EVALUATION OF GROWTH AND YIELD OF HYBRID AND INBRED RICE VARIETIES GROWN IN BORO SEASON

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CERTIFICATE

This is to certify that thesis entitled, "**EVALUATION OF GROWTH AND YIELD OF HYBRID AND INBRED RICE VARIETIES GROWN IN BORO SEASON**" *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 (M.S.) in AGRONOMY****, embodies the result of a piece of bona-fide research work carried out by* ***FAIZ MUHAMMAD AL-NOMAN****, Registration no.* ***09-03303*** *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.

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EVALUATION OF GROWTH AND YIELD OF HYBRID AND INBRED RICE VARIETIES GROWN IN BORO SEASON [1]

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ABSTRACT

A field experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from January to June 2015 to find out the performance of some hybrid rice lines comparing with 2 inbreds and 2 hybrids as check varieties in boro season. The experiment comprised of 23 varieties viz. (i) BRRI dhan28, (ii) BRRI dhan29, (iii) ACI-1, (iv) Sampad, (v) Hybrid line-1, (vi) Hybrid line-2, (vii) Hybrid line-3, (viii) Hybrid line-4, (ix) Hybrid line-5, (x) Hybrid line-6, (xi) Hybrid line-7, (xii) Hybrid line-8, (xiii) Hybrid line-9, (xiv) Hybrid line-11, (xv)Hybrid line-12, (xvi)Hybrid line-13, (xvii) Hybrid line-14, (xviii) Hybrid line-15, (xix) Hybrid line-16, (xx) Hybrid line-17, (xxi) Hybrid line-18, (xxii) Hybrid line-19 and (xxiii) Hybrid line-20. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. At the time of harvest, the longest plant (106.25 cm) and the highest number of unfilled grains panicle^{-1} (54.80) were found in Sampad; highest number of total tillers hill^{-1} (17.78) and effective tillers hill^{-1} (16.93) were achieved by Hybrid line-5; highest dry mater weight hill^{-1} (84.77 g), highest number of total grains panicle^{-1} (214.00) and filled grains panicle^{-1} (184.67) were found in BRRI dhan29; longest panicle (27.85 cm) and highest weight of 1000-grains (30.64 g) were recorded in Hybrid line-11 and ACI-1, respectively. However, the highest grain yield (10.63 t ha^{-1}), straw yield (12.42 t ha^{-1}) and biological yield (23.05 t ha^{-1}) were found in Hybrid line-17. In the case of days to maturity, the hybrid lines took 142 days (Hybrid line-2, 9 and 16) to 160 days (Hybrid line-4, 5, 6, 7, 8, 13, 14 and 20). Contrarily to that, the check varieties took 160 days (BRRI dhan28, ACI-1 and Sampad) to 165 days (BRRI dhan29) to get matured. The hybrids matured 5 to 23 days earlier than the check varieties. In addition, Hybrid line-17 showed 36.79%, 22.40%, 22.91% and 30.65% yield advantages over BRRI dhan28, BRRI dhan29, ACI-1 and Sampad, respectively. As such, the Hybrid line-17 could safely be recommended for further trials at multi-locations in boro season of Bangladesh.

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LIST OF ABBREVIATIONS

AEZ	Agro-Ecological Zone
Anon.	Anonymous
AIS	Agriculture Information Service
BARC	Bangladesh Agricultural Research Council
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BNNC	Bangladesh National Nutrition Council
BRRI	Bangladesh Rice Research Institute
CRRI	Central Rice Research Institute
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAT	Days After Transplanting
DRR	Directorate of Rice Research
eds.	editors
et al.	et alii (And others)
etc.	et cetera (and other similar things)
FAO	Food and Agricultural Organization
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
IRRI	International Rice Research Institute
L.	Linnaeus
LSD	Least Significant Difference
i.e.	id est (that is)
MoP	Muriate of Potash

NPTs	New Plant Types
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TDM	Total Dry Matter
TSP	Triple Super Phosphate
UNDP	United Nations Development Programme
var.	Variety
viz.	namely

Chapter I

Introduction

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.), a cereal crop belongs to the family Poaceae. It is the most important crop of the tropical world. Rice is grown under an extremely wide range of environmental conditions, which growth depends on the surrounding climatic conditions. There are 111 rice-growing countries in the world that occupies about 146.5 million hectares of land of which over 90% are in Asia (Anon., 1999). Rice is the staple food for nearly half of the world's population as well as for 148.10 million people of Bangladesh (AIS, 2008). To feed the fast increasing global population, the world's annual rice production must be increased to 760 million tons by the year 2020 (Kundu and Ladha, 1995).

Agriculture in Bangladesh is characterized by intensive crop production mainly rice. Rice plays absolutely dominant role in Bangladesh agriculture as it covers 68.35% of total cropped area (AIS, 2014). Annual per capita consumption of rice in Bangladesh is the highest in the world (Nasiruddin, 1993). It provides about 70% of an average citizen's total calorie intake (BRRI, 2010). It contributes 76% of the caloric and 66% of the protein intake (BNNC, 2008). Rice accounted for nearly 18% of the national GDP (BRRI, 2010). It is, by far, the largest sectoral source of income, employment, savings and investment in the economy. The fluctuations in the productivity of rice influence the food security and to some extent ensure political stability of the country. However, Bangladesh needs to increase the rice yield further in order to meet the growing demand. The national commission of agriculture projected that in order to remain self-sufficient, Bangladesh will need to produce 47 million tons of paddy (31.6 million tons of clean rice) by the year 2020, implying a required rate of growth of production is 1.7% per year. An earlier agricultural research strategy prepared by the Bangladesh Agricultural Research Council (BARC) projected the required paddy production of 52 million tons (34.7 million tons of rice) by 2020, which would require a production growth of 2.2% per year (BARC, 2006).

In Bangladesh, food security has been and will remain a major concern because food requirement is increasing at an alarming rate due to increasing population. The average yield of rice is 2.86 t ha^{-1} (BBS, 2014); which is quite lower compared to that of many other rice growing countries like China, Japan, Korea and USA where yields are 6.23, 6.79, 6.59 and 7.04 t ha^{-1}, respectively (FAO, 2004). It is estimated that the population will gradually increase to 161 million in 2020 although the population growth rate will be much lower than that in 1991. During this time, the total rice area will shrink from 10.71 to 10.28 million ha and rice yield will be needed to increase from 2.74 tons to 3.74 tons per capita. Rice area will gradually shrink to only 0.149 acre in 2020 and the required rice $head^{-1}$ day^{-1} will be decreased from 528 g in 2001 to 463 g in 2020 due to the increase of population. This indicates a decreasing trend of daily requirement of rice.

There are three rice growing seasons which distinctly appeared almost all over in Bangladesh namely aus, aman and boro. The total yield of rice in aus, aman and boro season was 2.33, 13.19 and 19.01 million metric tons, respectively (BBS, 2014). To ensure the food security for the increasing population, the cropping area under rice cultivation could hardly be increased. Instead, some land should be released for other non-rice crops and farming practices. Therefore, it is an urgent need of time to increase rice production through increasing yield. At the same time, the yield of high yielding varieties has come to stagnation in spite of using relatively high inputs and standard agronomic management practices. So, it is deemed important to look for an alternative way to boost up the production. Proper practices are the most effective means for increasing yield of rice at farmer's level which can be achieved by using inbred and hybrid varieties (BBS, 2005). Scientists are quite optimistic to break the existing yield ceiling by introducing a new approach in rice production through the hybrid technology.

Hybrid rice has a 15–30% advantage in yield over modern inbred rice varieties or conventional pure line varieties (Peng *et al.*, 1999; Julfiquar *et al.*, 2002; Yuan *et al.*, 2005; Julfiquar, 2009) but does not frequently exhibit higher yield potential (Ying *et al.*, 1998; Peng *et al.*, 1999; Yang *et al.*, 2002; Horie *et al.*, 2003; Nayak *et al.*, 2003; Ao *et al.*, 2008; Abou Khalifa, 2009). Higher grain yield of hybrid rice is an intricate outcome of genotype and environment interaction. In China, hybrid rice grows well and produce higher yield than modern cultivar and attracts farmer's attention (Lin and Yuan, 1980). 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 4 million hectare rice area annually for the production of other high value crops (Ahmed *et al.*, 2001). Outside of China, India is the first country to develop and commercially exploit the hybrid technology and 17 hybrids have been released (Hossain, 2004). At present, there are 78 hybrid rice varieties have been released in India (DRD, 2015).

Nowadays, different hybrid and high yielding rice varieties are available in Bangladesh which has more yield potential than conventional high yielding varieties (Akbar, 2004). The hybrid varieties mostly cultivated in Bangladesh are imported from China by private seed companies and four hybrid varieties has developed by Bangladesh Rice Research Institute (BRRI) and those have good potentiality regarding yield. Few seed companies have imported hybrid seeds of different varieties, which are also cultivated in farmer's field. However, the expansion of hybrid rice and HYV rice area is not satisfactory mainly due to its higher seed cost. In addition, the farmers are confusing about the growth characteristics and genetical yield potential of these hybrids in comparison with locally cultivated high yielding varieties in Bangladesh.

So, it is essentially required to know the impact of different hybrid rice varieties and also to determine their adaptability in prevailing environments of Bangladesh. Under the above circumstances, the present experiment was undertaken with the following objectives:

OBJECTIVES:

1. To compare the growth, yield and yield attributes of hybrid lines grown in Boro season.
2. To identify candidate hybrid line (s) with improved yield potential over inbred ones as check varieties.

Chapter II

Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

The growth and development of rice are influenced due to varietal performance of different rice cultivars and management practices. It may also be influenced by inbred and hybrid varieties. Experimental results are available from home and abroad to reveal that rice cultivars with high yield potential may influence growth and yield to a great extent. Relevant reviews on the above aspects have been presented and discussed in this chapter.

2.1 Comparison and contrast of hybrid and inbred rice varieties on plant growth characters

Rice has a wide adaptability to different environmental condition as it is evident from its worldwide distribution. Yield of a rice cultivar is determined by different parameters such as plant height, effective tillers $hill^{-1}$, number of filled grain $panicle^{-1}$ and number of unfilled grains $panicle^{-1}$, 1000-grain weight, panicle length, total dry matter weight $hill^{-1}$ and harvest index as well as by environmental factors. The growth parameters like plant height, effective tillers $hill^{-1}$, total dry matter weight $hill^{-1}$ etc. are also important to determine yield potentiality. Some available information and literature related to the plant growth characters of hybrid and inbred rice cultivars are cited below:

2.2 Morphological attributes

2.2.1 Plant height

Mandavi *et al.* (2004) showed that plant height was negatively correlated with grain yield. Thus, in improved genotypes, plant height was not a limiting factor for grain yield because of reduced lodging and conducted better translocation of assimilates.

Plant height varied from 182.5 cm to 206.2 cm for *Oryza rufipogon,* 60.1 cm to 74.9 cm for Minghui-63 and 186.9 cm to 199.8 cm for hybrids. The result showed that the plant height of hybrids was nearly the same as that of *Oryza* *rufipogon,* but was significantly greater than that of Minghui-63 (Song *et al.,* 2004).

De *et al.* (2002) concluded that plant height ranged from 80 cm to 132 cm; whereas, panicle length ranged from 22 cm to 29 cm; which was responsible for grain yield plant^{-1}.

Ghosh (2001) worked with four rice hybrids and four high yielding rice cultivars and concluded that hybrids have higher plant height as compared with high yielding varieties.

Mrityunjay (2001) concluded that hybrids in general gave higher values for plant height at harvest, panicle length and number of filled grains panicle^{-1}; performed better compared with the others in terms of yield and yield components.

Yuan (2001) suggested the plant height for rice is about 100 cm; with culm length of 70 cm.

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

Pruneddu and Spanu (2001) conducted an experiment and found that plant height ranged from less than 65 cm to 80–85 cm in Mirto, Tejo, Gladio, Lamone and Timo. Nine hybrid rice cultivars were resistant to lodging.

An experiment was conducted at BINA (1998) to find out varietal performance of advance line (BINA 8-110-2-6) along with three check varieties - Iratom 24, BR26 and BRRI Dhan27. The result indicated that BINA 8-110-2-6 appeared similar to BRRI Dhan27 in terms of plant height and panicle length.

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

Honarnejad (1995) observed that plant height was significantly and negatively correlated with tillers per plant and positively correlated with days from transplanting to first panicle appearance.

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

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

Hossain and Alam (1991) reported that plant height differed significantly among BR3, BR4, BR14, Pajam and Juguale varieties in Boro season. The values of plant height changed very little after heading.

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

Plant height may not have significant role in the expression of hybrid vigor (Dwivedi, 1985).

Dwarfness may be one of the most important agronomic characters, because it is often accompanied by lodging resistance and thereby adapts well to heavy fertilizer application (Futsuhara and Kikuchi, 1984).

2.2.2 Tillering pattern

Song *et al.* (2004) found that hybrids produced a significantly higher number of tillers than their parental species and Minghui-63 had the least number of tillers.

Siddique *et al.* (2002) studied some rice varieties including JPS, SWAT-1, SWAT-11, DILROSH-97, PARC-3, IETI-13711, IRRI-4, GOMAL-6 and GOMAL-7. The data were recorded on number of tillers hill^{-1}, plant height, no. of panicles plant^{-1}, 1000-grain weight, sterility percentage, grain yield, straw yield, biological yield and harvest index. The analysis of data reveled that statistically significant differences were found for all the parameters except no. of tillers plant^{-1} and no. of panicles plant^{-1}.

Laza *et al.* (2001) concluded that the early vigor of hybrid rice (*Oryza sativa* L.) developed in temperate region 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.

Ma *et al.* (2001) experimented with ADTRH1 which is a rice hybrid. It tillered profusely (12–15 productive tillers hill^{-1}) under (20 × 10) cm^2 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^{-1}.

Molla (2001) carried out an experiment to examine the performance of rice hybrids and HYV. The treatment consisted of two hybrid rice (Pro Agro-6201 and CNRH 3) and one HYV (IET 4786). Pro Agro-6201 had more profuse tillering habit at early stage than the HYV, which could be due to hybrid vigour.

Yang *et al.* (2001) studied the growth and yield components of two rice cultivars Jinongda3 (JND3) and Jinongda13 (JND13). They observed that JND3 exhibited a higher tillering ability than JND13.

Nuruzzaman *et al.* (2000) conducted an experiment to figure out the relationship between the tillering ability and morphological characters among 14 rice varieties. They observed that tillers number varied widely among the varieties and the number of tillers plant^{-1} at the maximum tillering stage ranged between 14.3 and 39.5 in 1995 and 12.2 and 34.6 in 1996. Among all the varieties, IR36 produced the highest no. of tillers plant^{-1} followed by Suweon 258 while Dawn produced the lowest no. of tillers plant^{-1}.

Behera (1998) found that the yield of rice per unit of area depended mainly on tillers number and average yield panicle^{-1}.

Islam (1995) observed variations in non-bearing tillers with four rice cultivars.

Hossain and Alam (1991) observed that total no. of tillers hill^{-1} and no. of grains panicle^{-1} differed significantly among the rice varieties

Devaraju *et al.* (1998) conducted an experiment with two rice hybrid - Karnataka Rice Hybrid 1 (KRH 1) and Karnataka Rice Hybrid 2 (KRH 2) using HYV IR20 as the check variety. They found that KRH 2 out yielded IR20. IR20 produced higher no. of tillers than KRH 2. The increased yield of KRH 2 was mainly attributed to the higher number of productive tillers, panicle length and number of grains panicle^{-1}.

Ashvani *et al.* (1997) studied 22 genotypically diverse strains of hybrid rice to correlate yield contributing characters. Number of effective tillers plant^{-1} showed significant and positive correlation at genotypic and phenotypic levels with grain yield panicle^{-1}, 1000-grain weight and total biological yield plant^{-1}.

Luh (1980) reported that tillering ability and the production of leaves are the main visible activity during the vegetative phase of rice. In the tropics maximum tiller and no. of leaves in rice occurred at 40 to 60 days after transplanting, depending upon the tillering ability of the variety, the spacing used and the fertility level. The high yielding tropical varieties produced 25 to 30 tillers when grown as isolated plants.

2.2.3 Total dry matter weight hill^{-1}

In order to study on the morphological and physiological indicators of rice genotypes, a field experiment was conducted at the Rice Research Institute of Iran. In that study, Onda had the greater total dry matter (TDM) among other genotypes (this genotype also had the highest grain yield). Higher TDM was obtained from improved genotype than traditional genotypes (1445 and 1626 GDD, respectively). At flowering the dry matter weight was higher for Jasesh and was lower for Ramazan Ali Tarom (923.93 g m^{-2} and 429 g m^{-2}, respectively). So the photosynthetic potential of improved genotypes was higher as reflected by their TDM which had positive correlation with grain yield (Mandavi *et al.* 2004).

Sharma and Haloi (2001) conducted a study in Assam during the kharif season with 12 varieties of scented rice cultivars and observed that cv. Kunkuni Joha consistently maintained a higher rate of dry matter production at all growth stages and the highest dry matter accumulation at the panicle initiation stage.

Achieving higher yield depends on increasing total crop biomass, because there is little scope to further increase the proportion of that biomass allocated to grain (Evans and Fisher, 1999).

Reddy *et al.* (1994) observed that dry matter production and grain yield were positively and significantly associated with each other and also with Net Assimilation Rate (NAR) and Harvest Index (HI).

2.3 Comparison and contrast of hybrid and inbred rice varieties on yield contributing characters and yield

Variety itself is a genetical factor which contributes a lot for producing higher yield of rice. Different researchers evaluated the performance of rice varieties on grain yield. Some available information and literature related to the yield contributing characters and yield of hybrid and inbred rice cultivars are discussed here.

