MORPHO- PHYSIOLOGICAL BEHAVIOUR AND YIELD OF HYBRID AND INBRED RICE VARIETIES IN *BORO* SEASON

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A THESIS

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A Thesis

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Dedicated to

My

Beloved Parents

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CERTIFICATE

This is to certify that thesis entitled, "**MORPHO-PHYSIOLOGICAL BEHABIOUR AND YIELD OF HYBRID AND INBRED RICE VARIETIES 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 IN*** Agricultural Botany, research work carried out by **RAFA BINTA EKRAM,** Registration Reg. No. 08-2827 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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ABSTRACT

The experiment was carried out at the research farm of the Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, during August 2013 to May 2014 to evaluate the morpho-physiological changes and yield performance of four hybrid (Heera-4, Aloron, BRRI hybrid-3 and Tia) and two inbred (BRRI dhan-29 and BRRI dhan-34) rice varieties. The experiment was set up in a randomized complete block design with four replications. Growth characters, yield and yield attributes were significantly different among the studied varieties. Hybrid (Heera-4, BRRI hybrid dhan-3) and inbred (BRRI dhan-29 and BRRI dhan-34) varieties exhibited superiority in respect of growth characters viz. tillers hill^{-1}, leaves hill^{-1}, TDM hill^{-1}, leaf area hill^{-1}, LAI, CGR, RGR over Aloron and Tia varieties. However, three hybrids (Heera-4, Aloron, and BRRI hybrid dhan-3) and inbred BRRI dhan-29 showed better performance in yield related characters viz, effective tillers hill^{-1}, panicle length, 1000-grain weight, biological yield, harvest index (HI) over the rest two varieties. So, these three rice varieties (Heera-4, Aloron, and BRRI hybrid dhan-3) produced the higher grain yield compared to BRRI dhan-34 and Tia. Higher grain yield is related with higher dry matter production and partitioning of the afore-mentioned varieties. However, Heera-4 showed the best performance (8.24 t ha^{-1}) closely followed by inbred BRRI dhan-29 (7.20 t ha^{-1}) and then BRRI hybrid-3 (6.65 t ha^{-1}). The hybrid varieties Heera-4 had maximum CGR, RGR particularly in the reproductive stage (90 DAT) possibly for high sink demand and thus, this variety produced around 34% higher yield over the inbred BRRI dhan-34 and Tia. Yield components, effective tillers hill^{-1} and 1000-grain weight mainly contributed to the higher grain yield. These results suggested that the hybrid rice variety, Heera-4 and inbred BRRI dhan-29 were the best among the test varieties.

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Introduction

CHAPTER I

INTRODUCTION

Rice is the second most important food crop around the world and the staple food approximately more than two billion people in Asia (Hien *et al.,* 2006). Ninety percent of all rice is grown and consumed in Asia (Anon., 1997, Luh, 1991). The population of Bangladesh is increasing at an alarming rate and the cultivable land is reducing due to urbanization and industrialization resulting in more shortage of food. The nation is still adding about 2.3 million every year to its total of 150 million people (Momin and Husain, 2009). Thus, the present population will swell progressively to 223 million by the year of 2030 which will require additional 48 million tons of food grains instead of current deficit of about 1.2 million tons every year (Julfiquar *et al*., 2008). So, the highest priority has been given to produce more rice (Bhuiyan, 2002).

In Bangladesh, population is increasing @1.42% (BBS, 2010) and arable land is decreasing @ 0.7% per annum limiting the horizontal expansion of rice area. As it is not possible to have horizontal expansion of rice area, rice yield per unit area should be increased to meet the ever increasing demand of food in the country Higher yield can be achieved by two processes, firstly through the cultivation of hybrid varieties, and secondly by following improved management practices (IRRI, 1993). Physiologist defined growth generally as increase in dry mass. It is the process of cell division and elongation. According to Tanaka (1980) growth is quantitative and qualitative changes that facilitate increased dry matter production and ultimate grain weight. Growth is directly related to various physiological processes such as photosynthesis, respiration, enzyme activity etc. The growth analysis means the calculation of the components viz. CGR, RGR, NAR, etc. These components are widely used by plant physiologists and provide same indices of the plant responses to its environment (Ahlawal and Saraf, 1983). The yield of rice depends on its different growth parameters (i.e. leaf area index, dry matter production and its partitioning, tillering, etc) (Shams, 2002). High dry matter production, leaf area index, leaf area duration (LAD), crop growth rate (Thakur and Patel, 1998).

Grain yield of rice can be increased in many ways of them developing new high yielding variety and by adopting proper agronomic management practices to the hybrid varieties to achieve their potential yield is important. Hybrids are generally more vigorous and larger in size than the parent stock. The young seedlings produce long roots and broad leaves that enable them to take up more nutrients thus, produce more grains. Zhende (1988) stated that hybrid rice has high tillering capacity. During vegetative growth, hybrid rice accumulates more dry matter in the early and middle growth stages which results in more spikelets panicle^{-1}. They have bigger panicles and more spikelets panicle^{-1}. These factors result in higher yields usually 15% or more than ordinary rice, also called inbred (Philrice, 2002). There are other hybrids at present which give an average yield of 5.7 tons/ha during the wet season (Vanzi, 2003). Several hybrid varieties had been developed and released up to the present. Different varieties perform differently in a particular environment. Janaiah and Hossain (2000) reported that although farmers got about

16% yield advantage in the cultivation of hybrids compared to the popularly grown inbred varieties, the gain yield were not stable among hybrids.

