biological yield per plant (0.504). On the other hand for unfilled grain per panicle, a highly positive significant correlation with plant height (0.487), days to 50% flowering (0.614), days to maturity (0.715), total grains per panicle (0.716), no. of filled spikelets per panicle (0.515) and biological yield per plant (0.536) in Table 7. Ganesan, K. N (2001) conducted that filled grains/panicle (0.895) had the highest significant positive direct effect on yield/plant followed by number of tillers/plant (0.688) panicle length (0.167) and plant height (0.149) showed in Table 7. Cristo, E *et al.,* (2000) observed the highest correlation between full grains per panicle, final height and panicle length and yield. There were associations between rice hybrids and their parents. Oka, M and Saito, Y (1999) experimented that among F_1 hybrids from crosses of rice cv. Sasanishiki with other cultivars there were relationships with parental values for grain number/panicle, panicle length, and panicle emergence date. Dhananjaya, M.V *et al.,* (1998) evaluated some 121 rice genotypes. Grain yield was positively correlated with number of filled grain/panicle, harvest index, panicle density, 1000-grain weight, number of productive tillers and plant height.

Liu, J.F *et al.,* (1997) evaluated 24 indica x japonica hybrids where, filled grain/panicle was positively correlated with GWP. Padmavathi, N *et al.,* (1996) concluded that number of filled grains/panicle, plant height 1000-grain weight, dry matter production, spikelets sterility, days to 50% flowering had positive direct effects on grain yield. Lin, T.F (1995) studied that the percentage of filled grains/panicle was the most important factor affecting grain yield. Ganapathy, S *et al.,* (1994) evaluated that the number of filled grains/panicle, productive tillers per hill, panicle length had a significant and positive association with grain yield. Ramalingam, J *et al.,* (1994) observed that varieties with long panicles, a greater number of filled grains/panicle and more primary rachis would be suitable for selection because these characters have high positive association with grain yield. Mahajan, C.R (1993) indicated that filled grains/panicle, grain yield/plant was positively and significantly correlated with straw yield/plant. Geetha, S (1993) indicated that number of ear-bearing tillers, filled grain/per panicle, percentage filled grain, and test weight, straw yield and harvest index were all correlated positively with grain yield. Liu, J.F and Yuan, L.P (2002) studied the relationships between high-yielding potential and yielding traits. Filled grains per panicle was positively correlated with biomass, harvest index and grain weight per plant Yuan, J.C *et al.,* (2005) the variation in fertile grain percentage/panicle in indica was greater than that in japonica. Chaudhary, M and Motiramani, N.K (2003) said that filled grain per panicle showed significant positive correlation with effective tillers per plant, spikelets density and biological yield per plant.

Total grains per panicle had a highly significant positive correlation with plant height (0.592), days to maturity (0.694), unfilled grains per panicle (0.716), no. of filled grains per panicle (0.811), and no. of filled spikelets per panicle (0.682) and with biological yield per plant (0.674) in Table 7. Dhananjaya, M.V *et al.,* (1998) most variation was observed for productive tillers/plant, number of fertile spikelets and total grain yield/plant. Grain yield was positively correlated with harvest index, panicle density, number of fertile spikelets, 1000-grain weight, number of grains and plant height.

Mishra, D *et al.,* (1996) observed that number of tillers per hill and total number of grains per panicle exhibited positively high significant correlation with yield. Ganapathy, S *et al.,* (1994) concluded that the number of productive tillers per hill, panicle length and grains/panicle had a significant and positive association with grain yield. Sarkar, K.K *et al.,* (2005) studied the number of grains/panicle was negatively associated with number of panicle. According to Zhang, Q *et al.,* (2005) the grain/ panicles had a positive correlation with the yield; while the spikelets per panicle had negative correlation with the yield.