Haque and Biswash (2014) experimented with five varieties of hybrid rice which were collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29. In the experiment the highest plant height was 101.5 cm for BRRI dhan28 and the lowest plant height was for Richer (82.5 cm). In case of days to 50% flowering, BRRI dhan29 required maximum days (116.3 days) and BRRI dhan28 required fewer days (95 days). In case of no. of effective tillers, Hira showed the best performance (17.7) and

Sonarbangla-1 showed the least performance (13.3). Considering the days to maturity, Sonarbangla-1 required fewer days (118 days) and BRRI dhan29 required the maximum days (148 days). In panicle length status, Richer showed the best performance (27.7 cm) while BRRI dhan28 showed the least performance (26 cm). Number of filled grains panicle^{-1} was the highest for BRRI dhan29 (163.3), whereas, Jagoron only 118. Number of total grains was highest in BRRI dhan29 (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 case of biological yield (g), BRRI dhan29 showed highest yield (49.6 g) and Hira only 18 g. Considering the performance of all the variety, the variety Aloron was the best than the respective commercial varieties under the study.

Islam *et al.* (2010) studied yield potential of 16 rice genotypes including 12 hybrids, 3 inbreds and 1 New Plant Type (NPT) at the International Rice Research Institute (IRRI) farm under optimum crop management to achieve maximum attainable yield during the wet season (WS) of 2004 and dry season (DS) of 2005. Yield and yield components were determined at maturity. IR76712H produced the highest grain yield (7.7 t ha^{-1}) followed by IR75217H and Magat (7.6 t ha^{-1}) in WS. In DS, IR79118H produced the highest grain yield (9.17 t ha^{-1}) followed by IR73855H (8.9 t ha^{-1}) and SL-8H (8.8 t ha^{-1}). The higher yield of hybrid rice was due to higher harvest index (0.50). Hybrid produced higher spikelets panicle^{-1} and 1000-grain weight than inbred rice. Spikelet filling percent was higher in inbred than hybrid rice. The NPT rice genotype had the lowest spikelet filling percent, but the highest 1000-grain weight across the season.

Islam *et al.* (2009) conducted pot experiments during T. aman season of 2001 and 2002 (wet season) in net house at Bangladesh Rice Research Institute (BRRI). Hybrid variety Sonarbangla-1 and inbred modern variety BRRI dhan31 were used in both the seasons and BRRI hybrid dhan1 was used in 2002. The main objective of the experiments was to compare the growth and yield behavior of hybrid and inbred rice varieties under controlled condition. In

2001, BRRI dhan3l had about 10-15% higher plant height, very similar tillers plant^{-1}, 15–25% higher leaf area at all days after transplanting (DAT) compared with Sonarbangla-1. BRRI dhan3l had higher panicles plant^{-1} than Sonarbangla-1, but Sonarbangla-1 had higher number of grains panicle^{-1}, 1000-grain weight and grain yield than BRRI dhan31. In 2002, BRRI dhan31 had the highest plant height at 25 DAT, but at 75 DAT; BRRI hybrid dhanl had the highest plant height. BRRI dhan31 gave the highest number of panicles plant^{-1} followed by Sonarbangla-1. BRRI hybrid dhanl had the highest grains panicle^{-1} followed by BRRI dhan31 and Sonarbangla-1 had the highest 1000-grain weight followed by BRRI dhan31. The highest amount of grains plant^{-1} (34.6 g) was obtained from BRRI dhan31.

Chaturvedi *et al.* (2004) evaluated newly released commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar Dhan 1) and two high yielding varieties as checks (Pant Dhan 4 and Pant Dhan 12) for their agronomic and morpho-physiological traits in a field experiment during kharif season of 2000. The highest yield of KHR 2 was higher than the best check variety Pant Dhan 4 (7.0 t ha^{-1}) but the difference was non-significant. Hybrids although could not excel the best HYV owing to high percentage of spikelet sterility but they showed potential for higher yield as these produced large sink (higher number of spikelets m^{-2}). However, hybrids showed 9–16 % heterosis in total dry matter yield. Heterosis was expressed in vegetative growth (profused tillering, tallness and increased plant dry matter) and reproductive growth (high number of total spikelets). Therefore, improvement for increased grain filling could be made. The grain yield (t ha^{-1}) was positively and significantly correlated with number of filled spikelets m^{-2}, days to 50% flowering, biological yield, thermal units and photo thermal units.

Siddique *et al.* (2002) studied the difference between hybrid and inbred rice in respect to their growth duration, yield and quality in boro season of 1999. Among the varieties, Aalok 6201 produced the highest grain yield followed by

BRRI Dhan29 and IR68877H but statistically they were similar. BRRI Dhan28 had the lowest grain yield, which was statistically similar to Loknath503. BRRI Dhan28 and the tested hybrid rice had shorter growth duration than BRRI Dhan29. Milling out turn varied from 67 to 70% among the tested varieties. Loknath 503 had the lowest milling out turn (70%); whereas, BRRI Dhan28 and BRRI Dhan29 had the highest milling out turn (70%) for unparboiled rice. In case of parboiled rice the highest milling out turn (73%) were found in BRRI Dhan28 and IR68877H. All tested hybrid rice were medium bold, whereas BRRI Dhan29 and BRRI Dhan28 were medium slender and long slender, respectively in both parboiled and unparboiled condition.

Cui *et al.* (2000) in a field trial examined varietal differences in harvest index and yield using 60 Japanese varieties and 20 high yielding varieties breed in Asian countries. It was reported that harvest index varied from 36.8% to 53.4%. Mean values of harvest index were 43.5% in the Japanese group and 48.8% in high yielding group. Yield ranged from 22.6 g $plant^{-1}$ to 40 g $plant^{-1}$. The mean value of yield in Japanese group was 27.8 g $plant^{-1}$ and that in the high yielding group was 34.1 g $plant^{-1}$. They also stated that a positive correlation was found between harvest index and yield in the high yielding group, but the correlation was not significant in the Japanese group.

BRRI (1995) conducted an experiment to find out the yield performance of BR4, BR11, BR22, BR23 and BR25 cultivars including two local check cultivars Challish and Nizersail. Experimental results indicated that BR4, BR10, BR11, Challish and Nizersail produced grain yield of 4.38, 3.12, 3.12, 3.12 and 2.70 t ha^{-1}, respectively. Challish cultivar flowered earlier than all other varieties. BR22 and BR23 showed poor performance.

2.4 Yield contributing characters and yield

2.4.1 Number of panicles hill^{-1}

Lee *et al.* (1992) showed that the number of spikelet panicle^{-1}, panicle length and grain yield panicle^{-1} were higher in the main tiller and decreased with increasing tiller order with delaying panicle emergence in rice.

2.4.2 Total grains panicle^{-1}

Yuan *et al.* (2005) studied the variation in the yield components of 75 high quality rice cultivars. Among the yield components, the greatest variation was recorded for number of grains panicle^{-1} in *indica* rice, and no. of panicles plant^{-1} in *japonica* rice.

Ma *et al,* (2001) examined a hybrid under 20 cm × 10 cm spacing, producing 142 grains panicle^{-1} and with more than 90% spikelet fertility. The hybrid recorded the highest grain yield (11.4 t ha^{-1}).

Oka and Saito (1999) experimented and found that among F_1 hybrids crosses with rice cv. Sasanishiki; plant height, panicle length and number of grains panicle^{-1} were higher in the hybrids than in Sasanishiki, but the 1000-grain weight was lower.

2.4.3 Panicle length

Chakma (2006) found that BINA dhan-5 produced the longest panicle (22.86 cm) followed by BRRI dhan29 (22.78 cm) and BINA dhan-6 (22.28 cm).

Ghosh (2001) studied the performance of 4 rice hybrids and 4 high yielding rice cultivars. Hybrids, in general, gave higher values for panicle length compared with high yielding cultivars.

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

Oka and Saito (1999) found that there were relationships with parental values for panicle length, grains panicle^{-1} and panicle emergence date. The hybrid MH2005 gave a yield of 6.09 t ha^{-1} compared with 4.36 t ha^{-1} from cv. Hitomebore.

Ramalingam *et al.* (1994) observed that varieties with long panicles, higher no. of filled grains panicle^{-1} and more primary rachis would be suitable for selection because these characters had higher positive association with grain yield and were correlated among themselves.

2.4.4 Number of filled grains panicle^{-1}

Parvez *et al.* (2003) reported that yield advantage for the hybrid rice was mainly due to the proportion of filled grains panicle^{-1}, heavier grain weight (35%) and increased harvest index values than the control (28%).

Shrirame and Mulley (2003) conducted an experiment on variability and correlation of different biometric and morphological plant characters with grain yield. Grain yield was significantly correlated with number of filled grains panicle^{-1}.

Ganesan (2001) experimented with 48 rice hybrids. Filled grains panicle^{-1} (0.895) had the highest significant positive direct effect on yield plant^{-1} followed by number of tillers plant^{-1} (0.688), panicle length (0.167) and plant height (0.149).

Mrityunjay (2001) conducted an experiment 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 panicle^{-1}, plant height at harvest and panicle length compared with the others.

Srivastava and Tripathi (1998) found that the increase in grain yield in local check variety in comparison with hybrid might be attributed to the increased fertile grains panicle^{-1}.

Ramana *et al.* (1998) observed that hybrids produced more panicles m^{-2} and filled grains $panicle^{-1}$ than conventional cultivars.

Singh and Gangwer (1989) conducted an experiment with four rice cultivars namely C-14-8, CR-1009, IET-565 and IET-6314. They reported that no. of grains $panicle^{-1}$; 1000-grain weight and biological yield were higher for C-14-8 than those of other three cultivars.

2.4.5 Number of unfilled grains panicle^{-1}

Chowdhury *et al.* (1995) reported that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e. number of productive tillers $hill^{-1}$, length of panicle, 1000-grain weight, grain and straw yield. On the other hand, the cultivar Pajam produced significantly taller plant, higher number of total spikelets $panicle^{-1}$, grains $panicle^{-1}$ and unfilled spikelets $panicle^{-1}$.

2.4.6 1000-grain weight

Neerja and Sharma (2002) conducted an experiment on non-aromatic (cvs. IRB, Jaya, PR113, PR103, PR106, PR108, PR115 and PR116) and aromatic (cvs. Basmati 370, Basmati 385, Basmati 386 and Pusa Basmati No. 1) rice and found that the highest 1000 kernel weight rice, brown rice and milled rice was recorded for PR113.

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

Uddin *et al.* (2001) conducted an experiment to find out the crop performance of hybrid, inbred and local improved rice varieties and reported that variety had significant effect on all crop characters under study. Sonarbangla-1 ranked first in respect of 1000-grain weight followed by Alok 6201 and Habigonj.

1000-grain weight which is an important yield-determining component, is a genetic character least influenced by environment (Ashraf *et al.*, 1999).

Srivastava and Tripathi (1998) carried out an experiment and showed that increase in grain yield in local check in comparison to hybrid might be attributed to the increased effective tillers m^{-2}, fertile grains $panicle^{-1}$, panicle weight and 1000-grains weight.

BRRI (1997) reported that weight of 1000-grains of Halio, Tilockachari, Nizershail and Latisail were 26.5 g, 27.7 g, 25.2 g and 25 g; respectively.

Wen and Yang (1991) observed higher 1000-grain weight by using 1 seedling $hill^{-1}$ than with 4 seedlings $hill^{-1}$.

2.4.7 Grain yield

Twenty-one advanced cultivars were evaluated in transplanted condition during 2005 wet season in a replicated trial along with three checks (Swarna, Pooja and Gayatri) for yield and yield contributing characters like plant height, days to flowering and number of ear bearing tillers. Variety Swarna (4.864 t ha^{-1}) and CR 874-59 (4.675 t ha^{-1}) gave higher grain yield compared with others. (Patnaik and Mohanty, 2006).

Several *indica/japonica* (I/J) lines were screened and evaluated for higher grain yield in the boro season. The highest grain yield of 9.2 t ha^{-1} was obtained from selected I/J line IR58565-2B-12-2-2, which was equal to that of indica hybrid CNHR3 and significantly higher than that of modern variety IR36 (Roy, 2006).

A rice cultivar Takanari showed the highest grain yield among the genotypes across 2 years, and successfully produced over 11 t ha^{-1} of grain yield in 2000. The genotypic difference in grain yield was most closely related to that in Crop Growth Rate (CGR) during the late reproductive period (14–0 days before full heading). Rice genotypes having higher CGR during this period produced a greater number of spikelets per unit land area. Therefore, Takanari appeared to have succeeded in over 11 t ha^{-1} of grain yield by achieving both the prerequisite of biomass production during the late reproductive period and better grain filling (Takai *et al.,* 2006).

Hassan *et al.* (2003) found that grain yield is a function of interplay of various yield components such as number of productive tillers plant^{-1}, spikelets panicle^{-1} and 1000-grain weight.

Shrirame and Mulley (2003) observed that grain yield exhibited a very strong positive correlation with harvest index. Grain yield was also significantly correlated with dry matter weight hill^{-1}, effective tillers hill^{-1} and no. of filled grains panicle^{-1}.

Pruneddu and Spanu (2001) conducted an experiment in Sardinia on varietal comparison of rice. They used 18 varieties and classified into groups according to grain properties (round, medium, long A. long B and aromatic). The highest yields were obtained from the long-grained varieties Alice (9.1 t ha^{-1}, long A) and Ebro (8.4 t ha^{-1}, long B).

BRRI (1999–2000) conducted a study on newly introduced BRRI varieties and one hybrid rice variety. They found that irrespective of different land types, the highest yield (7.02 t ha^{-1}) was obtained from BRRI Dhan29 followed by hybrid variety, BRRI Dhan28 and BRRI Dhan36 which gave an average yield of 6.03 t ha^{-1}, 5.53 t ha^{-1} and 4.69 t ha^{-1}, respectively.

Om *et al.* (1999) conducted a field experiment with four varieties (3 hybrids: ORI 161, PMS-2A and PMS-10A and 1 inbred variety: HKR 126) during rainy season. They observed that hybrid ORI 161 exhibited superiority over other varieties in terms of grain yield and straw yield.

Srinivasulu *et al.* (1999) noted that planting 1 seedling hill^{-1} in case of rice gave higher grain yield comparable to that of 2 seedlings hill^{-1}.

Julfiquar *et al.* (1998) reported that in the International Rice Hybrid Observational Nursery (IRHON-96), six hybrids out yielded the check varieties of which three hybrids – IR6229A/IR29723-143-3-2-1R, IR58025A/IR34683-

179-1-2-1R and IR58025A/IR21-567-18-3R gave 1 ton more yield than the check variety of the same duration. In International Rice Hybrid Observational Nursery (IRHON-97) seven hybrids out yielded the check var. BR14 by more than 1 t ha^{-1} but no one hybrid out yielded the check var. BRRI dhan29.

Kamal *et al.* (1998) performed an experiment to assess the yield of 9 modern varieties (MV) and 6 local improved varieties (LIV). They observed that modern variety BR11 gave the highest grain yield followed by BR10, BR23, Binasail and BR4.

Singh *et al.* (1998) evaluated the productivity of two rice hybrids viz. TNH-1 and TNH- 2 using Rasi and Jaya as standard checks during Kharif season of 1992 and found that Jaya produced significantly highest grain yield (5.12 t ha^{-1}). The grain yield of Rasi and TNH-1 were superior and at par but TNH-2 was recorded for the lowest grain yield (3.06 t ha^{-1}).

Chowdhury (1997) undertook a research on BINA-19, BR14, BR3 and Iratom-24 varieties with different methods of transplanting. He found that the yields for BINA-19, BR14, BR3 and Iratom-24 were 6.49 t ha^{-1}, 6.22 t ha^{-1}, 6.22 t ha^{-1}, 5.75 t ha^{-1} and 5.60 t ha^{-1} respectively.

Radhakrisna *et al.* (1996) in trials at Mamdya, Karnataka from 1992–1995 found that hybrid cultivar KRH-2 gave an average yield of 9.3 t ha^{-1} with an yield advantage of 1.5 t ha^{-1} over the best check variety Jaya.

Geetha *et al.* (1994) studied six hybrids for grain characters. ADRH4 was the highest yielding (19.7 gm $plant^{-1}$). The increased yield in this hybrid was due to higher no. of grains $plant^{-1}$. Correlation analysis revealed that only grains $plant^{-1}$ had a strong positive association with grain yield.

Leenakumari *et al.* (1993) evaluated eleven hybrid cultivars against four standard check varieties – Jaya, Rasi, IR20 and Margala. They concluded that hybrid cultivar OR 1002 gave the highest yield of 7.9 t ha^{-1} followed by the hybrid cultivar OR 1001 (6.2 t ha^{-1}). Among the control varieties, Jaya gave the highest yield (8.4 t ha^{-1}).

Suprihatno and Sutaryo (1992) evaluated the performance of seven IRRI hybrids and 13 Indonesian hybrids using IR64 and Way-Seputih as check varieties. They found that the check varieties were high yielding than the hybrids, IR64 was the highest yielding, significantly out yielding IR6461H, IR64610H and IR62829A/IR54 which in turn out yielded Way-Seputih.

Chandra *et al.* (1992) conducted an experiment with two hybrid cultivars and three control varieties. They observed that the hybrid cultivar IR 62829A out yielded the hybrid cultivar IR 58025A and all other control varieties.

2.4.8 Straw yield

Summers *et al.* (2003) trialled with eight common California rice cultivars at multiple sites for the 1999 and 2000 seasons and found variability in straw quantity and quality which can have critical impacts on biomass industries. The length of the pre-heading period was the strongest indicator for straw yield. Harvested straw yield is also strongly affected by cutting height with a non-linear distribution resulting in nearly half of the straw biomass occurring in the lower third of the plant.

2.4.9 Biological yield

Peng *et al.*, (2000) concluded that the increasing trend in yield of cultivars due to the improvement in harvest index (HI), while increase in total biomass was associated with yield trends for cultivars–lines.

Ramesha *et al.* (1998) found 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.

Kim and Rutger (1988) noted that hybrids that gave higher grain yields also produced higher 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 accumulates more total dry matter than conventional rice (Zhende, 1988).

2.4.10 Harvest index (%)

Senapati *et al.* (2004) observed adaptability of aman paddy under sundarban areas of West Bengal. Grain yield and number of days to maturity were evaluated in 40 aman rice genotypes grown during the kharif seasons of 1997, 1998, 1999 and 2000 under rainfed lowland condition of Kakdwip, West Bengal, India. They observed significant genetic variation and genotype-environment interaction for both traits. They found 21 genotypes were stable for number of days to maturity. Of these, CR-626-26-2-3, CR-383-10, Dudhraj, Lilabati, Dhusari and Bogamanohar were late matured variety, which was desirable for aman rice cultivation in Sundarban areas. Twenty-two genotypes were highly stable for grain yield and widely adapted to Sundarban areas.