However, hybrid rice varieties namely Heera-4, Aloron, BRRI hybrid-3, Tia have been got popularity in Bangladesh and inbred BRRI dhan-29 and BRRI dhan-34 are also popular. But research works on hybrid rice varieties is limited in Bangladesh in relation to their morpho-physiological characteristics. With conceiving the above scheme in mind, the present research work has been undertaken in order to fulfilling the following objectives:

i. To study the morpho-physiological parameters of the two inbred and four hybrid rice varieties in *Boro* season.
ii. To compare the yield performance of hybrid and conventional rice varieties in *Boro* season.

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Yield and yield contributing characters of rice are considerably depended on manipulation of basic ingredients of agriculture. The basic ingredients include variety, environment, agronomic practices and hazards factors. Among the above factors variety until now a considerable matter for rice growing in context of production. Varieties in respect of local, high yielding and hybrid are generally more adaptive to appropriate and they greatly affect the return of rice cultivation. But the available relevant reviews related to variety in respect of their performance are very limited in the context of Bangladesh and also in specific cropping season. Some of the recent past information on varietal performance on rice have been reviewed under the following headings:

2.1 Growth parameters

2.1.1 Plant height

BRRI (1995) reported that average plant height of BR3O, BR22, BR23 and Iratom-24 were 120 cm, 125 cm, 120 cm and 80 cm, respectively. Plant height is significantly and negatively correlated with tillers plant^{-1} and positively with days from transplanting to first panicle emergence. Plant height varied from 182.5 to 206.2 cm for shattering rice, 60.1 to 74.9 cm for Minghui-63 and 186.9 to 199.8 cm for hybrids (Song *et al*., 2004).

Kabir *et al*. (2006) reported that Bigunbitchi produced the tallest plant (66.52cm) at 35 days after transplanting and 50 days after transplanting (83.52cm), whereas chinigura-1 produced the tallest plants at harvest (148.20 cm).

Khisha (2002) observed that plant height was significantly influenced by variety. He found the tallest plant (129.94 cm) in BINA dhan, which significantly higher than those of Sonarbangla-1 and BRRI dhan 29.

Yuan (2010) suggested the plant height for rice is about 100 cm, with cuim length of 70 cm. Hybrids have higher plant height as compared to HYV (Ghosh. 2001).

2.1.2 Tillering pattern

Neda (improved genotype) and Ramazan Ali Tarom (traditional genotypes) had greatest and lowest tillering capacity, respectively (Mahdavi *et al*, 2004). Yuan (2001) suggested that plant is moderately compact type with moderate tillering capacity.

Yang *et al*. (2011) observed that JND3 exhibited a higher tillering capacity than JNDI3.

Nuruzzaman *et al*. (2000) found that plant height and specific leaf area had a strong negative and positive correlation, respectively with maximum tiller number. They observed that tiller number varied widely among the varieties and the number of tillers plant^{-1}' at the maximum tiller number stage ranged between 14.3 and 39.5 in 1995 and 12.2 and 34.6 in 1996. Among all the varieties IR36produced the highest tiller number followed by Suweon 258 and Down which produced the lowest tiller number. It was shown that hybrid produced a significantly higher number of tillers than their parental species and that cultivated Minghui-63 had the least number of tillers hill4 (Song *et. al*., 2009). The maximum tillering occurred at 738 GDD in all genotypes except Neda and Dasht that occurred at 920 GDD.

2.1.3 Leaves hill^{-1}

The rate of decline was the sharpest in local varieties than that of hybrid varieties. The higher LA during 2003 could be attributed to biological variability between the ears that resulted in a different leaf shape (length, width) and possibly number of leaves plant (Baloch *et al*., 2006).

Hassan (2001) showed that photo-synthetically active leaves hill of all varieties increased with the growth period up to booting stage except in Binasail. He also found that maximum number of leaves were produced at the tillering stage and then declined in later stages.

2.1.4 Leaf area hill^{-1}

In rice flag leaf area had positive correlation with grain yield and yield components (Rao, 1992). Briggs and Aylenfisu (1980) recorded a positive and significant association of flag leaf area with grain yield plant^{-1} and 1000-grain weight.

Islam (2006) showed that the increment of leaf area hill^{-1} varied significantly due to genotype at all growth stages. Sharma and haloi (2001) conducted an experiment on scented rice and found that there was remarkable variation in leaf area.

Chandra and Das (2000) found that leaf area was significantly and positively associated with dry matter of culms and grain yield.

Paranhos *et al*. (2008) studied the development of leaf area and found that all the cultivars produced maximum leaf area during panicle initiation stage.

Mahdavi *et al.* (2008) showed that flag leaf area was greater for improved genotypes than traditional genotypes. In this study flag leaf area had positive and poor correlation with grain yield. Cultivars with grater flag leaf area generally have high grain weight (Mahmood and Chowdhary, 2000).

2.1.5 Leaf area index (CGR)

Chandra and das (2002) found that LAI was significantly and positively associates with grain yield. Lu *et al*. (2000) obtained higher yield of rice due to better distribution of LAI after heading 2.1.6 Total dry matter hill^{-1}.

Wada *et al*. (2002) stated that a higher crop growth rate after anthesis mainly due to the high mean LAI during the ripening period. Y

uan (2001) showed that LAI of the top three leaves is about 6. Whereas, Mia *et al. (*1996) showed that LAI of 7.3 is the maximum that is necessary to give high grain yield. Yield increased with increasing LAI and maximum yield at LAI 7.

2.1.6 **Total dry matter (TDM) hill^{-1}**

Achieving greater 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 Fischer, 1999). At flowering the dry matter was genotypes for Jahesh ad was lower of Ramazan All Tarom (923.93 g m2 and 429 g respectively).