Biological yield per plant had highly significant positive correlation with plant height (0.462), days to maturity (0.825), unfilled grain per panicle (0.536), filled grain per panicle (0.504), and total grain per panicle (0.674) and with no. of filled spikelets per panicle (0.480) in Table 7. Sharma *et al.,* (1986) observed that two major yield components, biological yield and harvest index show positive correlation with yield, while biological yield and harvest index are negatively correlated. Similar type of association has been observed in the present study. However, Singh (1998) under similar situation in cotton has reported that the negative correlation of boll no. with boll weight and biomass with harvest index could be changed to positive by selective intermating among segregants of a selected cross combination. Peng, S *et al.,* (2000) concluded that the increasing trend in yield of cultivars due to the improvement in harvest index (HI), while an increase in total biomass was associated with yield trends for cultivars-lines. Similarly positive significant correlation between biological yields has also been reported by no. of workers in rice (Siddiq and Reddy, 1984; Malik *et al.,* 1988; Ganesan and Subramaniam, 1990). Kim and Rutger (1988) noted that hybrids that gave high grain yields also produced high biomass. Whereas, conventional rice has more in late growth stages. Geetha, S (1993) indicated that straw yield and harvest index were all correlated positively with grain yield.

Harvest index had highly significant positive correlation with plant height (0.622) and with panicle length (0.471) in Table 7.

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. Kiniry, J. R *et al.,* (2001) concluded that parameters describing processes of crop growth and yield production. Yield differences among cultivars were due to HI differences. Peng, S *et al.,* (2000) concluded that the increasing trend in yield of cultivars mainly due to the improvement in harvest index (HI). Sathya, A *et al.,* (1999) stated that productive tillers per plant was the principal character responsible for grain yield per plant followed by 100-grain weight, days to 50% flowering, plant height and harvest index as they had positive and significant association with yield. Geetha, S (1993) indicated that number of ear-bearing tillers, filled spikelets per panicle, percentage filled spikelets, and test weight, straw yield and harvest index were all correlated positively with grain yield. Lin and Xu. (1981) concluded that harvest index has strong positive direct effect on grain yield. In the present study while most of the hybrids show strong positive relationship between grain yield and harvest index. Other workers (Sahu and Murty, 1976; Vinaya Rai and Murty, 1979 and Sukanya and Rathinam, 1986) have also reported significant positive association between grain yield and harvest index.

1000-grain weight had highly significant positive correlation with panicle length (0.526), grain yield per plant (0.894), harvest index (0.624), grain yield per plot (0.771), and grain yield per square meter (0.771) and with grain yield per hectare (0.771) showed in Table 7. A significant negative correlation with plant height (-0.448). Sukanya and Rathinam (1986) and Vijayakumar *et al.,* (1997) reported high correlation between 1000-grain weight and grain yield per plant. Kim and Rutger (1988) observed positive yield predominantly in 1000-grain weight and no. of spikelets per plant. They also observed high correlation between 1000-grain weight and grain yield. Kumar *et al.,* (1994) stated that grain weight and filled grain ratio were not significant. They noted that grain weight was highly correlated to grain size.

Sathya, A *et al.,* (1999) reported that 1000-grain weight, days to 50% flowering, plant height and harvest index as they had positive and significant association with yield. Iftekharuddaula, K. M. *et al.,* (2001) said that days to flowering, days to maturity, and grains per panicle, 1000-grain weight and harvest index showed significant positive correlations with grain yield. Ashvani, P *et al.,* (1997) stated that 1000 grain weight and total biological yield/plant may be considered for further improvement of rice. Marekar, R.V and Siddiqui, M.A (1996) observed that positive and significant correlations between yield per plot and plant height, length of panicle, days to maturity, 1000-grain weight, length of grain and L/B ratio. Padmavathi, N *et al.,* (1996) concluded that number of tillers/plant, number of panicles/plant, panicle length and 1000-grain weight was positively associated with grain yield.

In the present study a significant correlation between effective tiller no. and grain yield and highly significant negative correlation between HI and effective tiller no. is observed. Positive correlation between grain no. per panicle and grain yield has been reported by no. of workers (Chauhan *et al.,* 1986, Janagale *et al.,* 1987 and Kalaimani and Kadambavansundaram, 1988). Interestingly it is observed in the present study that no. of filled spikelets, total no. of spikelets show positive but non-significant correlation. Kadoo (2002) also observed similar weak correlation among these traits. Thus the following traits viz. biological yield, panicle length, days to 50% flowering, days to maturity and plant height seem to be directly correlated with grain yield of hybrids. Sardana *et al.,* (1989) also observed similar results and they concluded that panicle length, days to 50% flowering, days to maturity and plant height were the most important characters contributing to yield. Where as many traits namely total tiller no., effective tiller no., no. of filled spikelets, total no. of spikelets, 1000 grain weight and harvest index show indirect correlation being associated with traits directly correlated with yield.