Shrirame and Mulley (2003) conducted an experiment on variability and correlation studies of different biometric and morphological plant characters of rice with grain yield. It was carried out with rice hybrids TNRH10, TNRH13 and TNRH18 and cultivar Jaya. They found that grain yield exhibited a very strong positive correlation with harvest index. Grain yield was also significantly correlated with dry matter weight hill^{-1}, effective tillers hill^{-1} and number of filled grains panicle^{-1}.

Kiniry *et al.* (2001) studied different parameters describing processes of crop growth and yield production. The mean harvest index was 0.32 (32%) for all four cultivars over the two harvests in each of the 2 years. They concluded that yield differences among cultivars were due to harvest index differences.

Liao-Yaoping *et al.* (2001) conducted an experiment where rice cv. Yuexiangzhan was compared with cv. Qishanzhan and Jingxian 89 and observed that the main reason for the higher harvest index and yield of Yuexiangzhan was balanced and co-ordinate sink, source and assimilate flow.

Peng *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 increasing yield trends for cultivars–lines developed after 1980.

Cui *et al.* (1998) conducted a varietal trial of Japanese rice varieties (J group) along with 20 high yielding Asian rice varieties (H group). They reported significantly higher yield and harvest index in H group than that of the J group. Days to heading (DTH) showed significantly positive correlation with total dry matter weight and a significantly negative correlation with harvest index.

Sitaramaiah *et al.* (1998) evaluated six promising rice hybrids with two check varieties and found that hybrids MTUHR 2033, MTUHR 2020 and MTUHR 2037 gave higher grain yield, greater biomass production and harvest index than other varieties. They also observed that higher yielding hybrids also recorded for higher biomass yield and harvest index. It was found that the hybrids showed a superior performance because of more grains panicle^{-1}, which was indicated by higher harvest index.

Jiang *et al.* (1995) evaluated 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 due to higher biomass production.

2.4.11 Days to maturity

Swain *et al.* (2007) found that among the medium-duration varieties (115–130 days), there was good agreement between simulated and observed leaf area index, biomass, and grain yield. The simulated biomass of long-duration varieties (135–150 days) showed large deviation from observed biomass at flowering. In the wet season of 2000, the model accurately predicted the grain yield, biomass and leaf area index of medium and long-duration varieties.

Patnaik and Mohanty (2006) showed that there was a wider variation in the maturity duration of varieties. The flowering duration was the longest in CR 874-23 (153 days) followed by CR 758-16 (151 days). The earliest variety found to be Swarna (110 days).

Wei *et al.* (2004) conducted an experiment with Yueza 122 which was bred by crossing GD-1S with Guanghui 122. They concluded that the hybrid showed wide adaptability, higher and stable grain yield, moderate growth period, fine grain quality, high resistance to rice blast and medium resistance to bacterial blight.

Parvez *et al.* (2003) observed that Sonarbangla-1 showed shorter field duration was observed in than the control.

Ma *et al.* (2001) studied comparative performance of 8 rice hybrids. All hybrids showed shorter growth duration (97–107 days) than the controls (110–116 days). They also experimented with ADTRH1 which is a rice hybrid. This hybrid was semi-dwarf and reached maturity in 115 days.

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

Huang *et al.* (1999) studied the morphological and physiological characteristics of Yueza 122. The results showed that it was an early matured hybrid combination with duration of 83 days from sowing to heading in the early cropping season.

Pruneddu and Spanu (1999) conducted an experiment and concluded that Ebro was the earliest hybrid rice cultivar, reaching maturity 114 days after sowing; whereas, Balilla, Tejo and Thaibonnet were the latest; reaching maturity 128 days after sowing.

Yang (1998) examined with Chao Chan 1 which is a hybrid rice variety. The growth period of it was 145 days.

Lin and Yuan (1980) reported that most hybrids had longer growth duration.

2.4.12 Days to 50% flowering

Most scientists indicated that days to 50% flowering has direct and indirect effect on yield, grains panicle^{-1} and also on plant height.

Iftekharuddaula *et al.* (2001) reported that days to 50% flowering, days to maturity, plant height and spikelets panicle^{-1} had positive and higher indirect effect on grain yield through grains panicle^{-1}.

Sathya *et al.* (1999) studied on eight quantitative traits in rice (*Oryza sativa*). Days to 50% flowering was the principal character responsible for grain yield plant^{-1} followed by 1000-grain weight, plant height and harvest index as they had positive and significant association with yield.

Vijayakumar *et al.* (1997) found that hybrids out yielded their parents when their days to 50% flowering were similar or more than their respective restorers.

Padmavathi *et al.* (1996) suggested that days to 50% flowering had higher positive direct effects on number of panicles plant^{-1} and panicle length. Days to 50% flowering, number of grains panicle^{-1} and plant height had positive direct effects on grain yield.

Roy *et al.* (1989) observed that generally the plants which needed more days for 50% flowering gave more yield.

2.5 Yield potential of hybrid

Parvez *et al.* (2003) conducted a comparative study to evaluate four imported hybrid rice cultivars with a high yielding variety (BRRI Dhan29).The Chinese cultivar Sonarbangla-1 gave the best performance in terms of all the parameters under consideration. The other three Indian cultivars (Amarsiri-1, Aalok and

Loknath) had lower performance than the control. Sonarbangla-1 produced 20% higher grain yield (7.55 t ha^{-1}) than the control (6.26 t ha^{-1}). Yield advantage for the hybrid rice was mainly due to heavier grain weight (35%).

Ma *et al.* (2001) studied 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^{-1}) which was 58.78% and 26.52% higher than those of PS02 and PTT1. They also experimented with ADTRH1 which was 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^{-1}. The hybrid recorded the highest grain yield (11.4 t ha^{-1}). The highest yield of the control in these trials was 9.6 t ha^{-1}.

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In a field trail at BAU (1998) in boro season, it was observed that hybrid rice Alok 6201 out-yielded the modern variety Iratom 24 by 29.48%. The maximum numbers of tillers hill^{-1}, effective tillers hill^{-1}, spikelets panicle^{-1} and panicle length was found from Alok 6201; whereas, Iratom 24 was found better in respect of 1000-grain weight only.

Khush *et al.* (1998) observed that the yield potential of modern high-yielding varieties grown under the best tropical conditions is 9–10 t ha^{-1}. Tropical rice hybrids under similar conditions have shown about 1 t ha^{-1} higher yield. They worked with several new-plant-type rice cultivars like a Chinese japonica rice breeding line Shen Nung 89-366 and a tropical japonica semi-dwarf selection, MD 2 from Madagascar. The researchers concluded that if these new plant cultivars are used to produce hybrid rice, it is expected to have a yield potential of 13 t ha^{-1}.

Ramana *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 comparing cultivars Chaitanya, BPT 5204 and

Tellahamsa, respectively. The mean grain yield of rice hybrids during 1996 was 23.7% and 26% higher than BPT 5204 and Tellahamsa, respectively.

DRR (1996) evaluated 44, 33 and 33 hybrids in International Rice Hybrid Observational Nursery (IRHON) in consecutive 3 years viz. 1994, 1995 and 1996 respectively. They reported that the hybrids gave 0.7 to 3.7 t ha^{-1} more yield than their corresponding check varieties. In observational yield trials DRR found that all the rice hybrids out yielded the local highest yielding check varieties.

Guok *et al.* (1997) in an experiment with hybrid rice cultivar IR62829A/IR46R and MH841-1A/MR 167 observed that the two hybrid rice lines, IR62829A/IR46R and MH841-1A/MR 167 were found to have a yield advantage of about 24% to 26% over the best local check in 1995–96.

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^{-1}. Tropical rice hybrids under similar condition have shown yield potential about 12 t ha^{-1}.

Chapter III

Materials & Methods

CHAPTER 3

MATERIALS AND METHODS

This chapter deals with the materials and methods of the experiment with a brief description on experimental site, climate, soil, land preparation, planting materials, experimental design, land preparation, fertilizer application, transplanting, irrigation and drainage, intercultural operation, data collection, data recording and their analysis. The details of investigation for achieving stated objectives are described below.

3.1 Site description

The experiment was conducted at the Sher-e-Bangla Agricultural University research farm, Dhaka, during the period from January 2015 to June 2015. The experimental site was located at 23°77′ N latitude and 90°37′ E longitudes with an altitude of 9 m.

3.2 Agro-ecological Region

The experimental site belongs to the agro-ecological zone of "Madhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Madhupur clay, where floodplain sediments buried the dissected edges of the Madhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988b). For better understanding, the experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.3 Climate and weather

The geographical location of the experimental site was under the sub-tropical climate characterized by three distinct seasons. The monsoon or rainy season extending from May to October which is associated with high temperature, high humidity and heavy rainfall; the winter or dry season from November to February which is associated with moderately low temperature and the pre-monsoon period or hot season from March to April which is associated with some rainfall and occasional gusty winds. Information regarding monthly maximum and minimum temperature, rainfall, relative humidity and sunshine during the period of study of the experimental site was collected from Bangladesh Meteorological Department, Agargaon and is presented in Appendix IV.

3.4 Soil

The experiment was carried out in a typical rice growing soil belonging to the Madhupur Tract. Top soil was silty clay in texture, red brown terrace soil type, olive–gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and had organic carbon 0.45%. The land was well drained with good irrigation facilities. The experimental site was a medium high land. It was above flood level and sufficient sunshine was available during the experimental period. The morphological characters of soil of the experimental plots are as following - Soil series: Tejgaon, General soil: Non-calcareous dark grey (Appendix II). The physicochemical properties of the soil are presented in Appendix III.

3.5 Crop / Planting materials

A total of twenty-three rice materials including hybrid and inbred varieties were used as planting materials. Among them, two varieties viz. BRRI dhan28 and BRRI dhan29 were used as inbred check; whereas, ACI-1 and Sampad were used as hybrid check varieties. BRRI dhan28 and BRRI dhan29 were collected from BRRI and ACI-1 and Sampad were supplied by ACI Seed Company. The hybrid materials were designated as follows:

(i) Hybrid line-1,
(ii) Hybrid line-2,
(iii) Hybrid line-3,
(iv) Hybrid line-4,
(v) Hybrid line-5,
(vi) Hybrid line-6,
(vii) Hybrid line-7,
(viii) Hybrid line-8,
(ix) Hybrid line-9,
(x) Hybrid line-11,

(xi) Hybrid line-12,
(xii) Hybrid line-13,
(xiii) Hybrid line-14,
(xiv) Hybrid line-15,
(xv) Hybrid line-16,
(xvi) Hybrid line-17,
(xvii) Hybrid line-18,
(xviii) Hybrid line-19 and
(xix) Hybrid line-20

3.6 Details of the Experiment

3.6.1 Experimental treatments

One factor experiment was conducted to evaluate the performance of hybrid lines comparing to the inbred and hybrid rice varieties in boro season.

3.6.2 Experimental design

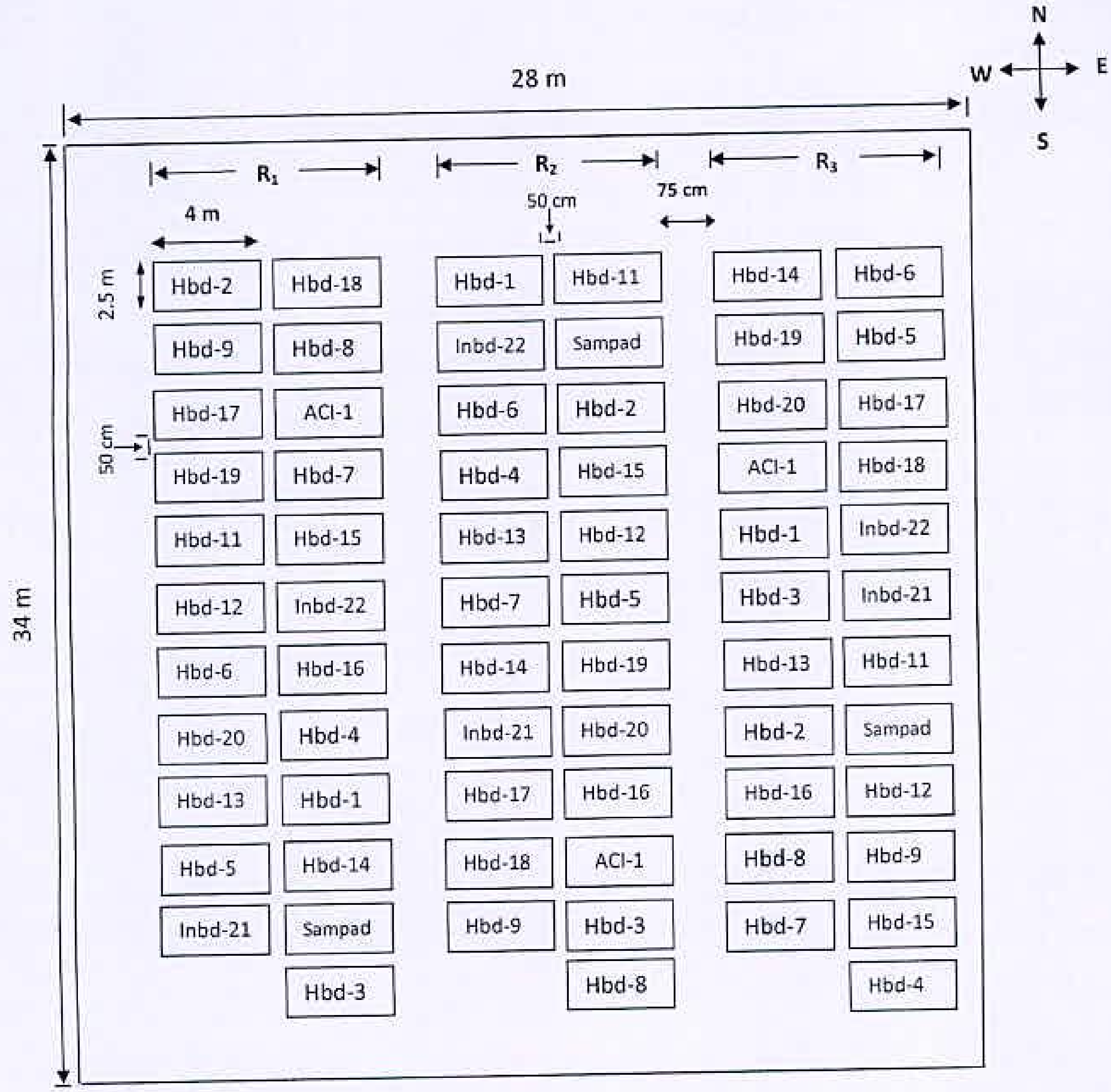
The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the variety. The experimental field was divided into 3 blocks. Each block was again divided into 23 plots. The total numbers of unit plots of the experiment were 69 (23 × 3). The size of the unit plot was 4 m × 2.5 m (10 m^2). There were 0.75 m width and 10 cm depth for drains between the blocks. Each treatment was again separated by drainage channel of 0.5 m width and 10 cm depth. The treatments were randomly distributed to each block following the experimental design (Figure 1).

3.7 Growing of crops

3.7.1 Raising Seedlings

3.7.1.1 Seed collection

The seeds of the test crops were collected from BRRI and ACI Seed Company. Although the seeds of hybrid lines were collected from ACI Seed Company, these are not released as variety for commercial cultivation.



Unit plot size = 4.0 m × 2.5 m,
Plot spacing = 0.5 m
Between replication = 0.75 m

Hybrid lines:
Hbd-1 = Hybrid line-1,
....
....
Hbd-20 = Hybrid line-20.

Check varieties:
Inbd - 21 = BRRI dhan28 (Inbred check)
Inbd - 22 = BRRI dhan29 (Inbred check)
ACI-1 (Hybrid check)
Sampad (Hybrid check)

Figure 1: Field layout of the experiment in Randomized Complete Block Design (RCBD).

3.7.1.2 Seed Sprouting

Healthy seeds were selected by specific gravity method and then immersed in water bucket for 24 hours and then it was kept tightly in gunny bags after discarding the water in buckets. The seeds started sprouting after 3 days and were sown in nursery bed.

3.7.1.3 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m width. Adequate amount of seeds were sown in the seedbed on 15 December 2014 in order to have seedlings of 40 days old. No fertilizer was used in the seedbed.

3.7.2 Preparation of the main field

The selected plot for the experiment was opened in 13 January 2015 with a power tiller and was exposed to the sun for a week. On 19 January 2015, the selected land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed and a desired tilth was obtained finally for transplanting of seedlings.

3.7.3 Fertilizer application

Recommended doses of fertilizers were applied to the each plot. Fertilizers such as Urea, TSP, MoP, Gypsum and Zinc sulfate were used as sources for N, P, K, S and Zn, respectively. The full doses of all fertilizers and one third of urea were applied as basal dose to the individual plot during final land preparation on 19 January 2015 at the time of final land preparation through broadcasting method. The first split of urea was applied on 25 days after transplanting (DAT) and the second split of urea was applied at maximum tillering stage (45 DAT).

The doses of fertilizers with their sources are given below:

Nutrient	Source	Dose (kg ha^{-1})
N (Nitrogen)	Urea (46% N)	200
P (phosphorus)	TSP (20% P_2O_5)	30
K (potassium)	MoP (50% K_2O)	100
S (Sulphur)	Gypsum (18% S)	75
Zn (Zinc)	Zinc sulphate (36% Zn)	15

Source: Adhunik Dhaner Chash, BRRI

3.7.4 Uprooting seedlings

Forty days old seedlings were uprooted carefully and were kept in soft mud in shade. The seed beds were made wet by application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots.

3.7.5 Transplanting of seedlings in the field

The seedlings were transplanted as per experimental treatment on 24 January 2015 without causing much mechanical injury to the roots. Line to line distance was 20 cm and hill to hill distance was 15 cm. One seedling $hill^{-1}$ was used during transplanting in all the plots. In each plot, there were 16 rows; each row contained 20 hills of rice seedlings. There were in total 320 hills in each plot.