Sharma and Haloi (2001) observed that the check variety Kunkuni Joha consistently maintained a high rate of dry matter production at all growth stages and high dry matter accumulation at the panicle in initiation stage.

Chandra and Das (2000) reported that dry matter production of culms and leaves were significantly positively associated with grain yield and leaf area index. Jian Chang *et al*.

(2006) found that highest total dry matter weight at maturity (>22 t ha^{-1}). Mahdavi *et al.* (2004) reported that the photosynthetic potentials of improved genotypes were greater as reflected by their TDM production. TDM had positive correlation with grain yield.

2.1.7 Crop growth rate (CGR)

Rice genotypes having higher CGR during this period produced a greater number of spikelets per unit land area. The higher CGR also led to larger accumulation of non-structural carbohydrate (NSC) in the culms and leaf sheaths during the period that was positively correlated with the rapid translocation of NSC to panicle in the initial period of grain filling. Solar radiation during grain filling was higher in 2000 than 1999. Therefore, Takanari appeared to have succeeded in over 11 t ha^{-1} of grain yield by achievement of both prerequisite biomass production during the late reproductive period and better grain filling. A rice cultivar Takanari showed the highest grain yield among the genotypes across the 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). A large genotypic variability in CGR during the late reproductive period was mainly derived from that in radiation use efficiency.

Mia *et al*. (2000) found that crop growth rate (CGR) during the heading to maturity stage were the lowest among the cultivars due to the gradual decreasing of LAI and SPAD at grain filling stage. The genotypes, which had greatest and lowest dry matter production, had highest and lowest CGR, respectively. It represented high dry matter at flowering stage which influenced grain yield (Pheloung and Siddique, 1991).

Yang *et al*. (2010) found that CGR was significantly positively correlated with yield of rice. However, at the early stage of growth CGR was not significantly different with the yield.

Hone (2006) observed that the most critical growth attribute for rice yield under intensive management is crop growth rate (CGR) during the latter half of the reproductive period (15 to 0 d before heading).

Mahdavi *et al.* (2004) showed that maximum CGR occurred at flowering stage for all genotypes. Generally, CGR was greater in modern genotypes than old genotypes.

2.1.8 Relative growth rate (RGR)

Mahdavi *et al*., (2004) showed that RGR and NAR were higher for traditional genotypes than improved genotypes. RGR had negative and significant correlation with grain yield that was similar to that reported by Pirdashti (1998).

Chatta and Khan (1991) found that RGR had strong positive correlation with NAR.

Zahad *et al*. (2007) observed that RGR of rice was found to be increased steadily during the early growth stage and then decreased slowly. Similar result was also reported by Mia (2001) and Rahman (2002). They observed that the RGR was the highest at the period of 15-30 DAT and then decreased gradually.

Chakma (2006) found that RGR was higher at early vegetative growth stage and gradually decreased with the advancement of plant age. The higher RGR at early vegetative stage might be due to rapid increase of leaf area and there increased metabolic activities.

2.2 Yield attributes

2.2.1 Panicles hill^{-1}

Among yield is mainly a function of the number of panicle bearing tillers unit area.Number of productive tillers plant^{-1} is generally associated with higher productivity. Hybrids recorded significant positive standard heterosis produced more productive tillers plant (Malini *et al*., 2006)

Ashraf *et al*. (1999) stated that transplanting of two and three seedlings hill^{-1} of 35 d old nursery gave more promising results in terms of more productive tillers unit area.

2.2.2 Non- effective tillers hill^{-1}

Chakma (2006) observed that variety had significant effect on the number of non-bearing tillers m^{2}. He also found that BINA dhan-5 had the highest non- bearing tillers m^{-2} (8.61) while the lowest was observed in BINA dhan-6 (6.83).

2.2.3 Panicles

Hossain *et al*., (2003) conducted an experiment with new rice cv. Sonar Bangla-1, BRRI dhan39 and Nijarshail, and reported that the cultivars were not different significantly in panicle length.

Ghosh (2001) noted that hybrids, in general, gave higher values for panicle length compared to cultivars. Chandra and Das (2000) reported that panicle m^2 was significantly and negatively correlated with panicle weight and sterility percentage, while the association of panicle length with panicle weight and 1000-grain weightwas found positive and highly significant.

Diaz *et al*. (2000) noted wide variation in panicle length, panicle type, grain panicle1 and panicle weight and secondary branches panicle^{-1}.

Malini *et al.* (2006) showed that the best hybrid was IR 68885A or white ponni, which showed standard heterosis and heterobeltiosisfor panicle length, spikelets panicle^{-1}, grains panicle^{-1} straw yield and grain yield. The panicle length of the genotype CR 874-59 was observed to be highest (28.8 cm) followed by CR 2008-129 (26.9 cm) (patnaik and Mohanty, 2006) whereas, chakma (2006) found that BINA dhan-5 produced the longest panicle (22.86 cm) followed by BRRI dhan-29 (22.78 cm) and BINA dhan-6 (22.28 cm).

Dixit *et al*. (2008) conducted an experiment with three lines i.e. IR-58025 A, IR-58025 B and BR-827-1-1 R (A,B and R lines respectively) and reported that A line produced the highest of panicles hill (8.9) which was significantly superior to the R and B lines, while the lowest (7.7) was obtained in the R line.

2.2.4 Grains panicle^{-1}

Mishra and Pandey (1998) reported that panicle length, number of filled grains panical^{-1} and 1000- seed weight had contributed for increased grain yield.