SUMMARY AND CONCLUSION

Five varieties of hybrid rice collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI) were used for this experiment. Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid 1 and two checks are BRRI dhan 28 and BRRI dhan 29. The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. The genotypes were randomly assigned to each plot within each replication. The out come of the investigations is summarized as under:

In the experiment plant height for BRRI dhan 28 was 101.5 cm. and lowest for Richer (82.5 cm). For days to 50% flowering BRRI dhan 29 required maximum days (116.3 days) and BRRI dhan 28 required lowest days (95 days). For number of effective tillers, Hira showed maximum performance (17.7) and Sonarbangla showed lowest performance (13.3). For days to maturity, Sonarbanglr required lowest days (118 days) and BRRI dhan 29, highest days (148 days). In panicle length status, Richer showed maximum performance (27.7 cm) and for BRRI dhan 28 was the lowest (26 cm). Number of filled grains was the highest for BRRI dhan 29 (163.3) whereas, Jagoron only 118. Number of total grains was highest in BRRI dhan 29 (201.7) and for Jagoron it was only 133.7. On the other hand, for 1000-grain weight, Aloron was the best than other hybrids. In biological yield (g), BRRI dhan showed highest yield (49.6 g) and Hira only 18 g. For harvest index, Jagoron was the best (64%) and for BRRI dhan 28 only 38%. For grain yield/plant Aloron expressed highest performance (47.87 g), whereas, BRRI dhan 28 it was only 30.45 g. In case of, grain yield/plot, Aloron was the best than others. For grain yield/ha, Aloron was the best (7.4 t) than others.

In yield advantage for plot basis also Aloron was the best (54.45%) over BRRI dhan 27 and 24.75% over BRRI dhan 29, respectively. Maturity was also earlier for Aloron than others. Therefore, Aloron may be considered as earlier variety for cultivation. Analysis of variance revealed highly significant variation present among the hybrids and checks for all the characters studied. Existing of significant level of variation present in the materials indicate the possibility of improving the yield potential. Heritability was high for days to maturity (99.93%). The maximum variation was found in biological yield per plant (12-81 g). In correlation analysis a highly significant positive association were found for plant height, days to maturity, days to 50% flowering, panicle length and filled grains per panicle. All the six hybrids were superior to best yielding checks. Hybrid Aloron was highest in mean performance with respect to grain yield, harvest index, 1000-grain weight and panicle length. The selected hybrids were of medium early to medium maturity period and had semi dwarf to tall plant stature. All the hybrids showed higher grain yield per hectare (6.15 to 7.45 t/ha) than all the checks (4.83 to 5.97 t/ha) on plot harvest basis. The yield advantage of hybrids over BRRI dhan 29 ranged from 2.98% to24.75% over BRRI dhan 28 ranged from27.50% to 54.45% on plot harvest basis.In general biological yield per plant had highly significant positive correlation with plant height, days to maturity, filled grain per panicle, and total number of grains per panicle. Grain yield per plant had highly significant positive correlation with plant height, panicle length, 1000-grain weight, harvest index, grain yield per plot, grain yield per square meter and with grain yield per hectare. Considering varietal characters and yield performance, the variety Aloron was the best than the respective commercial variety under the study and will be cultivate for higher yield. So, more or less the genotypes Aloron will be recommended for future.