3.7.6 Cultural operations

The details of different cultural operations performed during the course of experimentation are given below:

3.7.6.1 Irrigation and drainage

The experimental field was irrigated with adequate water and was maintained throughout the crop growth period. Flood irrigations were given as and when necessary to maintain 3–5 cm water in the rice field. A good drainage facility was also maintained for immediate release of excess rainwater from the field.

3.7.6.2 Gap filling

A minor gap filling was done at 7–10 days after transplanting (DAT) with same aged seedlings from the same source.

3.7.6.3 Weeding

The experimental plots were infested with some common weeds, which were removed twice by uprooting. First weeding was done from each plot at 20 DAT and second weeding was done from each plot at 40 DAT.

3.7.6.4 Plant protection measures

Plants were infested with rice stem borer, leaf roller and 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. For controlling birds, scarecrow was given and watching was done properly; especially during morning and afternoon.

3.8 Harvesting and post-harvest operation

The rice plant was harvested depending upon the maturity of plant. Harvesting was done manually from each plot. Harvesting was started at 102 DAT and continued up to 125 DAT. Maturity of crop was determined when 80% of the grains become golden yellow in color. The harvested crop of each plot was bundled separately, tagged properly and brought to the threshing floor. Proper care was taken for harvesting, threshing and cleaning of rice seeds. Fresh weight of grain and straw were recorded plot wise. The grains were cleaned and sun dried. The weight was adjusted to a moisture content of 14%. Straw was also sun dried properly. Finally, grain and straw yield $plot^{-1}$ were recorded and converted to t ha^{-1}. Five pre-selected hills per plot from which different data were collected; harvested separately, bundled properly, tagged separately from outside and then brought to the threshing floor for recording grain and straw yield.

3.9 Recording of plant data

During the study period, data were recorded on physical characters and yield components for all the entries on five randomly selected hills per plot from the middle rows in each replication as follows:

3.9.1 Crop growth characters

a) Plant height (cm)

b) Total tillers hill^{-1} (no.)

c) Total dry matter weight hill^{-1} (g)

d) Days to 50% flowering

e) Days to maturity

3.9.2 Yield contributing characters

a) Effective tillers hill^{-1} (no.)

b) Panicle length (cm)

c) Grains panicle^{-1} (no.)

d) Filled grains panicle^{-1} (no.)

e) Unfilled grains panicle^{-1} (no.)

f) Weight of 1000-grains (g)

3.9.3 Harvest yields

a) Grain yield (t ha^{-1})

b) Straw yield (t ha^{-1})

c) Biological yield (t ha^{-1})

d) Harvest index (%)

3.9.4 Procedure of recording data

3.9.4.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at the time of 30, 40, 50, 60, 70, 80, 90 DAT and at harvest. Data were recorded as the average of same 5 hills selected at random from the outer side rows (started after 2 rows from outside) of each plot. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading; and to the tip of panicle after heading.

3.9.4.2 Total tillers $hill^{-1}$ (no.)

The number of total tillers $hill^{-1}$ was recorded at 30, 40, 50, 60, 70, 80, 90 DAT and at harvest by counting total tillers as the average of same 5 hills pre-selected at random from the inner rows of each plot.

3.9.4.3 Total dry matter weight $hill^{-1}$ (g)

Total dry matter weight $hill^{-1}$ was recorded at the time of 30, 60, 90 DAT and at harvest by drying plant samples. The plant samples were oven dried at 72 °C temperature until a constant level from which the weight of total dry matter were recorded. Data were recorded as the average of 3 sample hills $plot^{-1}$ selected at random from the outer rows of each plot leaving the border line and expressed in gram.

3.9.4.4 Days to 50% flowering

Days to 50% flowering was considered when 50% of the plants within a plot were showed up with panicles. The number of days to 50% flowering was recorded from the date of sowing.

3.9.4.5 Days to maturity

Days to maturity was considered when the 80% grains of the plants within a plot become golden yellow in color. The number of days to maturity was recorded from the date of sowing.

3.9.4.6 Effective tillers hill^{-1}

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

3.9.4.7 Non-effective tillers hill^{-1}

The tillers having no panicle were regarded as non-effective tiller.

3.9.4.8 Panicle length (cm)

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 5 panicles.

3.9.4.9 Grains panicle^{-1}

The total number of grains was collected from the randomly selected 5 panicles in each plot and then average number of grains panicle^{-1} was calculated.

3.9.4.10 Filled Grains panicle^{-1}

Panicle was considered to be fertile if any kernel was present there in. The number of total filled grains present on each panicle was recorded.

3.9.4.11 Unfilled Grains panicle^{-1}

Panicle was considered to be sterile if no kernel was present there in. The number of total unfilled grains present on each panicle was recorded.

3.9.4.12 Weight of 1000-grains (g)

One thousand cleaned dried seeds were counted randomly from the total cleaned harvested grains of each individual plot and then weighed with a digital electric balance at the stage the grain retained 14% moisture and the mean weight were expressed in gram.

3.9.4.13 Grain yield (t ha^{-1})

The grain of the whole plot, i.e. 4 m × 2.5 m = 10 m^2 excluding the border row was harvested, cleaned, threshed, dried and weighed. Finally, grain yield plot^{-1} was converted and expressed in t ha^{-1} on 14% moisture basis. Grain moisture content was measured by using a digital moisture tester. Grain weight plot^{-1} was calculated by using following formula:

$$\text{Grain weight (final)} = \text{Initial weight} \times \frac{100 - \text{initial moisture content}}{100 - \text{final moisture content}}$$

3.9.4.14 Straw yield (t ha^{-1})

The dry weight of straw of the whole plot, i.e. 4 m × 2.5 m = 10 m^2 excluding the border row was harvested, cleaned, threshed, dried and weighed. Finally, straw yield plot^{-1} was converted and expressed in t ha^{-1} on 14% moisture basis.

3.9.4.15 Biological yield (t ha^{-1})

Biological yield is the summation of grain yield and straw yield. It was calculated as the following formula:

Biological yield (t ha^{-1}) = Grain yield + Straw yield.

3.9.4.16 Harvest index (%)

Harvest Index denotes the ratio of economic yield to biological yield and was calculated with the following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Economic Yield (Grain weight)}}{\text{Biological Yield (Total dry weight)}} \times 100$$

It was expressed in percentage.

3.10 Statistical analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques to obtain the level of significance by using MSTAT-C computer package program (Russell, 1986). The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability. Correlation and regression analyses were done by using Microsoft Excel software.

Chapter IV

Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

This chapter comprises of the presentation and discussion of the results obtained from the present study. The results have been presented, discussed and possible interpretations were given in tabular and graphical forms. The results obtained from the experiment have been presented under separate headings and sub-headings as follows:

4.1 Growth parameters

4.1.1 Plant height (cm)

Significant effect on plant height was found in inbred and hybrid varieties and lines of boro rice (Table 1 and Appendix V). The increasing pattern of plant height was almost similar in all varieties.

Results showed that at 30 DAT, Hybrid line-1 showed the highest plant height (39.77 cm) which was statistically similar to Hybrid line-17 (39.71 cm). At 40 DAT, highest plant height was observed in Hybrid line-9 (58.95 cm) among all the varieties. Hybrid line-11 produced the tallest plant at 50 and 60 DAT (66.22 cm and 75.73 cm), respectively. But as the plants appeared at the maturity, the tallest plant was observed among the check varieties compared to all the varieties under study. At 70 DAT, the highest plant height was recorded from BRRI dhan28 (106.74 cm) which was statistically similar to Hybrid line-11 (99.65 cm). BRRI dhan28 produced the tallest plant (107.76 cm) at 80 DAT which was statistically similar to variety Sampad (106.73 cm). Sampad produced the tallest plant at 90 DAT (106.59 cm) and at harvest (106.25 cm).

On the other hand, the shortest plant was observed from BRRI dhan29 at 30 and 50 DAT (32.18 cm and 55 cm, respectively). Hybrid line-4 produced the shortest plant at 40 DAT and at harvest (50.24 cm and 83.79 cm, respectively), whereas; Hybrid line-5 produced the shortest plant at 60, 70 and 90 DAT (63.27 cm, 81.91 cm and 87.15 cm, respectively). The shortest plant at 80 DAT was observed from Hybrid line-18 (88.10 cm).

The results corroborated with the findings of Islam *et al.* (2009), Bisne *et al.* (2006), BINA (1993) and Hossain and Alam (1991) who observed various plant heights due to different varieties.

4.1.2 Number of total tillers hill^{-1}

The production of tillers hill^{-1} was significantly influenced by the tested different inbred and hybrid varieties and lines (Table 2 and Appendix VI). The tiller number of the varieties increased with the advancement of growth stages. But it was not consistent as reduced number of tillers hill^{-1} was observed at harvest in some of the varieties. Death of some tillers was the reason behind the reduction of effective tillers.

Hybrid line-5 showed the highest number of tillers hill^{-1} at 50, 60 DAT and at harvest (15.93, 26.73 and 17.78, respectively). At 40 DAT, Hybrid line-17 produced the highest number of tillers hill^{-1} (14.00). BRRI dhan29 produced the highest number of tillers hill^{-1} at 30, 70, 80 and 90 DAT (8.91, 18.11, 17.92 and 17.92, respectively).

On the other hand, minimum tillers hill^{-1} at 30 and 40 DAT were recorded in Hybrid line-12 (4.99 and 8.00 respectively). At 50 and 60 DAT; Hybrid line-8 showed the minimum tillers hill^{-1} (10.47 and 15.60, respectively). Hybrid line-6 produced the lowest number of tillers hill^{-1} at 70 DAT (10.73). Hybrid line-2 produced the lowest number of tillers hill^{-1} at 80 DAT and at harvest (11.11 and 10.30 respectively). At 90 DAT, ACI-1 showed the minimum tillers hill^{-1} (10.20).

Islam *et al.* (2009), Bisne *et al.* (2006) and Bhowmick and Nayak (2000) reported similar trend of tillering habits with different varieties of rice.

4.1.3 Total dry matter weight hill^{-1} (g)

Total dry matter weight hill^{-1} of plant was significantly varied due to varietal differences but was statistically insignificant at 60 and 90 days after transplanting (Table 3 and Appendix VII).

At 30 DAT, the highest dry matter weight hill^{-1} was observed in variety Sampad (3.72 g) which was statistically similar to BRRI dhan28 (3.69 g), ACI–1 (3.63 g) and Hybrid line – 15 (3.62 g). At 60 DAT, Hybrid line-19 produced the highest dry matter weight hill^{-1} (19.33 g). BRRI dhan28 showed the highest value for dry matter weight hill^{-1} at 90 DAT (46.67 g). At harvest, BRRI dhan29 produced the highest dry matter weight hill^{-1} (84.77 g) which was statistically similar to Hybrid line-17, BRRI dhan28 and Hybrid line-13 (72.21 g, 69.23 g and 65.93 g, respectively).

On the other hand, Hybrid line-6 produced the lowest dry matter weight hill^{-1} at 30 DAT (1.59 g). At 60 DAT, the lowest dry matter weight hill^{-1} was observed in Hybrid line-4 (8.17 g). Hybrid line-6 produced the lowest dry matter weight hill^{-1} at 90 DAT (27.50 g). At harvest, Hybrid line-9 produced the lowest dry matter weight hill^{-1} (42.48 g) which was statistically similar to Hybrid line-2 and Hybrid line-6 (43.09 g and 44.20 g, respectively).

Researcher have suggested that (Islam *et al.*, 2009; Amin *et al.*, 2006; Son *et al.*, 1998 and Patnaik *et al.*, 1990) dry matter accumulation capacity mainly depends on varietal performances.

Table 1: Plant height of selected hybrid lines and check varieties of boro rice.

Treatment	Plant height (cm) at different days after transplanting							
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	90 DAT	At harvest
Hybrid line -1	39.77 a	55.09	58.13	70.03 a-h	87.41 e-j	91.97 d-g	93.11 f-k	89.83 i-l
Hybrid line-2	38.22 abc	55.87	64.14	73.97 abc	94.72 b-e	98.47 bcd	97.51 b-g	98.20 b-g
Hybrid line-3	38.26 abc	56.75	63.75	72.76 a-f	93.96 b-f	94.29 c-g	96.37 c-h	92.59 g-k
Hybrid line-4	35.21 cd	50.24	55.23	67.37 d-i	83.52 ij	88.27 g	87.93 jk	83.79 m
Hybrid line-5	35.46 cd	50.76	56.59	63.27 i	81.91 j	88.37 g	87.15 k	85.77 lm
Hybrid line-6	38.38 abc	55.09	59.81	66.73 e-i	87.70 d-j	89.09 fg	90.65 g-k	88.33 j-m
Hybrid line-7	36.78 abc	52.74	58.07	66.47 f-i	84.97 hij	90.19 efg	91.13 g-k	87.00 klm
Hybrid line-8	38.74 abc	58.37	64.36	71.87 a-g	93.33 b-g	96.46 c-f	95.43 d-i	95.12 d-i
Hybrid line-9	39.31 ab	58.95	64.90	74.53 abc	95.00 bcd	95.14 c-g	94.58 e-j	96.27 c-h
Hybrid line-11	39.64 ab	58.25	66.22	75.73 a	99.65 ab	105.04 ab	103.93 ab	99.22 b-e
Hybrid line-12	37.59 abc	55.07	61.94	74.85 ab	96.94 bc	100.49 abc	99.95 a-f	94.49 e-i
Hybrid line-13	36.49 abc	55.80	61.39	71.52 a-g	89.61 c-i	91.27 d-g	91.00 g-k	90.08 i-l
Hybrid line-14	38.52 abc	57.47	63.88	74.27 abc	94.85 bcd	100.23 abc	100.07 a-f	99.00 b-f
Hybrid line-15	38.53 abc	56.87	64.20	73.44 a-d	92.94 b-g	96.70 c-f	95.37 d-i	91.97 h-k
Hybrid line-16	36.53abc	54.09	59.11	65.93 ghi	87.68 d-j	89.51 fg	88.13 ijk	90.53 i-l
Hybrid line-17	39.71 a	56.39	63.14	66.53 f-i	88.79 d-j	97.61 b-e	98.90 b-f	97.71 b-g
Hybrid line-18	38.60 abc	54.40	59.43	64.19 hi	86.93 f-j	88.10 g	89.06 h-k	88.32 j-m
Hybrid line-19	37.37 abc	54.44	57.87	68.52 c-i	89.97 c-i	89.95 efg	88.65 ijk	90.25 i-l
Hybrid line-20	38.45 abc	57.69	63.93	71.13 a-g	91.83 c-h	95.55 c-g	94.20 f-k	93.53 f-j
BRRI dhan28	35.85 bcd	53.14	61.29	72.95 a-e	106.74 a	107.76 a	103.50 abc	103.10 ab
BRRI dhan29	32.18 d	51.16	55.00	71.49 a-g	86.19 g-j	98.39 bcd	102.29 a-d	101.51 abc
ACI-1	39.28 ab	57.91	61.85	68.86 b-i	84.49 hij	100.89 abc	101.89 a-e	100.58 bcd
Sampad	37.82 abc	55.29	61.01	75.48 a	90.91 c-i	106.73 a	106.59 a	106.25 a
LSD (.05)	3.80	Ns	Ns	6.29	7.43	8.06	7.41	5.61
CV%	6.12	8.27	8.24	5.42	4.97	5.12	4.71	3.63

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

Within a column, means followed by the same letter(s) are not significantly different at 5% level of probability by LSD.

Ns = nonsignificant at 5% level of significance.

Table 2 : Total tillers hill^{-1} of selected hybrid lines and check varieties of boro rice

Treatment	Total tiller hill^{-1} at different days after transplanting							
	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	90 DAT	At harvest
Hybrid line-1	5.87 e-h	9.93 c-g	11.80 b-g	19.65 b-e	12.03 def	12.69 d-h	14.17 b-e	12.7 c-f
Hybrid line-2	5.60 fgh	9.67 d-g	10.93 efg	16.56 de	11.40 ef	11.11 h	11.42 ghi	10.30 f
Hybrid line-3	5.36 gh	9.20 fg	11.33 d-g	18.29 cde	11.08 ef	12.35 e-h	11.87 f-i	11.58 ef
Hybrid line-4	6.50 c-h	10.33 b-g	13.40 a-f	19.53 b-e	15.77 abc	15.80 abc	14.00 c-f	12.44 def
Hybrid line-5	7.90 abc	12.73 a-e	15.93 a	26.73 a	16.83 ab	15.33 a-d	16.33 ab	17.78 a
Hybrid line-6	6.17 d-h	10.20 b-g	11.13 efg	17.18 cde	10.73 f	13.53 b-h	12.64 d-h	14.18 b-e
Hybrid line-7	6.17 d-h	10.80 a-g	13.60 a-e	20.03 b-e	13.33 c-f	13.58 b-h	13.61 c-h	13.80 b-e
Hybrid line-8	5.42 gh	9.33 efg	10.47 g	15.60 e	11.78 ef	11.78 gh	10.31 i	12.62 def
Hybrid line-9	7.01 b-g	9.60 d-g	10.60 g	18.43 cde	13.67 b-f	14.47 b-g	12.75 d-h	13.84 b-e
Hybrid line-11	7.65 a-d	13.60 ab	13.07 b-g	18.02 cde	11.78 ef	13.20 c-h	13.64 c-g	12.13 def
Hybrid line-12	4.99 h	8.00 g	10.80 fg	18.53 b-e	11.83 ef	12.82 d-h	12.16 e-i	13.08 c-f
Hybrid line-13	7.72 a-d	13.00 a-d	14.07 a-d	20.93 bcd	15.09 a-d	13.87 b-g	15.42 bc	14.80 a-e
Hybrid line-14	7.22 b-f	11.33 a-g	12.47 b-g	18.00 cde	13.61 b-f	13.07 d-h	11.67 ghi	12.72 c-f
Hybrid line-15	6.69 c-g	10.40 b-g	11.60 c-g	19.27 b-e	13.94 b-f	14.27 b-g	12.20 e-i	12.80 c-f
Hybrid line-16	5.52 gh	9.40 efg	11.07 efg	17.62 cde	13.11 c-f	12.53 e-h	12.90 d-h	11.98 def
Hybrid line-17	8.64 ab	14.00 a	14.53 ab	20.18 bcd	14.05 b-e	15.03 b-e	14.73 bcd	14.20 b-e
Hybrid line-18	6.35 c-h	9.47 efg	11.00 efg	17.48 cde	11.55 ef	12.27 fgh	11.75 f-i	13.53 b-f
Hybrid line-19	6.70 c-g	11.87 a-f	13.07 b-g	20.14 bcd	14.22 b-e	14.48 b-f	14.33 b-e	16.03 abc
Hybrid line-20	5.85 e-h	8.93 fg	11.80 b-g	17.90 cde	13.88 b-f	12.08 fgh	12.48 d-i	11.98 def
BRRI dhan28	7.36 a-e	11.07 a-g	13.07 b-g	19.13 b-e	16.33 abc	16.00 ab	15.33 bc	15.23 a-d
BRRI dhan29	8.91 a	13.20 abc	13.67 a-e	23.00 ab	18.11 a	17.92 a	17.92 a	16.57 ab
ACI-1	5.86 e-h	10.07 c-g	11.80 b-g	17.83 cde	11.27 ef	11.80 fgh	10.20 i	11.80 ef
Sampad	6.76 c-g	12.27 a-f	14.13 abc	21.13 bc	13.18 c-f	12.16 fgh	11.33 hi	13.77 b-e
LSD (.05)	1.68	3.42	2.78	4.51	3.24	2.69	2.29	3.39
CV%	15.44	19.23	13.62	14.3	14.68	12.05	10.58	15.29

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

Within a column, means followed by the same letter(s) are not significantly different at 5% level of probability by LSD.