Jian Ching *et al.* (2006) found that super-high- yielding rice had more spikelets paniele^{-1} and higher filled-grain percentage (>90%) than the high-yielding rice.

Shriame and Muly (2003) concluded that grain yield was significantly correlated with number of filled grains panicle.

2.2.5 1000-grain weight

Wen and Yang (1991) reported that higher 1000 -grain weight by using one seeding hill^{-1} than with four seeding hill^{-1}.

Lockhart and Wiseman (1988) showed that higher number of tillers reduces the number, size and weight of grain. Thousand-grain weight, an important yield determining component, is a genetic character least influenced by environment (Ashraf *et al*, 2000).

BRRI (1997) reported that weight of 1000- grains of Halio, Tilockachari, Nizershail andLatisail were 26.5 g, 27.7 g, 25.2 g and 25 g respectively. A 1000-grain weight of about 25 g is considered ideal for rice (Kush, 1994).

2.2.6 Crop duration

Rao and Patnaik (2006) observed that most of the long duration hybrids possessed long panicles with high grain number panicle^{-1}. The flowering duration was observed to be longest in CR 874-23 (153 days) followed by CR 758-16 (151 days). The earliest varieties were found to be Swarna(110 days). Hybrid JR 6408A 827 having growth duration of 110 days gave the highest yield of 6.08 MT/ ha in the summer cropping season of 1996, compared to 4.38 MT/ha of CR203 (check), 5.1 MT/ha of Shan You 63, and 4.95 MT/ha of Shan You Gui 99 (DAFE, 2003). In the medium-duration varieties (115-130 d), there was good agreement between simulated and observed leaf area index, biomass, and grain yield. The simulated biomass of long-duration varieties (135-1 50 d) showed large deviation from observed biomass at flowering.

Patnaik and Mohanty (2006) showed that there was a wide variation in the maturity duration of varieties.

2.2.7 Grain yield

The highest yield of 9.2 t ha' was obtained from selected I/J line JR 5865-2B-12-2-2, which was equal to that of indica hybrid CNHR3 and significantly higher than that of modem variety IR 36 (Roy, 2006).

Oad *et al.*(2002) reported that rice grain yield was interrelated with all agronomical and physiological traits including plant height, total dry matter, leaf area index, relative growth rate, crop growth rate,1000-grain weight, panicle length and number of panicle plant^{-1}. A rice cultivar Takanari showed the highest grain yield among the genotypes across the two years, and successfully produced over 11 t ha1 of grain yield (Takai *et al.*, 2006).

Sharma and Singh (2002) found that total dry matter and photosynthetic rate had very high direct and indirect effects on grain yield.

Kamal *et al*. (1998) observed that modem variety BR11 gave the highest grain yield followed by BR 10, BR23, Binasail and BR4. High grain yield of hybrids in the dry seasons was the result of high number of spikelts square^{-1} meter due to a large number of spikelts panicle^{-1} and high harvest index rather than biomass production (Yang *et al.*, 2007).

2.2.8 Straw yield

Rejaul (2005) stated that straw yield was significantly affected due to varieties. The highest straw yield (5.64 t ha1 was observed in BRRI dhan29. Patel (2000) studied the varietal performance of Kranti and 1R36 and observed that kranti produced significantly higher straw yield than JR 36. The mean straw yield increases with Kranti over 1R36 was 10%. The tiller plants and total tillers hilV', might be contributed for higher straw yield of BRRI dhan29. The lowest straw yield (5.43 t ha^{-1} was obtained from BRRI dhan28.

2.2.9 Harvest index (HI)

High yield is determined by physiological process leading to a high net accumulation of photosynthates and it's partitioning into plant and seed.

Liao *et al*. (2008) observed that the main reason for the high harvest index and yield of Yuexiangzhan was balanced and coordination of sink, source and assimilate flow. Harvest index is about 0.55% for rice (Yuan, 2010).Harvest index is a measure of the efficiency of conversion of photosynthates into economic yield of a crop (Dutta and Mondal, 1998).

Jian Chang *et al*. (2006) found that super-high-yielding rice had more harvest index (5 1%) than the high -yielding rice. Shriame and Muley (2003) found that grain yield exhibited a very strong positive correlation with harvest index.

Chapter III

Materials & Methods

CHAPTER III

MATERIALS AND METHODS

Details of different materials used and methodologies followed in the experiment are presented in this chapter. This chapter deals with a brief description of experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and analysis etc.

3.1 Description of the experimental site

3.1.1 Experimental site and time

The experiment was conducted at the research farm of the Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. It is located under the Agro-ecological zone of Madhupur Tract, AEZ-28 (23^0 $41^'$ N latitude and 90^0 $22^'$) at an elevation of 8 m above the sea level (Appendix-I).

3.1.2 Climate

The geographic location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from August to December and the pre-monsoon period or hot season from March to April and monsoon period from May to October. Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, Dhaka-1207. Climatic data is presented in Appendix – II.

3.1.3 Soil

The soil of the experimental field belongs to Joydebpur series of Shallow Red-Brown Terrace soil type with silty clay in surface and silt clay loam in sub-surface region. As per USDA soil classification, the experimental soil was under Ochrept sub-order of Inceptisol order. The land was above flood level. Soil samples from 0-15 cm depth were collected from experimental filed. The analysis was done at Soil Resources and Development Institute (SRDI), Dhaka. The physio-chemical properties of the soil are presented in Appendix-III.