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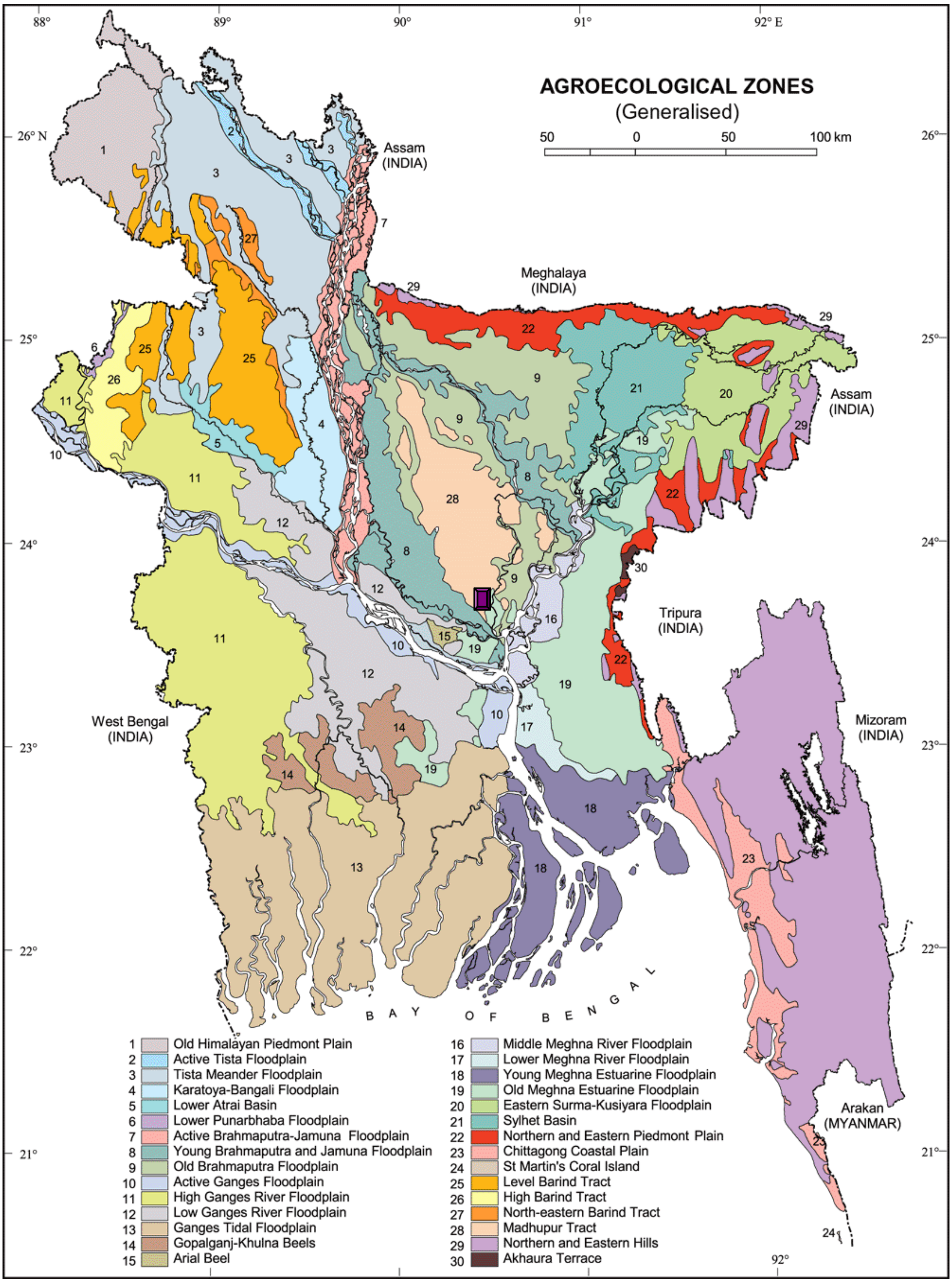
APPENDICES

Appendix i. Ranking wise grouping of the hybrids based on yield performance with range of mean