Table 3 : Total dry matter weight $hill^{-1}$ of selected hybrid lines and check varieties of boro rice

Treatment	Total dry matter weight (g $hill^{-1}$) at different days after transplanting			
	30 DAT	60 DAT	90 DAT	At harvest
Hybrid line-1	2.44 ab	17.83	33.00	57.27 b-f
Hybrid line-2	1.70 b	12.00	29.83	43.09 f
Hybrid line-3	1.82 b	10.67	32.00	44.91 ef
Hybrid line-4	2.50 ab	8.17	28.33	48.56 def
Hybrid line-5	1.96 b	12.17	34.33	58.60 b-f
Hybrid line-6	1.59 b	13.00	28.00	44.20 f
Hybrid line-7	1.73 b	13.83	35.67	54.12 b-f
Hybrid line-8	1.90 b	15.33	30.33	57.47 b-f
Hybrid line-9	2.00 b	16.17	29.83	42.48 f
Hybrid line-11	1.80 b	14.33	29.33	49.66 def
Hybrid line-12	2.04 b	16.00	36.17	45.17 ef
Hybrid line-13	2.64 ab	17.83	28.17	65.93 a-d
Hybrid line-14	2.71 ab	12.50	32.00	44.14 f
Hybrid line-15	3.62 a	16.00	33.00	49.27 def
Hybrid line-16	1.72 b	11.50	27.50	44.49 f
Hybrid line-17	2.37 ab	11.33	28.83	72.21 ab
Hybrid line-18	2.38 ab	16.50	37.50	45.58 ef
Hybrid line-19	2.95 ab	19.33	31.67	57.60 b-f
Hybrid line-20	3.47 a	11.33	29.67	51.94 c-f
BRRI dhan28	3.69 a	16.67	46.67	69.23 abc
BRRI dhan29	2.88 ab	12.00	39.33	84.77 a
ACI-1	3.63 a	16.50	31.83	55.52 b-f
Sampad	3.72 a	18.67	44.67	63.90 b-e
LSD (.05)	1.42	Ns	Ns	19.07
CV%	34.63	32.79	25.70	21.33

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.

Within a column, means followed by the same letter(s) are not significantly different at 5% level of probability by LSD.

Ns = nonsignificant at 5% level of significance.

4.2 Yield contributing parameters

4.2.1 Effective tillers hill^{-1}

Different varieties and lines showed a significant variation in number of effective tillers hill^{-1} (Table 4 and Appendix VIII). Results indicated that the highest number of effective tillers hill^{-1} (16.93) was found in Hybrid line-5 which was statistically similar to BRRI dhan29, BRRI dhan28, Hybrid line-13 and Hybrid line-19 (16.00, 13.73, 13.80 and 13.53 respectively). The lowest number of effective tillers hill^{-1} was obtained from Hybrid line–08 (9.40).

The results support the findings of Patnaik *et al.* (1990) and BRRI (1991) who observed that effective tillers producing capacity depends on the performance of different varieties.

4.2.2 Panicle length (cm)

Panicle length was significantly influenced by different hybrid lines and inbred an hybrid rice varieties under the present study (Table 4 and Appendix VIII). Different length of panicle was observed due to its varietal performance. Results showed that the longest panicle (27.85 cm) was produced by Hybrid line-11 which was closely followed by Hybrid line-12 (27.75 cm) and Hybrid line-9 (26.61 cm). On the other hand, the shortest panicle length (23.17 cm) was found in Hybrid line-18 which was statistically similar to Hybrid line-7 (23.31 cm) and Hybrid line-4 (23.95 cm).

The results obtained under the present study were in conformity with the findings of Wang *et al.* (2006).

4.2.3 Total grains panicle^{-1}

Performance of test varieties and lines under the present study showed a significant difference in respect of total grains panicle^{-1} (Table 4 and Appendix VIII). The highest number of total grains panicle^{-1} (214.00) was observed in BRRI dhan29 which was statistically similar to Sampad (205.20). Among the hybrid varieties, Hybrid line-16 showed better performance for grains panicle^{-1}

than all the other hybrids (182.87) which was statistically similar to Hybrid line-9 (181.47). Hybrid line-19 produced the lowest number of total grains panicle^{-1} (128.87) which was statistically similar to Hybrid line-18 (142.67) and Hybrid line-5 (143.20).

4.2.4 Filled grains panicle^{-1}

Number of filled grains panicle^{-1} was significantly influenced by test varieties and lines under the present study (Table 4 and Appendix VIII). BRRI dhan29 produced the highest number of filled grains panicle^{-1} (184.67) which was statistically similar to BRRI dhan28 (167.80) and ACI-1 (167.33). Among the hybrids, Hybrid line-20 showed the best performance (154.35) for filled grains panicle^{-1} which was statistically similar to Hybrid line-15 (151.00). On the other hand, the lowest number of filled grains panicle^{-1} was observed in Hybrid line-19 (97.53) which was statistically similar to Hybrid line-11 (100.33).

The results obtained by Murthy *et al.* (2004), Bhowmick and Nayak (2000) and Patel (2000) was in agreement with findings of present study.

4.2.5 Unfilled grains panicle^{-1}

Different varieties an lines had significant effect on unfilled grains panicle^{-1} (Table 4 and Appendix VIII). Results showed that the highest number of unfilled grains panicle^{-1} was observed in Sampad (54.80), which was statistically similar with Hybrid line-11 (51.07), Hybrid line-16 (49.80), Hybrid line-9 (45.13) and Hybrid line-13 (43.47). On the other hand, the lowest number of unfilled grains panicle^{-1} (9.13) was obtained from ACI-1, which was statistically similar to Hybrid line-18 (17.00), Hybrid line-5 (17.67), Hybrid line-7 (17.53), BRRI dhan28 (19.00) and Hybrid line-8 (21.73).

4.2.6 Weight of 1000 grains (g)

Significant influence of different varieties lines was observed on 1000-grain weight (Table 4 and Appendix VIII). It was observed that the highest 1000-grain weight (30.64 g) was obtained from ACI-1 which was significantly different from all other test varieties. Among the hybrids, Hybrid line-8 showed the higher value (28.11 g) for 1000-grain weight compare to others and it was statistically similar to Hybrid line-19 (27.30 g), Hybrid line-7 (26.81 g) and Hybrid line-2 (26.28 g). On the other hand, the lowest 1000-grains weight was observed in BRRI dhan29 (20.99 g) which was statistically similar with BRRI dhan28 (22.20 g), Hybrid line-17 (22.49 g), Sampad (22.64 g) and Hybrid line-11 (22.65 g).

The results are in agreement with the findings of Rahman *et al.* (2002) who observed the varied 1000-grains weight among different varieties of rice.

Table 4: Yield contributing characters of selected hybrid lines and check varieties of boro rice

Treatment	Effective tillers $Hill^{-1}$ (no.)	Panicle length (cm)	Total Grains $panicle^{-1}$ (no.)	Filled grains $panicle^{-1}$ (no.)	Unfilled grains $Panicle^{-1}$ (no.)	1000-grain weight (gm)
Hybrid line-1	10.93 cde	25.14 d-h	176.80 c-f	147.53 b-e	29.27 f-j	25.24 d-g
Hybrid line-2	9.93 cde	25.04 d-h	168.87 c-g	137.13 cde	31.73 d-h	26.28 b-e
Hybrid line-3	11.33 cde	24.92 e-h	176.07 c-f	147.47 b-e	28.60 f-j	24.84 d-g
Hybrid line-4	11.27 cde	23.95 hi	156.47 e-h	128.13 d-g	28.33 f-j	24.27 e-h
Hybrid line-5	16.93 a	24.33 ghi	143.20 hi	125.53 efg	17.67 ijk	23.32 ghi
Hybrid line-6	11.00 cde	25.61 cde	153.67 fgh	113.53 fgh	40.13 b-f	24.43 e-h
Hybrid line-7	11.00 cde	23.31 i	154.73 fgh	137.20 cde	17.53 ijk	26.81 bcd
Hybrid line-8	9.40 e	25.07 d-h	156.53 e-h	134.80 c-f	21.73 g-k	28.11 b
Hybrid line-9	11.33 cde	26.61 abc	181.47 bc	136.33 c-f	45.13 a-d	25.23 d-g
Hybrid line-11	10.27 cde	27.85 a	151.40 ghi	100.33 gh	51.07 ab	22.65 hij
Hybrid line-12	9.80 de	27.75 ab	170.33 c-g	140.93 cde	29.40 f-j	24.47 e-h
Hybrid line-13	13.80 abc	24.75 e-h	180.80 cd	137.33 cde	43.47 a-e	24.30 e-h
Hybrid line-14	10.87 cde	26.59 bc	168.67 c-g	134.60 c-f	34.07 d-g	23.68 f-i
Hybrid line-15	10.20 cde	25.44 c-g	181.40 cd	151.00 bc	30.40 e-j	23.91 f-i
Hybrid line-16	10.80 cde	26.21 cd	182.87 bc	133.07 c-f	49.80 abc	25.41 c-f
Hybrid line-17	12.47 b-e	24.69 e-h	157.67 d-h	125.53 efg	32.13 d-h	22.49 hij
Hybrid line-18	11.80 cde	23.17 i	142.67 hi	125.67 efg	17.00 jk	24.24 e-i
Hybrid line-19	13.53 a-d	25.12 d-h	128.87 i	97.53 h	31.33 d-i	27.30 bc
Hybrid line-20	11.07 cde	24.24 ghi	179.87 cde	154.35 bc	35.87 c-f	24.82 d-g
BRRI dhan28	13.73 abc	24.35 f-i	186.80 bc	167.80 ab	19.00 h-k	22.20 ij
BRRI dhan29	16.00 ab	25.33 d-g	214.00 a	184.67 a	29.33 f-j	20.99 j
ACI-1	9.67 de	25.59 c-f	176.47 c-f	167.33 ab	9.13 k	30.64 a
Sampad	10.73 cde	25.47 c-g	205.20 ab	150.40 bcd	54.80 a	22.64 hij
LSD (.05)	3.88	1.25	23.73	22.48	13.99	2.05
CV%	20.24	3.01	8.52	9.89	26.90	5.05

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD. Within a column, means followed by the same letter(s) are not significantly different at 5% level of probability by LSD.

4.2.7 Unfilled Grains (%)

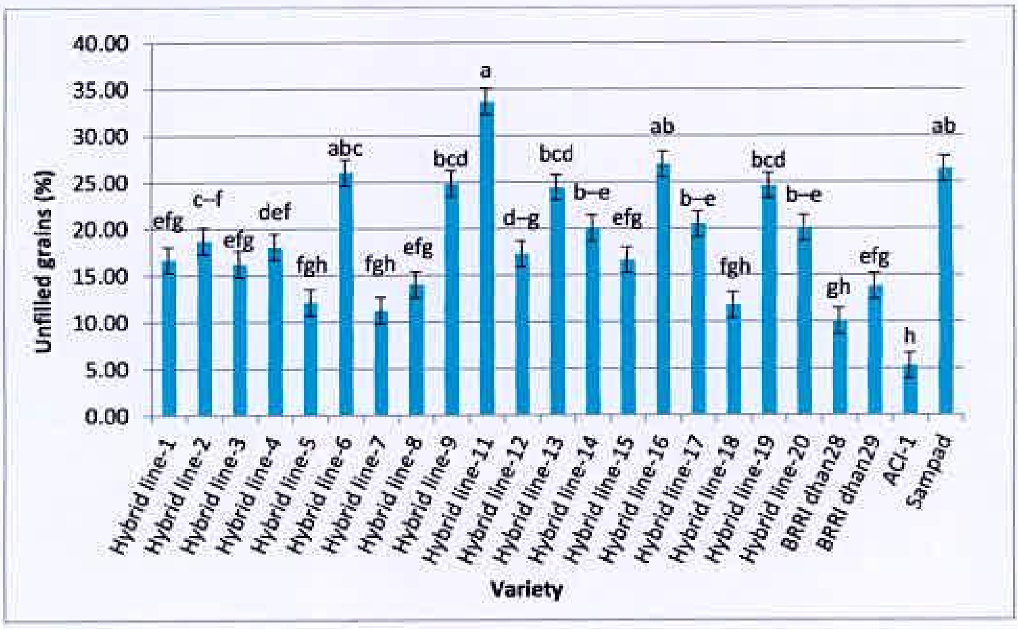


Figure 2: Relative performance of hybrid lines and check varieties on unfilled grains (%) in boro season. Vertical bar represents standard error. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD. (LSD $_{(.05)}$ =7.69)

Different hybrid and inbred varieties and lines had significantly different values for Unfilled Grains (%) (Figure 2 and Appendix VIII). Among the tested 23 varieties, Hybrid line-11 showed the highest value for unfilled grains (33.69%). Hybrid line-6 (26.07%), Hybrid line-16 (26.90%) and Sampad (26.44%) produced higher amount of unfilled grains and these values were statistically similar. On the other hand, ACI-1 (5.29%), BRRI dhan28 (10.10%), Hybrid line-7 (11.26%), Hybrid line-18 (11.82%) and Hybrid line-5 (12.12%) produced lower no. of unfilled grains compared to other tested varieties under study. Among them, ACI-1 (5.29%) produced the lowest no. of unfilled grains. Except the variety Sampad, the other 3 check varieties produced significantly lower percentage of unfilled grains compared to all hybrid varieties.

4.3 Yield parameters

4.3.1 Grain yield hill^{-1} (g)

The performance of any hybrid or inbred variety is finally estimated on the basis of the grain yield (Table 5 and Appendix IX). Different hybrid and inbred varieties and lines produced significantly different grain yield hill^{-1}. BRRI dhan29 produced the highest grain yield hill^{-1} (45.04 g). Among the hybrids, Hybrid line-17 produced higher grain yield hill^{-1} (33.41 g) than the others which was statistically similar to Hybrid line-13 (31.80 g). On the other hand, Hybrid line-6 produced the lowest grain yield hill^{-1} (19.26 g).

4.3.2 Grain yield (t ha^{-1})

Different hybrid and inbred varieties and lines produced significantly variable grain yield (Table 5 and Appendix IX). Among the tested twenty-three varieties, Hybrid line-17 showed it's superiority in producing highest grain yield (10.63 t ha^{-1}) which was statistically similar to Hybrid line–19 (9.63 t ha^{-1}) and Hybrid line-11 (9.56 t ha^{-1}). Among the other hybrids, Hybrid line-5 (8.51 t ha^{-1}), Hybrid line-7 (7.94 t ha^{-1}), Hybrid line-8 (8.18 t ha^{-1}), Hybrid line-14 (8.52 t ha^{-1}) and Hybrid line-15 (8.16 t ha^{-1}) gave lower yield compared to the 3 varieties mentioned above and were statistically similar. Among the check varieties, the grain yield ranged from 7.77 t ha^{-1} (BRRI dhan28) to 8.69 t ha^{-1} (BRRI dhan29) which were significantly higher than most of the hybrids except the highest yielding three hybrids mentioned above. Hybrid line-18 (6.69 t ha^{-1}) produced the lowest grain yield among all the varieties under the present study. The results are in agreement with the findings of Islam *et al.* (2009), Bisne *et al.* (2006) and Siddique *et al.* (2002) who stated that grain yield differed significantly among the varieties.

4.3.3 Straw yield hill^{-1} (g)

Significant variation was found in case of straw yield hill^{-1} among the tested rice varieties and lines under the present study (Table 5 and Appendix IX). Hybrid line-17 produced the highest straw yield hill^{-1} (38.80 g) which was statistically similar to Sampad (33.17 g) and BRRI dhan29 (32.67 g). On the other hand, Hybrid line-16 produced the lowest straw yield hill^{-1} (19.62 g) which was statistically similar to Hybrid line-18 (19.73 g) and Hybrid line-3 (19.87 g).

4.3.4 Straw yield (t ha^{-1})

Straw yield differed significantly due to varietal difference (Table 5 and Appendix IX). Hybrid line-17 produced the highest straw yield (12.42 t ha^{-1}) which was statistically similar to Sampad (10.97 t ha^{-1}). The lowest straw yield was obtained from Hybrid line-16 (5.38 t ha^{-1}) which was statistically similar to Hybrid line-3 (5.40 t ha^{-1}) and Hybrid line-2 (5.57 t ha^{-1}). The differences in straw yield among the varieties may be attributed to the genetic make-up of the varieties. The results uphold with the findings of Patel (2000) and Om *et al.* (1999) where they concluded that straw yield differed significantly among the varieties.