3.2 Experimental treatments and source of plant materials

Six rice varieties were used as treatments for this study viz:

Heera-4: is a hybrid variety and was imported from china and approved by the National Seed Board of Bangladesh. The variety is well adapted the climate conditions of Bangladesh. Supreme Seed Company Pvt. Ltd is the importer of this rice in Bangladesh. The plant type is semi dwarf (95-105 cm), growth duration is 145-150 days and its average grain rages from 9 to 10 tha^{-1}.

Aloron: This paddy variety has been imported from China and successfully reproducing the seeds by using Chinese technology. Farmers are getting up to 1.35 ton of Aloron per hectare- almost thrice the normal yield from the other varieties. The variety has the ability to produce grain yield 6.5 to 8.5 tha^{-1} & growth duration 100 to 104 days, plant height is semi dwarf (100 to 120 cm) and suitable in irrigated soil.

BRRI hybrid-3: It is a hybrid rice variety and shorter lifetime and lower production cost. BRRI hybrid dhan-1 and BRRI hybrid dhan-2 carries lifetime between 155 days and 160 days and BRRI hybrid-3 is about 10 days less than that of two. Its yield acre^{-1} is 3.04 ton.

Tia: A tender type hybrid rice variety is a traditional variety of *Boro* season. Growth duration is 125-130days and its average grain rages from 4 to 5 tha^{-1}.

BRRI dhan29: This high yielding variety is very much suitable for *Boro* season, grain medium fine and tasty. Growth duration is 140-155 days. Average yield for BRRI dhan29 is arround 6.5 t ha^{-1}.

BRRI dhan-34: BRRI dhan34 showed the best performance among the varieties studied. Grain yield was recorded the highest 4.5 tha^{-1} and highest number of grains panicle^{-1}.

Seeds of all these hybrid and inbred varieties were collected from the respective seed companies and BRRI, Gazipur.

3.3 Preparation of experimental field

The land was prepared with the help of power tiller by three successive ploughing and cross-ploughing followed by laddering. The experimental field was puddled by stagnant water. Weeds and crop residues of previous crop were removed from the field. The experimental area was laid out according to the design of the experiment. The unit plot was leveled before transplanting.

3.4 Fertilizer management

At the time of first ploughing, cow-dung was applied at the rate of 10 t ha^{-1}. The experimental area was fertilized with 120, 80, 80, 20 and 5 kg ha^{-1} N, P_2O_5, K_2O, S and Zn applied in the form of urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate respectively. The full amounts of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied at final land preparation as a basal dose. Urea was applied in three installments. The first one-third of urea was top dressed after seedling recovery, second one at 15 days after first top dressing and rest at the time of panicle initiation.

3.5 Experimental treatments

In this experiment two inbred and four hybrid rice varieties were used as different treatment viz:

V_1 = Heera-4

V_2 = Aloron

V_3 = BRRI dhan3

V_4 = Tia

V_5 = BRRI dhan29

V_6 = BRRI dhan34

3.6 Experimental design and layout

The unit plots were arranged randomized complete block design. The experiment was replicated thrice. The unit plot size was 4m x 3m. The spacing between block was 1 m and between plots 0.5 m. The layout of the experiment has been shown in Appendix-IV.

3.7 Raising of seedlings

The seedlings of different varieties were raised in the separate seedbed in traditional way with initial seed soaking in water for 24 hours and incubated for a period until radicles came out. No fertilizer was applied in seedbed. Sprouted seeds were sown in beds by broadcast method. Nursery beds were irrigated as and when necessary. Due care was taken to protect the seedbed from damages by birds and pests.

3.8 Uprooting of seedlings

The seedbeds were made wet by application of water both in the morning and evening on the previous day before uprooting the seedlings. The seedlings were uprooted carefully to safeguard the seedling from mechanical injury in the roots and the seedlings were kept in soft mud under shade.

3.9 Transplanting of seedlings

On 24 December of 2013, 30 days old seedlings of all studied hybrid rice and check variety were transplanted in the experimental field keeping row to row distance 25 cm and plant to plant distance 20 cm.

3.10 Intercultural operations

To maintain a required plant population, gap filling was done up to 7 days after transplanting. Two weeding were done manually at 25 and 50 DAT. Weedicide namely, Sunrice was applied at the rate of 100 kg ha^{-1} at the time of first urea top dressing. The field was irrigated properly. Steps were taken to maintain a constant level of standing water up to 5-10 cm in the field almost throughout the growing season.

3.11 Growth parameters

3.11.1 Sampling for growth analysis

Six hills plot^{-1} were selected at 50 DAT (vegetative stage) and uprooted carefully for maximum retention of roots. Roots of the sampled plants washed. Then, the plants were taken to the laboratory for data collection. Same procedure was followed at 70 and 90 DAT (reproductive stage) too.

3.11.2 Data collection

Data were recorded on the following crop characters:

3.11.2.1 Plant height

Plant height was measured at 10 days interval starting from 30 days after transplantation and continued up to harvest from randomly preselected ten hills plot^{-1}. 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.

3.11.2.2 Tillers hill^{-1}

Number of tillers hill^{-1} were counted at 10 days interval starting from 20 day after transplantation and up to harvest from preselected ten hills plot^{-1} and finally the mean value was calculated as their number hill^{-1}. Only those tillers having three or more leaves were considered for counting.

3.11.2.3 Leaves hill^{-1}

Leaves hill^{-1} in each plot was counted at different growth stage viz. 50(vegetative stage), 70 and 90 DAT (reproductive stage) and at harvesting.