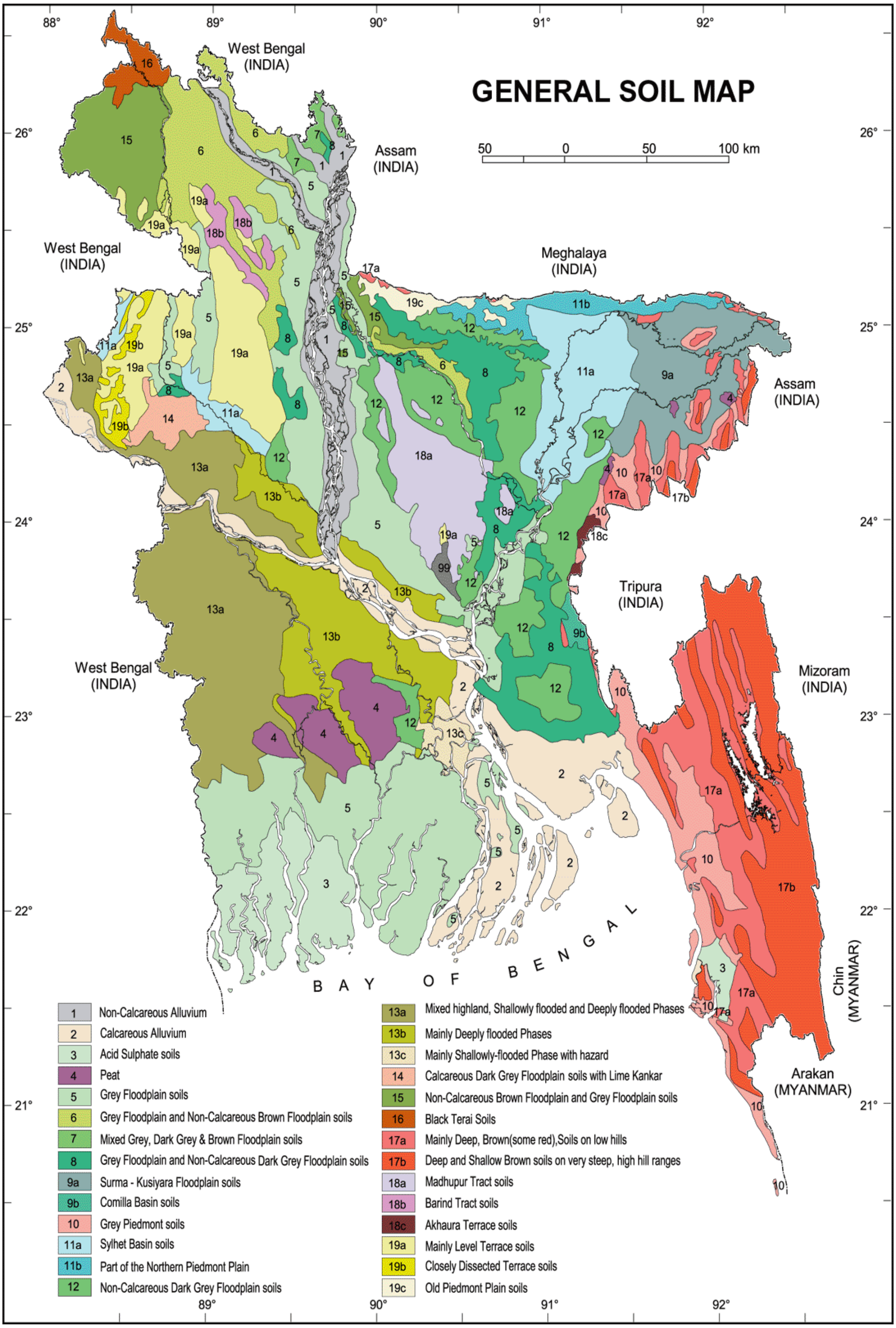
Rank	Name of hybrids basis of range of mean yield	Mean of yield/plant
Rank – I	Aloron	47.87
Rank – II	Sonarbangla – 1	46.47
Rank – III	Jagoron	46.22
Rank – IV	Richer	44.30
Rank – V	Hira	42.90
Rank – VI	BRRI hybrid 1	42.88
Rank – VII	BRRI Dhan 29	36.87
Rank - VIII	BRRI Dhan 28	30.45

Appendix ii. Map showing the experimental sites under study



■ The experimental site under study

Appendix iii. Map showing the general soil sites under study



Appendix iv. Morphological, physical and chemical characteristics of initial soil (0-15 cm depth)

Physical composition of the soil

Soil separates	%	Methods employed
Sand	26.90	Hydrometer method (Day, 1915)
Silt	45.40	Do
Clay	29.66	Do
Textural class	Silty-clay	Do

Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.87	Walkley and Black, 1947
2	Total N (kg/ha)	1792.00	Bremner and Mulvancy, 1965
3	Total S (ppm)	225.80	Bradsley and Lanester, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	53.00	Bremner, 1965
6	Available P (kg/ha)	69.00	Olsen and Dean, 1965
7	Exchangeable K (kg/ha)	90.50	Pratt, 1965
8	Available S (ppm)	16.59	Hunter, 1984
9	pH (1:2.5 soil to water)	5.55	Jackson, 1958
10	CEC	11.80	Chapman, 1965

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

Year	Month	Air temperature (^oC)			Relative humidity (%)	Rainfall (mm)	Sun shine (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- 1207