Table 5: Yield performance of selected hybrid lines and check varieties of boro rice

Treatment	Grain yield $hill^{-1}$ (g)	Grain yield (t ha^{-1})	Straw yield $hill^{-1}$ (g)	Straw yield (t ha^{-1})
Hybrid line-1	27.40 b-f	7.20 efg	27.48 b-e	6.70 d-g
Hybrid line-2	23.62 efg	7.49 d-g	20.70 de	5.57 fg
Hybrid line-3	27.44 b-f	7.37 d-g	19.87 e	5.40 g
Hybrid line-4	24.56 d-g	6.77 g	28.44 b-e	5.87 efg
Hybrid line-5	29.94 b-f	8.51 b-f	26.47 b-e	7.99 c-f
Hybrid line-6	19.26 g	6.89 fg	20.94 de	6.24 efg
Hybrid line-7	26.92 c-g	7.94 b-g	27.20 b-e	6.57 d-g
Hybrid line-8	28.81 b-f	8.18 b-g	28.67 a-e	8.13 cde
Hybrid line-9	22.21 fg	7.72 d-g	22.77 cde	5.85 efg
Hybrid line-11	24.06 d-g	9.56 abc	23.83 b-e	7.33 c-g
Hybrid line-12	23.57 efg	8.96 a-d	20.57 de	6.94 d-g
Hybrid line-13	31.80 bcd	7.73 d-g	29.47 a-d	7.28 c-g
Hybrid line-14	23.87 d-g	8.52 b-f	20.90 de	7.27 c-g
Hybrid line-15	26.21 c-g	8.16 b-g	23.07 cde	7.63 c-g
Hybrid line-16	23.56 efg	7.91 c-g	19.62 e	5.38 g
Hybrid line-17	33.41 bc	10.63 a	38.80 a	12.42 a
Hybrid line-18	24.38 d-g	6.69 g	19.73 e	9.68 bc
Hybrid line-19	27.60 b-f	9.63 ab	30.47 abc	6.31 d-g
Hybrid line-20	30.21 b-f	7.85 c-g	21.73 de	8.07 cde
BRRI dhan28	35.10 b	7.77 d-g	23.00 cde	7.59 c-g
BRRI dhan29	45.04 a	8.69 b-e	32.67 ab	8.33 cde
ACI-1	31.12 b-e	8.65 b-e	24.40 b-e	8.76 bcd
Sampad	30.04 b-f	8.14 b-g	33.17 ab	10.97 ab
LSD (.05)	**8.13**	**1.71**	**10.04**	**2.48**
CV%	**17.75**	**12.77**	**24.04**	**20.16**

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.
Within a column, means followed by the same letter(s) are not significantly different at 5% level of probability by LSD.

4.3.5 Biological yield (t ha^{-1})

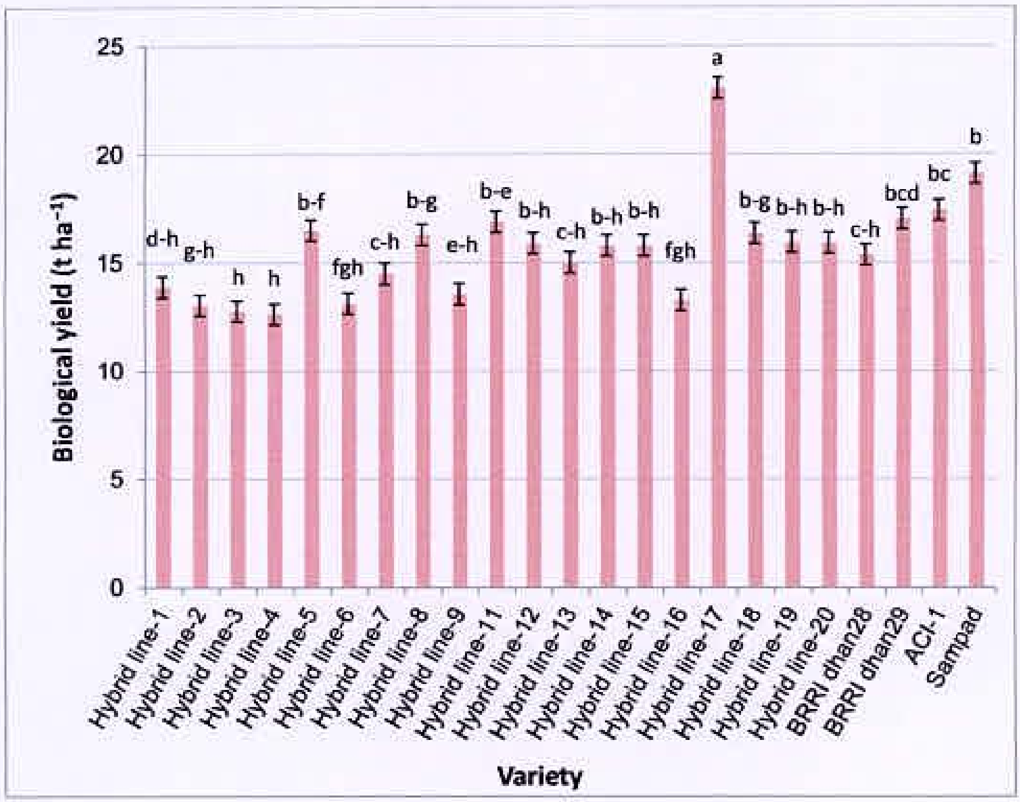


Figure 3: Relative performance of some hybrid lines and check varieties on biological yield in boro season. Vertical bar represents standard error. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD. (LSD $_{(0.05)}$ =3.43)

Significant influence of different varieties and lines was observed on biological yield (Figure 3 and Appendix IX). Among the hybrid varieties, biological yield ranged from 12.64 t ha^{-1} in Hybrid line-4 to 23.05 t ha^{-1} in Hybrid line-17. In case of checks, BRRI dhan28 showed the lowest value (15.36 t ha^{-1}) and ACI-1 showed the highest value (19.11 t ha^{-1}). Most of the hybrids showed lower biological yield than the check varieties except Hybrid line-17. The differences in biological yield may be attributed to the genetic make-up of the varieties.

4.3.6 Harvest index (%)

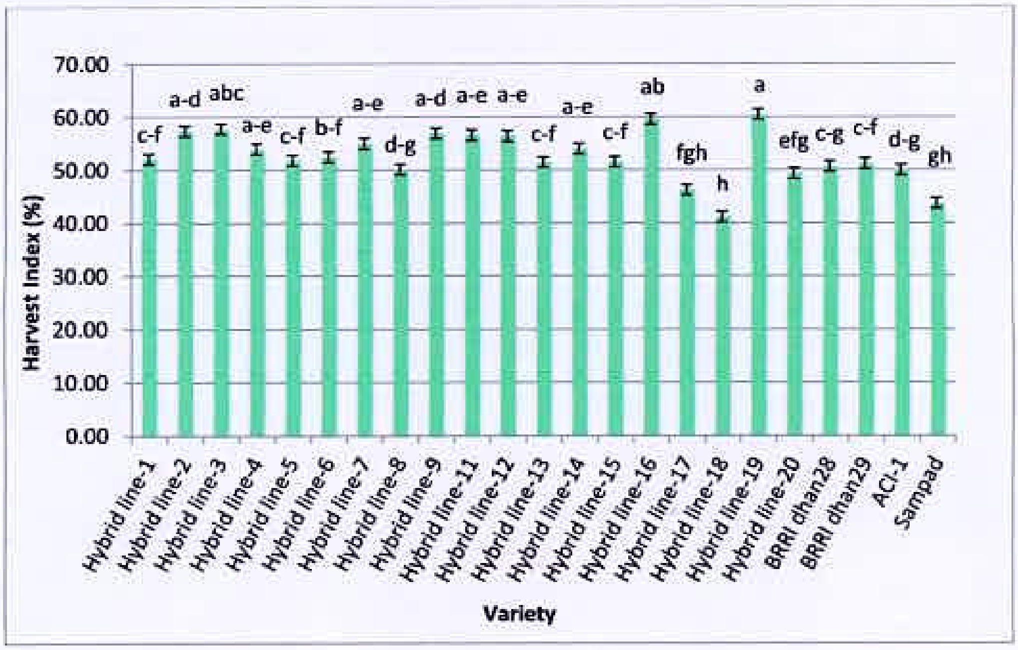


Figure 4: Relative performance of some hybrid lines and check varieties on harvest index in boro season. Vertical bar represents standard error. Bars with different letters are significantly different at $p \leq 0.05$ applying LSD. (LSD $_{(0.05)}$ =7.46)

Harvest index was significantly influenced by different hybrid and inbred varieties and lines under the present study (Figure 4 and Appendix IX). Results focused that the highest harvest index (60.50%) was observed in Hybrid line-19 which was statistically at par with Hybrid line-2 (57.35%), Hybrid line-3 (57.71%), Hybrid line-4 (53.92%), Hybrid line-7 (54.95%), Hybrid line-9 (56.91%), Hybrid line-11 (56.60%), Hybrid line-12 (56.37%), Hybrid line-14 (54.04%) and Hybrid line-16 (59.58%). The lowest harvest index (41.18%) was observed in Hybrid line-18 which was statistically at par with Sampad (43.70%). Almost all the hybrid varieties exhibited better harvest index than the inbred check varieties under the present study. Jiang *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.

4.4 Days to 50% flowering

The number of days taken for 50% flowering ranged from 110 days (Hybrid line-1 and Hybrid line-2) to 85 days (Hybrid line-20, BRRI dhan29, ACI-1 and Sampad) (Table 6 and Appendix X). Among the hybrid lines, Hybrid line-1, Hybrid line-2 and Hybrid line-18 showed minimum days to 50 % flowering (110 days). Among the check varieties, BRRI dhan28 showed earlier flowering (115 days) and BRRI dhan29, ACI-1 and Sampad showed delayed flowering (125 days). Most of the hybrid lines showed minimum days to 50 % flowering than the check varieties except Hybrid line-20 (125 days). All the check varieties were taller than the hybrid lines and took more days to 50 % flowering. However, considering this parameter, Hybrid line-1, Hybrid line-2 and Hybrid line-18 could be expected to harvest a bit early. Endo *et al.* (2000) said that flowering occurred by 88 days after seedling emergence of hybrid.

4.5 Days to maturity

Days to maturity among hybrid lines ranged from 142 days (Hybrid line-2, Hybrid line-9 and Hybrid line-16) to 160 days (Hybrid line-4, Hybrid line-5, Hybrid line-6, Hybrid line-7, Hybrid line-8, Hybrid line-13, Hybrid line-14 and Hybrid line-20) (Table 6 and Appendix X). In case of check varieties; BRRI dhan28, ACI-1 and Sampad matured earlier (160 days) than BRRI dhan29 (165 days). The hybrid lines matured 5 to 23 days earlier than the check varieties. From the table it can be said that most of the hybrid lines are early maturing compared to the check varieties under the present study.

Table 6 : Days to 50% flowering and growth duration of selected hybrid lines and check varieties

Treatment	Days to 50% flowering	Days to maturity
Hybrid line-1	110 c	151 c
Hybrid line-2	110 c	142 d
Hybrid line-3	115 b	151 c
Hybrid line-4	115 b	160 b
Hybrid line-5	115 b	160 b
Hybrid line-6	115 b	160 b
Hybrid line-7	110 c	160 b
Hybrid line-8	115 b	160 b
Hybrid line-9	115 b	142 d
Hybrid line-11	115 b	151 c
Hybrid line-12	115 b	151 c
Hybrid line-13	115 b	160 b
Hybrid line-14	115 b	160 b
Hybrid line-15	115 b	145 d
Hybrid line-16	115 b	142 d
Hybrid line-17	115 b	145 d
Hybrid line-18	110 c	151 c
Hybrid line-19	115 b	145 d
Hybrid line-20	125 a	160 b
BRRI dhan28	115 b	160 b
BRRI dhan29	125 a	165 a
ACI-1	125 a	160 b
Sampad	125 a	160 b
LSD (.05)	**3.44**	**3.83**
CV%	**2.75**	**2.04**

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD.
Within a column, means followed by the same letter(s) are not significantly different at 5% level of probability by LSD.

4.6 Yield advantages of hybrid lines over check varieties (%)

A comparative performance of yield advantage of hybrid lines over the check varieties has been presented in tabular form in Table 7. The yield hectare^{-1} for hybrid lines ranged from 6692.95 kg (Hybrid line-18) to 10633.64 kg (Hybrid line-17), with a mean of 8089.97 kg ha^{-1}.

The yield advantage for Hybrid line-17 over check varieties ranged from 22.40% (BRRI dhan29) to 36.79% (BRRI dhan28). In case of Hybrid line-19, yield advantage ranged from 10.84% (BRRI dhan29) to 23.86% (BRRI dhan28). Hybrid line-11 has a range of yield advantage of 10.03% (BRRI dhan29) to 22.97% (BRRI dhan28). Hybrid line-12 showed yield advantage from 3.14% (BRRI dhan29) to 15.26% (BRRI dhan28). These 4 hybrid lines have positive yield advantage over all the check varieties under study.

Yuan *et al.* (2005) reported that *indica* hybrid showed yield increases of 38.46% against an improved inbred variety in Jiangsu province of China. Mishra (2003) reported 18% to 44.9% yield advantage of 17 released *indica* hybrids over standard check from on farm evaluation experiment in India. Yuan (1998) found that an experimental *indica/japonica* hybrid gave 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 inbred with a maximum yield of 11.7 t ha^{-1}.

Table 7: Yield performance of selected hybrid lines and check varieties

Name of hybrid lines	Grain yield (kg ha^{-1})	Yield advantage over check varieties (%)			
		BRRI dhan28	BRRI dhan29	ACI-1	Sampad
Hybrid line-17	10633.64	36.79	22.40	22.91	30.65
Hybrid line-19	9628.65	23.86	10.84	11.29	18.30
Hybrid line-11	9558.94	22.97	10.03	10.49	17.45
Hybrid line-12	8959.91	15.26	3.14	3.56	10.09
Hybrid line-14	8515.93	9.55	− 1.97	− 1.57	4.63
Hybrid line-5	8505.93	9.42	− 2.09	− 1.68	4.51
Hybrid line-8	8182.19	5.26	− 5.82	− 5.43	0.53
Hybrid line-15	8160.94	4.98	− 6.06	− 5.67	0.27
Hybrid line-7	7936.29	2.09	− 8.65	− 8.27	− 2.49
Hybrid line-16	7905.78	1.70	− 9.00	− 8.62	− 2.87
Hybrid line-20	7845.81	0.93	− 9.69	− 9.31	− 3.60
Hybrid line-13	7734.77	− 0.50	− 10.97	− 10.60	− 4.97
Hybrid line- 9	7723.88	− 0.64	− 11.09	− 10.72	− 5.10
Hybrid line- 2	7491.57	− 3.63	− 13.76	− 13.41	− 7.95
Hybrid line- 3	7371.42	− 5.17	− 15.15	− 14.80	− 9.43
Hybrid line- 1	7200.02	− 7.38	− 17.12	− 16.78	− 11.54
Hybrid line-6	6887.07	− 11.40	− 20.7	− 20.40	− 15.38
Hybrid line-4	6773.68	− 12.86	− 22.03	− 21.71	− 16.77
Hybrid line-18	6692.95	− 13.90	− 22.9	− 22.64	− 17.77
Mean	8089.97				
Checks					
BRRI dhan29	8687.37	11.76	0.00	0.41	6.74
ACI-1	8651.55	11.30	− 0.41	0.00	6.30
Sampad	8138.98	4.70	− 6.31	− 5.92	0.00
BRRI dhan28	7773.51	0.00	− 10.52	− 10.15	− 4.49
Mean	8312.85				

4.7 Correlation and Regression study

The relationship between grain yield, biological yield, harvest index, plant height, panicle length, no. of filled and unfilled grains panicle^{-1} etc. varied from variety to variety. As shown in Table 8, the results of association between pairs of yield components among the hybrids revealed that plant height had significant positive correlation with filled grains panicle^{-1} (0.454), biological yield ha^{-1} (0.472) and days to 50% flowering (0.485). Ganesan (2001) reported that plant height, days to flowering, no. of tillers plant^{-1} and productive tillers plant^{-1} had both positive and negative indirect effects on yield. Cristo *et al.* (2000) observed the highest correlation between final height and panicle length and filled grains panicle^{-1} and yield.

Tillers hill^{-1} was found to have highly significant and positive correlation with total dry matter weight hill^{-1} (0.690), effective tillers hill^{-1} (0.900) and grain yield hill^{-1} (0.600) and significant positive correlation with days to maturity (0.415). On the other hand, a significant negative correlation with 1000-grain weight (−0.437) was found in case of tillers hill^{-1}. Padmavathi *et al.* (1996) concluded that number of tillers hill^{-1}, number of panicles plant^{-1}, panicle length and 1000-grain weight were positively associated with grain yield. Ganapathy *et al.* (1994) reported that the number of productive tillers hill^{-1}, panicle length and grains panicle^{-1} had a significant and positive correlation with grain yield.

Total dry matter weight hill^{-1} showed highly significant and positive correlation with effective tillers hill^{-1} (0.617), grain yield hill^{-1} (0.929) and biological yield ha^{-1} (0.583) and significant positive correlation with filled grains panicle^{-1} (0.429), days to maturity (0.424) and days to 50% flowering (0.434). Chauhan *et al.* (1999) said that grain yield was positively correlated with dry matter weight at 50% flowering, biological yield and harvest index. Kim and Rutger (1988) noted that hybrids that gave higher grain yield also produced higher biomass.