3.11.2.4 Leaf area hill^{-1}

Then, the sampled plants were separated into leaf, stem and roots. Leaf area was measured by an electronic area meter (LI 3000, USA) and then their corresponding dry weight was recorded after drying at 72 ±20 C for 24 hours. Sub-sampling was done when the sample volume was excess and difficult to handle. Finally, leaf area was calculated hill^{-1}.

3.11.2.5 Leaf area index

LAI is the ratio of leaf to its ground area. It was determined by the following formula from the sampled plants as follows

$$LAI = \frac{LA}{A}$$

Where,

LA = Leaf area (cm^{-2})

A =Unit land area (cm^{-2})

3.11.2.6 Total dry matter hill^{-1}

The sub-samples of 5 hills plot^{-1} uprooting the plant with root from 2nd line were oven dried until a constant level of weight was attained from which the weight of total dry weight were recorded at 10 days interval up to harvest.

3.11.2.7 Crop growth rate

Increase of plant material per unit of time per unit of land area.

$$CGR= \frac{1}{A} \times \frac{(W_2-W_1)}{(T_2-T_1)} \text{ gm}^{-2}\text{d}^{-1}$$

Where,

W1= Total plant dry matter at time T1 (g)

W2 = Total plant dry matter at time T2 (g)

A = Ground area (m^2)

3.11.2.8 Relative growth rate

Increase of plant material per unit of material present per unit of time.

$$RGR = \frac{(Lnw_2 - Lnw_1)}{(T_2 - T_1)} \; gg^{-1}d^{-1}$$

Where,

W1 = Total plant dry matter at time T1 (g)

W2 = Total plant dry matter at time T2 (g)

Ln = Natural logarithm

3.12 Yield parameters

3.12.1 Harvesting and processing

Depending on the maturity of test hybrid and inbred rice varieties, they were harvested on different days. Harvesting was done when 80 to 90% of the grains become golden in colour. Sampled plants were cut at the ground Level and were separately bundled and properly tagged for recording of necessary data. Grain yield was determined by harvesting one sq. meter which was prefixed at the corner of each plot. The harvested crops were then threshed and cleaned. The grain weight was recorded after proper drying in the sun (14% moisture).

3.12.2 Data on yield

Data were recorded on the following yield parameters:

3.12.2.1 Effective tillers hill^{-1}

The effective tillers from ten hills were counted and mean value was calculated as hill^{-1} basis. The panicle which had at least one grain was considered as effective tillers.

3.12.2.2 Non-effective tillers hill^{-1}

Non-effective tillers hill1 from the sampled plants of each plot was counted at final harvesting.

3.12.2.3 Panicle length

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

3.12.2.4 Filled and unfilled grains panicle^{-1}

Presence of any food material in the spikelets was considered as filled grain and total number of grains present in each panicle was counted. Spikelets lacking any food material inside were considered as unfilled grains and such spikelets present on the each panicle were counted.

3.12.2.5 1000- grain weight

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained 12% moisture and the mean weight were expressed in gram.

3.12.2.6 Crop duration

Crop duration was recorded counting seeding to harvesting days.

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

Grain yield was recorded from the central 6 m^2 undisturbed area of each plot was used to calculate grain yield m^{-2} and then it was expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester

3.12.2.8 Straw yield

Straw yield was taken from the central 5 m^2 undisturbed area of each plot was used to calculate straw yield m^{-2}. After threshing, the sub-sample was oven to a constant wt. and finally converted to t ha^{-1}.

3.12.2.9 Biological yield

Grain yield and straw yield are all together recorded as biological yield. The biological yield was calculated with following formula:

Biological yield (BY)= Grain yield + straw yield.

3.12.2.10 Harvest index

Harvest index expresses the relationship between grain yield and biological yield. It was calculated by using the following formula:

$$HI= \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.13 Statistical analysis

The data collected on different parameters were statistically analyzed to obtain the level of significance using the MSTATC (Russell, 1986) computer package program. Analysis of variance was done following two factors randomized complete block design. The mean differences among the treatments were compared by least significant difference (LSD) test at 5% level of significance.

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the growth and its contribution to the yield of hybrid and inbred rice varieties in *Boro* season. The results have been presented and discusses with the help of table and graphs and possible interpretations given under the following headings:

4.1 Growth parameters

4.1.1 Plant height

Plant height at different days after transplanting (DAT) was exhibited remarkable among the test rice varieties (Table I). Plant height increased progressively with the advance of time. At 50 days after transplanting, the tallest plant was obtained from BRRI dhan-29 (79.50 cm) followed by Heera-4(76.66 cm) and the lowest height was recorded in Tia (63.75 cm) followed by Aloron (67.56 cm). At reproductive phase (70 and 90 DAT), the highest plant height was achieved from BRRI dhan-29 (102.45 cm and 109.67 cm, respectively) and the shortest was recorded in Aloron (79.21 cm and 80.50 cm respectively).

At final harvest, BRRI dhan-29 had highest height (111.00cm) followed by BRRI hybrid-3(109.00cm) and the shortest was in Aloron (81.56cm) proceeded by BRRI dhan-34 (95.00cm) with same statistical rank. Rest of the varieties showed intermediate status. Shalauddin (2012) DRR (1996), Om *et al*.(1998) and Kabir *et al* (2004) also found difference in plant height due to varietal differences. Result focused that BRRI dhan-29 was the tallest and Aloron the shortest plant.

Table 1. Plant height at different days after transplanting and at harvest of hybrid rice and inbred rice varieties in Boro season

Rice variety	Plant height(cm)			
	50 DAT	**70 DAT**	**90 DAT**	**At harvest**
Tia	63.75b	85.49bc	96.25b	95.00b
Aloron	67.56b	79.21 c	80.50c	81.56 c
Heera-4	76.66 a	97.75a	103.25ab	105.34a
BRRI hybrid-3	75.87a	96.67a	106.70ab	109.00a
BRRI dhan-29	79.50a	102.45 a	109.67a	111.00a
BRRI dhan-34	67.87b	88.67b	109.10a	107.29a
$LSD_{(0.05)}$	5.23	7.31	12.23	9.33
CV%	13.2	11.3	15.8	13.9

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

4.1.2 **Tillers hi1l^{-1}**

Total number of tillers hill^{-1} showed significant variation among the hybrid and inbred rice varieties at DAT (Table 2). Number of tillers hill^{-1} increased with the advancement of vegetative growth. But at reproductive stages, number of total tillers hill^{-1} decreased in all the studied rice varities. At 50 DAT, the highest number of tillers hill^{-1} was produced by Heera-4 (15.26) that was significantly different from the rest. The lowest number of tillers hill^{-1} was found d in BRRI dhan-34(10.33).

At 70 and 90 DAT, maximum number of tillers hill^{-1} was achieved from Heera-4 (20.67 and 20.65). Yield also deceased considerable with the decrease of tillers hill^{-1} (Hoque, 2004). This type of result was also observed in the present study. Mondal *et al*. (2005) found significant difference in number of tillers hill^{-1} in 17 rice varieties. Marambe (2005) observed that the tiller number varied from 14 to 18 plant^{-1} with 6-9 panicles plant^{-1}. Kabir *et al.* (2004) and {Shalauddin, 2012) reported that significant variation observed among the rice cultivars.

Table 2. Tillers hill^{-1} at different days after transplanting (DAT) in hybrid and inbred rice varieties.

Rice variety	Leaf area index at			
	50 DAT	**70 DAT**	**90 DAT**	**At final**
Tia	10.56c	15.45b	14.26c	13.75b
Aloron	10.34c	12.34c	13.45c	12.88b
Heera-4	15.26a	20.87a	20.56a	18.15a
BRRI hybrid-3	12.50b	14.50bc	15.65b	14.88b
BRRI dhan-29	12.45b	12.13c	13.87c	14.54b
BRRI dhan-34	10.33c	13.35c	13.24c	14.49b
$LSD_{(0.05)}$	5.23	7.31	12.23	9.33
CV(%)	13.2	11.3	15.8	13.9

Values with common letter(s) within a column do not differ significantly at 5% level of probability analyzed by LSD.

4.1.3 Leaves hill^{-1}

Leaves hill^{-1} at DAT was varied significantly among the studied rice varieties (Table 3). The number of leaves hill^{-1} was continued to increase up to 70 DAT then declined. At (50 DAT the highest number of leaves hill^{-1} was observed in Heera-4 (77.56) and at par with BRRI hybrid-3 (69.45). At 70 DAT, the maximum leaves hill^{-1} observed in Heera-4 (93.56) followed by BRRI hybrid-3 (88.95). At 90DAT, the maximum number of leaves hill^{-1} (90.32) was recorded from Heera-4. In 50 and 70 DAT, BRRI dhan-34 and BRRI dhan-29 produced the lowest number of leaves. However, Heera-4 produced the highest number of leaves hill^{-1} and BRRI dhan-34 produced the lowest number of leaves.

Table 3. Leaves hill^{-1} at different days after transplanting (DAT) in hybrid and inbred rice varieties in *Boro* season

Rice variety	Stem dry matter hill^{-1} (g) at		
	50 DAT	**70 DAT**	**90 DAT**
Tia	52.67d	72.34b	63.24b
Aloron	60.51c	70.50bc	62.45b
Heera-4	77.56 a	93.56a	90.32a
BRRI hybrid-3	69.45b	88.95a	89.34a
BRRI dhan-29	45.84e	66.45c	74.23b
BRRI dhan-34	55.23cd	52.09a	69.57b
$LSD_{(0.05)}$	6.25	12.91	7.80
CV (%)	10.82	15.37	12.49

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

4.1.4 Leaf area hill^{-1}

Leaf area (LA) in the test rice varieties was varied considerable during the different DAT (Table 4). LA increased up to heading and thereafter declined. The rate of leaf area development hill^{-1} varied significantly among the rice varieties. In 50 and 70 DAT, the highest leaf area hill^{-1} was produced by Heera-4 (2081 cm^2 and 1966 cm^2). The lowest leaf was recorded in Tia and Aloron. Variation in leaf area might occur due to the variation in number of leaves (Sarkar, 2014).

4.1.5 4 Leaf area index (LAI)

Leaf area index (LAI) significantly differed in the studied rice varieties from 50 DAT to 90 DAT (Table 4). At 50DAT, the maximum LAI was observed in Heera-4(2.62) closely followed by BRRI hybrid-3(2.46). At 50 and 70 DAT, Tia and

Aloron showed the lowest LAI (1.51 and 1.68 respectively). Rest of the varieties showed intermediate values. On the other hand, at 90 DAT the hybrid variety Heera-4 showed the highest value (3.96) and Tia and Aloron the lowest LAI (2.81 and 3.04), respectively. Mondal *et al.* (2007) who stated that the variation in LAI could be attributed due to the changes in number of leaves and the rate of leaf expansion and abscission. The high yielding varieties possessed higher LAT values throughout the whole growth period which led to the higher biomass production and yield (Ready *et al.*, 1995).