Table 8 : Estimates of simple correlation coefficients for yield and yield components in hybrid lines and check varieties

Variables	Plant height	Tillers hill^{-1}	Total dry matter weight hill^{-1}	Effective tillers hill^{-1}	Panicle Length	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000 grain weight	Grain yield hill^{-1}	Grain yield plot^{-1}	Grain yield ha^{-1}	Biological yield ha^{-1}	Harvest index	Days to maturity	Days to 50% flowering
Plant height	-														
Tillers hill^{-1}	−0.132	-													
Total dry matter weighthill^{-1}	0.368	0.690 (**)	-												
Effective tillers hill^{-1}	−0.120	0.900 (**)	0.617 (**)	-											
Panicle Length	0.407	−0.287	−0.258	−0.333	-										
Filled grains panicle^{-1}	0.454 (*)	0.053	0.429 (*)	0.081	−0.142	-									
Unfilled grains panicle^{-1}	0.211	−0.175	−0.127	−0.136	0.537 (**)	−0.286	-								
1000 grain weight	−0.201	−0.437 (*)	−0.370	−0.490 (*)	−0.071	−0.085	−0.373	-							
Grain yield hill^{-1}	0.412	**0.600 (**)**	**0.929 (**)**	0.613 (**)	−0.281	0.636 (**)	−0.256	−0.303	-						
Grain yield plot^{-1}	0.394	0.156	0.404	0.185	0.392	−0.179	0.091	−0.097	0.330						
Grain yield ha^{-1}	0.394	0.156	0.404	0.185	0.392	−0.179	0.091	−0.097	0.330	1.000 (**)	-				
Biological yield ha^{-1}	0.472 (*)	0.228	0.583 (**)	0.191	0.017	0.045	−0.032	−0.248	0.486 (*)	0.745 (**)	0.745 (**)	-			
Harvest index	−0.207	−0.197	−0.396	−0.088	0.442 (*)	−0.286	0.212	0.249	−0.348	0.092	0.092	−0.588(**)	-		
Days to maturity	0.075	0.415 (*)	0.424 (*)	0.258	−0.277	0.373	−0.281	−0.124	0.444 (*)	−0.173	−0.173	0.086	−0.396	-	
Days to 50% flowering	0.485 (*)	0.115	0.434 (*)	0.134	0.073	0.531 (**)	0.095	−0.026	0.545 (**)	0.244	0.244	0.376	−0.265	0.512 (*)	-

* Significant at 5% Level of Probability, ** Significant at 1% Level of Probability.

Effective tillers hill^{-1} had highly significant and positive correlation with grain yield hill^{-1} (0.613). On the other hand, it showed significant negative correlation with 1000-grain weight (−0.490). Ganapathy *et al.* (1994) concluded that the number of productive tillers hill^{-1}, panicle length and grains panicle^{-1} had a significant and positive correlation with grain yield. Sathya *et al.* (1999) stated that productive tillers hill^{-1} was the principal character responsible for higher grain yield hill^{-1} followed by 1000-grain weight, days to 50% flowering, plant height and harvest index as they had positive and significant correlation with yield. In the present study a significant correlation between effective tillers hill^{-1} and grain yield and negative correlation between harvest index and effective tiller hill^{-1} is observed.

Panicle length was found to be highly significant and positively correlated with unfilled grains panicle^{-1} (0.537) and significantly and positively correlated with harvest index (0.442).

Filled grains panicle^{-1} showed highly significant and positive correlation with grain yield hill^{-1} (0.636) and days to 50% flowering (0.531). Iftekharuddaula *et al.* (2001) reported that days to maturity, days to 50% flowering and plant height had positive and higher indirect effect on grain yield through grains panicle^{-1}. Mahajan *et al.* (1993) indicated that grain yield hill^{-1} was positively and significantly correlated with straw yield hill^{-1} and filled grain panicle^{-1}. Chaudhary and Motiramani (2003) reported that grain yield hill^{-1} showed significant positive correlation with effective tillers hill^{-1}, spikelet's density and biological yield hill^{-1}. Chaudhary and Motiramani (2003) concluded that filled grains panicle^{-1} showed significant positive correlation with effective tillers plant^{-1}, spikelet's density and biological yield plant^{-1}. Dhananjaya *et al.* (1998) evaluated some 121 rice genotypes. Grain yield was positively correlated with number of filled grains panicle^{-1}, harvest index, panicle density, 1000-grain weight, number of productive tillers hill^{-1}and plant height. Liu and Yuan (2002) studied the relationships between high-yielding potential and yielding traits. Filled grains panicle^{-1} was positively correlated with biomass, harvest index and grain weight plant^{-1}.

Grain yield hill^{-1} was found to be highly significant and positively correlated with days to 50% flowering (0.545) and positively correlated with biological yield ha^{-1} (0.486) and days to maturity (0.444). Grain yield plot^{-1} was found to be perfectly and positively correlated with grain yield ha^{-1} (1.000) and highly significant and positively correlated with biological yield ha^{-1} (0.745). Sathya *et al.* (1999) studied 24 hybrids and 11 parents. Days to 50% flowering was the principal character responsible for grain yield hill^{-1} followed by 1000-grain weight, plant height and harvest index as they had positive and significant correlation with yield. Paul and Sharma (1997) noted that yield was positively correlated with days to maturity, plant height and filled grains panicle^{-1}. Geetha *et al.* (1994) studied six hybrids for grain characters where correlation analysis revealed that only grains plant^{-1} had a strong positive correlation with grain yield.

Biological yield ha^{-1} showed highly significant but negative correlation with Harvest index (−0.588). Peng *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. Similarly positive significant correlation between biological yield and different parameters has also been reported by several researchers on rice (Siddiq and Reddy, 1984; Malik *et al.*, 1988; Ganesan and Subramaniam, 1990). Peng *et al.* (2000) concluded that the increasing trend in yield of cultivars was mainly due to the improvement in harvest index. Ashvani *et al.* (1997) stated that 1000 grain weight and total biological yield hill^{-1} may be considered for further improvement of rice.

Days to 50% flowering had positive correlation with days to maturity (0.512).

From the discussion, it can be said that plant height, tiller number hill^{-1}, total dry weight, no. of effective tillers hill^{-1}, filled grains panicle^{-1}, days to maturity and days to 50% flowering seem to be directly correlated with grain yield $hill^{-1}$. 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.

Hybrid line-17 was found to be the highest yielding variety among all the varieties under the present study. In case of Hybrid line-17, regression analysis revealed that increases in tillers $hill^{-1}$ (Figure 5), dry matter weight $hill^{-1}$ (Figure 6) and effective tillers $hill^{-1}$ (Figure 7), was correlated with the corresponding increase in grain yield $plot^{-1}$. Similarly, increases in unfilled grains $panicle^{-1}$ (Figure 8) was correlated with the corresponding decrease in grain yield $plot^{-1}$.

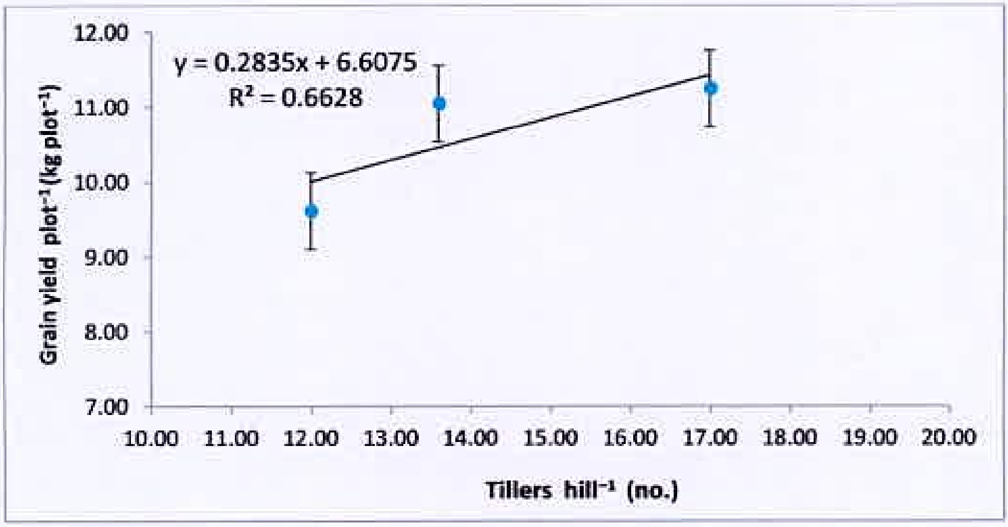


Figure 5: Relationship between the grain yield $plot^{-1}$ and tillers $hill^{-1}$ at harvest for Hybrid line-17. R^2 calculated as 5% level of significance. Vertical bar represents standard error.

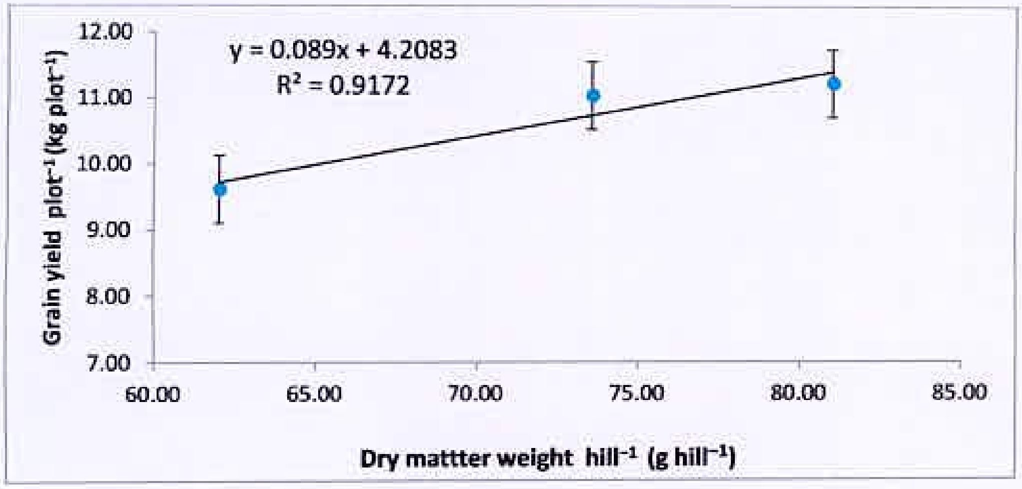


Figure 6: Relationship between the grain yield plot^{-1} and dry matter weight hill^{-1} at harvest for Hybrid line-17. R^2 calculated as 5% level of significance. Vertical bar represents standard error.

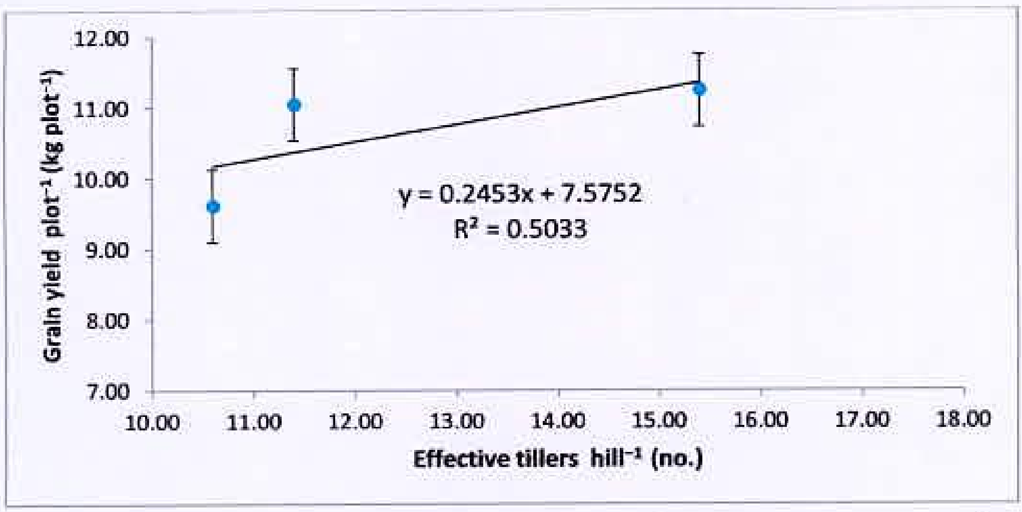


Figure 7: Relationship between the grain yield plot^{-1} and effective tillers hill^{-1} at harvest for Hybrid line-17. R^2 calculated as 5% level of significance. Vertical bar represents standard error.

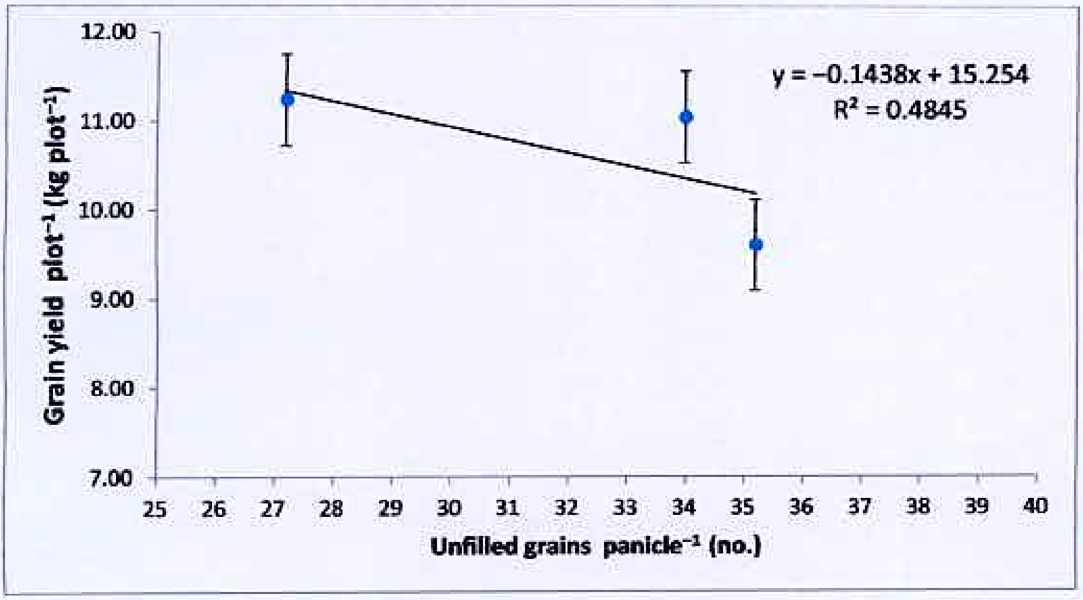


Figure 8: Relationship between the grain yield plot^{-1} and unfilled grains panicle^{-1} at harvest for Hybrid line-17. R^2 calculated as 5% level of significance. Vertical bar represents standard error.

Chapter V

Summary and Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy field of central research farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from January 2015 to June 2015 to study the 'performance of some hybrid and inbred rice varieties in boro season'.

The experiment comprised of 23 varieties viz. (i) BRRI dhan28 (check), (ii) BRRI dhan29 (check), (iii) ACI-1 (check), (iv) Sampad (check), (v) Hybrid line-1, (vi) Hybrid line-2, (vii) Hybrid line-3, (viii) Hybrid line-4, (ix) Hybrid line-5, (x) Hybrid line-6, (xi) Hybrid line-7, (xii) Hybrid line-8,(xiii) Hybrid line-9, (xiv) Hybrid line-11, (xv) Hybrid line-12, (xvi) Hybrid line-13, (xvii) Hybrid line-14, (xviii) Hybrid line-15, (xix) Hybrid line-16, (xx) Hybrid line-17, (xxi) Hybrid line-18, (xxii) Hybrid line-19 and (xxiii) Hybrid line-20.

The size of the unit plot was 4 m × 2.5 m (10 m^2) having 23 treatments for the present study with three replications. The total number of unit plots of the experiment was 69 (23 × 3). All management practices were done in proper time.

The treatments of the experiment were assigned at random into each replication following the experimental design. The experiment was laid out in Randomized Complete Block Design (RCBD). Seedlings of 40 days old were transplanted following line to line distance 20 cm and hill to hill distance 15 cm with 1 seedling $hill^{-1}$.

Significant variation was recorded for data on growth, yield and yield contributing parameters of experimental materials. Data were collected on crop growth characters like plant height (cm), tillers $hill^{-1}$, dry matter weight $hill^{-1}$ (g) and days to 50% flowering were recorded at different days after transplanting in the field and yield as well as yield contributing characters like effective tillers $hill^{-1}$, panicle length (cm), grains $panicle^{-1}$, filled grains panicle^{-1}, unfilled grains panicle^{-1}, weight of 1000-grains (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) were recorded after harvest. Five hills (excluding border hills) were randomly selected from each plot prior to harvest for collecting data on different crop characters. After sampling the whole plots were harvested at maturity. Data on different crop characters were recorded from the randomly selected hills in each plot. Grain and straw yields were recorded after harvest of whole plot. The analysis was performed using the MSTAT–C (Version 2.10) computer package program developed by Russell (1986). The mean differences among the treatments were compared by least significant difference test (LSD) at 5 % level of significance.

Records on plant height at 30 DAT revealed that Hybrid line-1 showed the highest plant height (39.77 cm) and at 40 DAT, highest plant height was observed in Hybrid line-9 (58.95 cm) among all the varieties. Hybrid line-11 produced the tallest plant at 50 and 60 DAT (66.22 and 75.73 cm), respectively. At 70 and 80 DAT, the highest plant height was recorded from BRRI dhan28 (106.74 cm and 107.76 cm, respectively). Sampad produced the tallest plant at 90 DAT (106.59 cm) and at harvest (106.25 cm). The shortest plant was observed from BRRI dhan29 at 30 and 50 DAT (32.18 cm and 55 cm, respectively). Hybrid line-4 produced the shortest plant at 40 DAT and at harvest (50.24 cm and 83.79 cm, respectively), whereas; Hybrid line-5 produced the shortest plant at 60, 70 and 90 DAT (63.27 cm, 81.91 cm and 87.15 cm, respectively). The shortest plant at 80 DAT was observed from Hybrid line-18 (88.10 cm).

In terms of total tillers hill^{-1}, BRRI dhan29 produced the highest number of tillers hill^{-1} at 30, 70, 80 and 90 DAT (8.91, 18.11, 17.92 and 17.92 respectively). At 40 DAT, Hybrid line-17 produced the highest number of tillers hill^{-1} (14.00). Hybrid line-5 showed the highest number of tillers hill^{-1} at 50, 60 DAT and at harvest (15.93, 26.73 and 17.78, respectively). The minimum tillers hill^{-1} at 30 and 40 DAT was recorded in Hybrid line-12 (4.99

and 8.00 respectively). At 50 and 60 DAT; Hybrid line-8 showed the minimum tillers $hill^{-1}$ (10.47 and 15.60, respectively). Hybrid line-6 produced the lowest number of total tillers $hill^{-1}$ at 70 DAT (10.73). Hybrid line-2 produced the lowest number of total tillers $hill^{-1}$ at 80 DAT and at harvest (11.11 and 10.30, respectively). At 90 DAT, ACI-1 showed the minimum tillers $hill^{-1}$ (10.20).

Records on dry matter weight $hill^{-1}$ revealed that at 30 DAT, the highest dry matter $hill^{-1}$ (3.72 g) was observed in variety Sampad. At 60 DAT, Hybrid line-19 produced the highest dry matter weight $hill^{-1}$ (19.33 g). BRRI dhan28 showed the highest value for dry matter weight $hill^{-1}$ at 90 DAT (46.67 g). At harvest, BRRI dhan29 produced the highest dry matter weight $hill^{-1}$ (84.77 g). On the other hand, Hybrid line-6 produced the lowest dry matter weight $hill^{-1}$ at 30 DAT (1.59 g). At 60 DAT, the lowest dry matter weight $hill^{-1}$ was observed in Hybrid line-4 (8.17 g). Hybrid line-16 produced the lowest dry matter $hill^{-1}$ at 90 DAT (27.50 g). At harvest, Hybrid line-9 produced the lowest dry matter $hill^{-1}$ (42.48 g)

Results indicated that the highest number of effective tillers $hill^{-1}$ (16.93) was found in Hybrid line-5, whereas; the lowest number of effective tillers $hill^{-1}$ was obtained from Hybrid line-8 (9.40). The result designated that Hybrid line-5 produced 23.30%, 5.81% and 22.68% higher effective tillers $hill^{-1}$ than BRRI dhan28, BRRI dhan29 and Hybrid line-13, respectively.

In case of panicle length, the longest panicle (27.85 cm) was produced by Hybrid line-11 and the shortest panicle (23.17 cm) was found in Hybrid line-18. The result designated that Hybrid line-11 produced 14.37%, 9.94% and 20.19% longer panicle than BRRI dhan28, BRRI dhan29 and Hybrid line-18, respectively.

The highest number of total grains $panicle^{-1}$ (214.00) was observed in BRRI dhan29 and the lowest number of total grains $panicle^{-1}$ (128.87) was found in Hybrid line-19. Among the hybrid lines, Hybrid line-16 showed better performance than all the other hybrid lines (182.87). BRRI dhan29 produced

66.05%, 17.02% and 14.56% higher total grains panicle^{-1} than Hybrid line-19, Hybrid line-16 and BRRI dhan28, respectively.

From the experiment, it was observed that BRRI dhan29 produced the highest number of filled grains panicle^{-1} (184.67). The lowest number of filled grains panicle^{-1} was observed in Hybrid line-19 (97.53). BRRI dhan29 produced 89.34% and 10.05% higher filled grains panicle^{-1} than Hybrid line-19 and BRRI dhan28, respectively.

Results showed that the highest number of unfilled grains panicle^{-1} was observed in Sampad (54.80), whereas; the lowest number of unfilled grains panicle^{-1} (9.13) was obtained from ACI-1. Among the hybrid lines, Hybrid line-11 produced higher amount of unfilled grains panicle^{-1} (51.07) than other hybrid lines.

It is attained that the highest 1000-grain weight (30.64 g) was obtained from ACI-1. Among the hybrid lines, Hybrid line-8 showed the higher value (28.11 g) for 1000-grains weight compared to others. On the other hand, the lowest 1000-grains weight was observed in BRRI dhan29 (20.99 g). Hybrid line-8 produced 26.62%, 33.92% and 24.16% higher 1000-grains weight than BRRI dhan28, BRRI dhan29 and Sampad but 9% lower 1000-grains weight than ACI-1.

Among the twenty-three tested varieties, Hybrid line-17 showed it's superiority in producing highest grain yield (10.63 t ha^{-1}) whereas; Hybrid line-18 (6.69 t ha^{-1}) produced the lowest yield among all the varieties under the present study. BRRI dhan28, BRRI dhan29, Hybrid line-11 and Hybrid line-19 also gave comparatively higher grain yield which were 36.79%, 22.40%, 11.19% and 10.38% lower respectively than Hybrid line-17.

In terms of straw yield, Hybrid line-17 gave the highest result (12.42 t ha^{-1}) whereas; the lowest straw yield was obtained from Hybrid line-16 (5.38 t ha^{-1}). Hybrid line-17 produced 63.63%, 49.09% and 28.30% higher straw yield than

BRRI dhan28, BRRI dhan29 and Hybrid line-18, respectively. Most of the hybrid lines produced lower amount of straw yield than the check varieties.

Results focused that the highest harvest index (60.50%) was observed in Hybrid line-19 and the lowest harvest index (41.18%) was observed in Hybrid line-18. Almost all the hybrid lines exhibited better harvest index than the check varieties under the present study.

In case of required days to 50 % flowering, Hybrid line-1, Hybrid line-2 and Hybrid line-18 showed minimum days to 50 % flowering (110 days) and BRRI dhan29, ACI-1, Sampad and Hybrid line-20 showed maximum days to 50 % flowering (125 days). Most of the hybrid lines showed lesser days to 50 % flowering than the check varieties except Hybrid line-20 (125 days). All the check varieties were taller than the hybrid lines and took more days to 50 % flowering.

Days to maturity among hybrid lines ranged from 142 days for Hybrid line-2, Hybrid line-9 and Hybrid line-16 to 160 days for Hybrid line-4, Hybrid line-5, Hybrid line-6, Hybrid line-7, Hybrid line-8, Hybrid line-13, Hybrid line-14 and Hybrid line-20. In case of check varieties; BRRI dhan28, ACI-1 and Sampad matured earlier (160 days) than BRRI dhan29 (165 days).

From the above summary of the study, it can be concluded that among the twenty–three varieties, Hybrid line-17 demonstrated the best performance followed by Hybrid line-19, Hybrid line-11 and Hybrid line-12. On the other hand, Hybrid line-4, Hybrid line-16 and Hybrid line-18 showed lower performance regarding growth, yield and yield contributing characters. In case of check varieties, BRRI dhan28, BRRI dhan29, ACI-1 and Sampad showed comparatively better performance in respect of yield.

Conclusion:

Based on the experimental results, it may be concluded that-

i) Hybrid line-17 and Hybrid line-19 can be treated as the best varieties among the twenty-three varieties from the present study.

ii) For wider acceptability, the same experiment can be repeated at different agro-ecological zones of the country.

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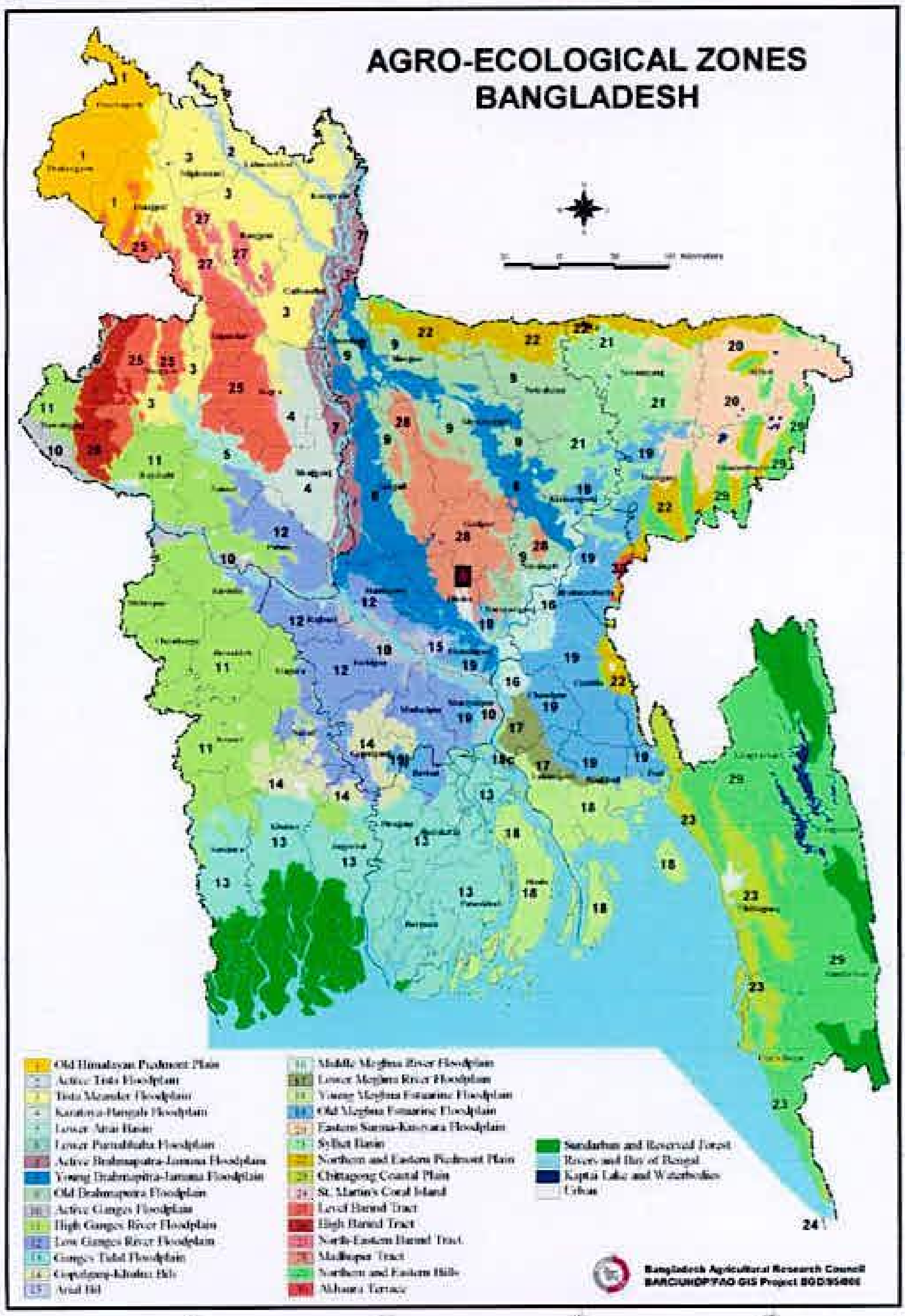
Appendices

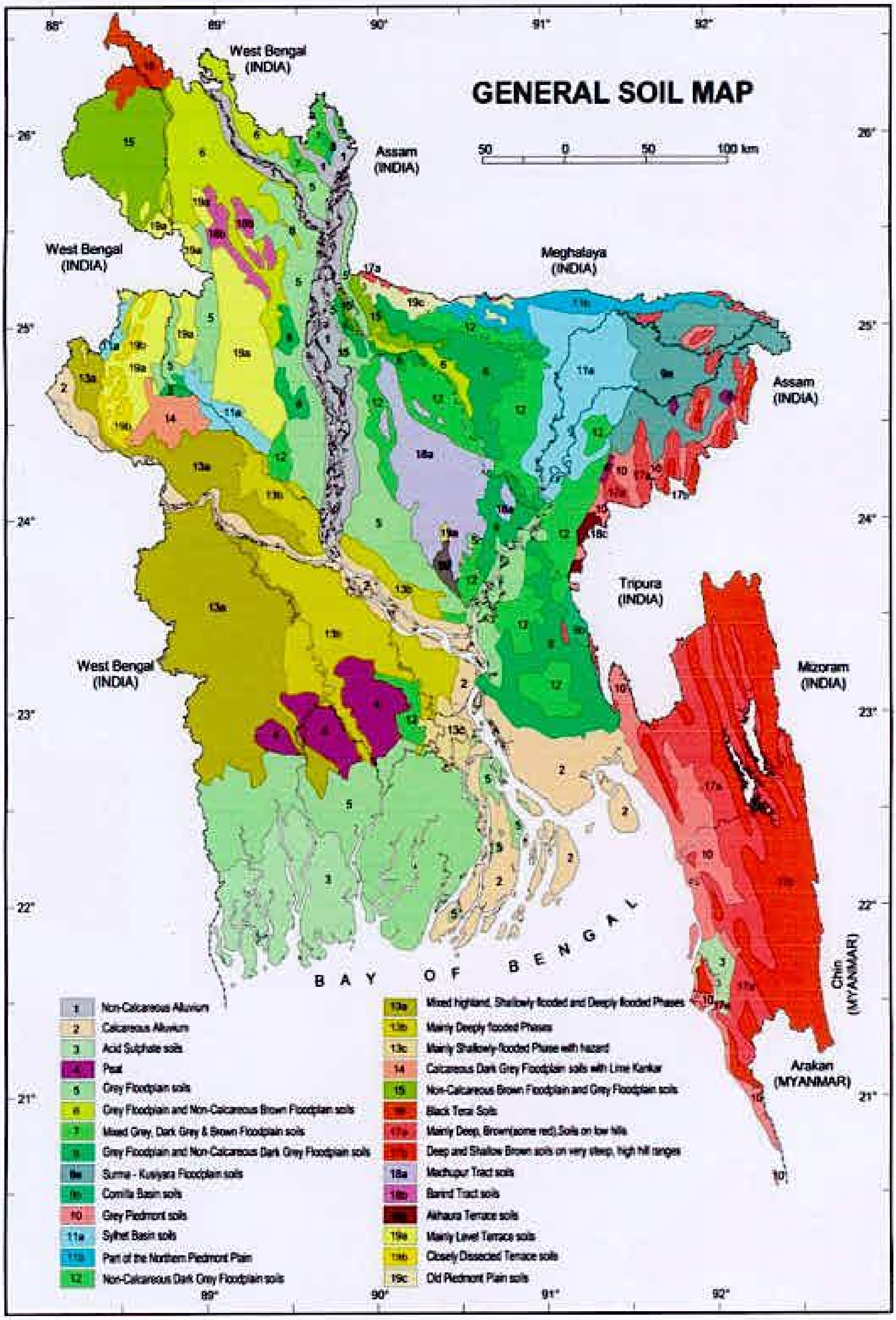
APPENDICES

Appendix I: Map showing the experimental sites under study



■ The experimental site under study

Appendix II: Map showing the general soil sites under study



Appendix III: Characteristics of soil of experimental site is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Experimental field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Boro–Aman–Boro

B. Physical and chemical properties of the initial soil

Characteristics	Value
%Sand	27
%Silt	43
%clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel 1.00 g soil)	0.10
Available S (ppm)	45

Source: SRDI, 2014

Appendix IV: Monthly average of Temperature, Relative humidity, total Rainfall and sunshine hour of the experiment site during the period from January 2015 to May 2015

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
		Maximum	Minimum	Mean			
2015	January	24.73	14.31	19.52	60.52	46	166.26
	February	28.59	17.16	22.88	50.96	3	205.05
	March	32.82	22.11	27.47	48.19	53	222.58
	April	33.45	23.63	28.54	61.87	106.2	241.40
	May	35.18	26.39	30.78	64.77	138.2	219.48

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

Appendix V: Analysis of variance (mean square) of plant height of selected hybrid lines and check varieties at different days after transplanting

Sources of variation	Degrees of freedom	Mean Square of plant height at different days after transplanting							
		30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	90 DAT	At harvest
Replication	2	39.749 **	81.380 *	42.976	66.231 *	8.857	88.988 *	2.324	6.633
Treatment	22	9.666 *	18.114	30.998	42.728 **	98.249 **	108.095 **	101.279 **	105.453 **
Error	44	5.326	20.921	25.318	14.619	20.410	23.999	20.278	11.628

* indicates significant at 5% level of probability.
** indicates significant at 1% level of probability.

Appendix VI: Analysis of variance (mean square) of Total tiller hill^{-1} of selected hybrid lines and check varieties at different days after transplanting

Sources of variation	Degrees of freedom	Mean Square of tiller number hill^{-1} at different days after transplanting							
		30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	90 DAT	At harvest
Replication	2	3.358 *	4.899	4.801	0.830	1.328	26.768 **	0.471	0.059
Treatment	22	3.337 **	8.261 *	6.557 **	16.159 **	11.867 **	8.156 **	10.979 **	9.153 *
Error	44	1.045	4.312	2.856	7.521	3.878	2.672	1.944	4.241

* indicates significant at 5% level of probability
** indicates significant at 1% level of probability

Appendix VII: Analysis of variance (mean square) of dry matter weight hill^{-1} of selected hybrid lines and check varieties at different days after transplanting

Sources of variation	Degrees of freedom	Mean Square of dry matter weight hill^{-1} at different days after transplanting			
		30 DAT	60 DAT	90 DAT	At harvest
Replication	2	16.615 **	51.406	55.721	1334.143 **
Treatment	22	1.575 *	26.114	78.641	361.322 **
Error	44	0.743	22.091	71.687	134.360

* indicates significant at 5% level of probability

** indicates significant at 1% level of probability

Appendix VIII: Analysis of variance (mean square) of yield components of selected hybrid lines and check varieties

Sources of variation	Degrees of freedom	Mean Square of yield components						
		Effective tillers Hill^{-1} (No.)	Panicle length (cm)	Grains panicle^{-1} (No.)	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	Unfilled grains (%)	1000-grain weight (gm)
Replication	2	2.254	1.841	50.094	8.950	17.437	4.869	0.151
Treatment	22	11.405 *	4.249 **	1191.270 **	1223.273 **	418.969 **	133.767 **	13.554 **
Error	44	5.555	0.576	207.939	186.625	72.308	21.857	1.557

* indicates significant at 5% level of probability.

** indicates significant at 1% level of probability.

Appendix IX: Analysis of variance (mean square) of yield of selected hybrid lines and check varieties

Sources of variation	Degrees of freedom	Mean square of yields and harvest index					
		Grain yield hill^{-1} (gm)	Grain yield (t ha^{-1})	Straw yield hill^{-1} (gm)	Straw yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest index (%)
Replication	2	63.062	0.589	453.867 **	1.889	0.379	43.922
Treatment	22	87.018 **	2.732 **	79.122 *	9.166 **	16.409 **	68.178 **
Error	44	24.410	1.078	37.258	2.279	4.345	20.539

* indicates significant at 5% level of probability.

** indicates significant at 1% level of probability.

Appendix X: Analysis of variance (mean square) of days to 50% flowering and maturity of selected hybrid lines and check varieties

Sources of variation	Degrees of freedom	Mean Square of days to 50% flowering and maturity	
		Days to 50 % flowering	Days to Maturity
Replication	2	9.957	15.696
Treatment	22	65.810 **	168.675 **
Error	44	4.366	5.423

* indicates significant at 5% level of probability.
** indicates significant at 1% level of probability.

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