Table 4. Leaf area hill^{-1} and Leaf area index (LAI) at different days after transplanting (DAT) in hybrid and inbred rice varieties

Rice variety	Leave area hill^{-1} (cm^2)				Leave area index (LAI)		
	50 DAT	70 DAT	90 DAT		50 DAT	70 DAT	90 DAT
Tia	744e	1423d	1411e		1.51d	2.83e	2.81d
Aloron	896d	1523d	1507de		1.68cd	3.03de	3.04cd
Heera-4	1311a	2081a	1966a		2.62a	4.16a	3.96a
BRRI hybrid-3	1233b	1803b	1794b		2.46b	3.79b	3.66ab
BRRI dhan-29	1096c	1656c	1600cd		2.17c	3.31cd	3.81a
BRRI dhan-34	1013d	1705c	1662c		2.01cd	3.41c	3.32bc
$LSD_{(0.05)}$	0.59	0.61	1.29		1.29	2.81	0.43
CV%	7.98	5.10	6.17		6.17	9.11	11.30

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

4.1.6 Root dry matter hill^{-1}

There was a significant variation observed in root dry matter production among tested rice varieties at different growth stages (Table 5). At vegetative stages (50 DAT) maximum root dry matter was observed in Heera-4 and the lowest was found in Aloron. At reproductive stage (70 and 90 DAT) the maximum root dry matter was found in Heera-4 and the lowest was found in the inbred variety. Result revealed that root dry matter was gradually increased with time.

4.1.7 Stem dry matter hill^{-1}

There was significant difference observed in stem dry matter among the hybrid and inbred rice varieties at different DAT (Table 4). At 50 DAT maximum stem dry matter was recorded in BRRI hybrid-3 and the minimum was obtained from Aloron. At 70 and 90 DAT, the maximum stem dry matter was achieved in Heera-4 and the minimum was found in Aloron. Result revealed that stem dry matter was gradually increased with time.

4.1.8 Leaf dry matter hill^{-1}

Leaf dry matter significantly varied among the rice varieties at different DAT (Table 4). At 50 DAT, the maximum leaf dry matter was recorded in Heera-4 and the minimum was rescored from Aloron. At 70 and 90 DAT the highest leaf dry matter was found in Heera-4 and the minimum was received in the Aloron. It means that leaf dry matter was gradually increased with time.

4.1.9 Total dry matter hill^{-1}

Total dry matter (TDM) accumulation showed remarkable variation among hybrid and inbred rice varieties (Table 5). Dry matter production increased with age of rice plant. But dry matter accumulation in plant was low at 50 DAT and thereafter increased rapidly. At 90 DAT, Heera-4 (81.50g) provided the highest dry matter hill^{-1} followed by BRRI hybrid-3(80.55g) while Aloron produced the lowest TDM (63.45g). The increase of TDM was dependent on the leaf area production as reported by Chandra and Das (2010). This result was also supported by the result of Sarkar, (2014) who reported that TDM increased with increasing plant age up to physiological maturity and high yielding rice always maintained higher TDM hill^{-1}.

Table 5. Dry matter accumulation of hybrid and inbred rice varieties at different days after transplanting in *Boro* season.

Rice variety	Root dry matter hill^{-1} (g)			Stem dry matter hill^{-1} (g)			Leaf dry matter hill^{-1} (g)			Total dry matter hill^{-1} (g)		
	50DAT	70DAT	90DAT	50DAT	70DAT	90DAT	50DAT	70DAT	90DAT	50DAT	70DAT	90DAT
Tia	3.40c	5.46c	10.34bc	9.34a	23.45c	43.45b	4.34b	11.34b	12.54b	18.45c	42.10b	67.34cd
Aloron	2.56d	4.56c	10.23c	8.45b	20.34c	42.34b	3.99b	9.56c	12.34b	16.45c	41.34b	65.45de
Heera-4	5.32a	7.45a	13.42a	14.13a	34.56a	53.45a	6.40a	13.83a	15.40a	24.83a	53.50a	81.50a
BRRI hybrid-3	5.34a	7.23a	12.34ab	14.34a	32.54a	52.34a	6.34a	13.34a	14.54ab	23.54ab	52.56a	80.55a
BRRI dahn-29	3.56c	7.43a	10.13c	13.45a	32.34a	53.06a	6.23a	14.56a	14.56ab	22.34b	51.45a	76.45ab
BRRI dhan-34	4.34b	5.34b	11.56b	9.34b	26.44b	44.56b	5.23ab	11.56a	13.43b	21.44b	44.30b	71.45c
$LSD_{(0.05)}$	0.59	0.61	1.29	2.81	4.31	5.21	1.31	1.23	1.54	2.31	2.11	4.58
CV(%)	7.98	5.10	6.17	9.11	11. 30	7.91	12.80	3.83	7.23	8.32	6.2	7.057

Values with common letter(s) within a column do not differ significantly at 5% level of probability analyzed by LSD.

4.1.10 Crop growth rate

At vegetative stage, (50 -70 DAT), the BRRI hybrid-3 exhibited the highest CGR (44.02 $gm^{-2}d^{-1}$) followed by Heera-4(41.9 $gm^{-2}d^{-1}$) .While the minimum CGR were found in Tia (29.27 $gm^{-2}d^{-1)}$ and Aloron (26.23 $gm^{-2}d^{-1}$). At reproductive stage (70 - 90 DAT), the highest CGR was recorded in Heera-4 (40.67 $gm^{-2}d^{-1}$) closely followed by BRRI hybrid-3(39.45 $gm^{-2}d^{-1}$).The monimum CGR at 70-90 DAT was observed in Aoron (25.75$gm^{-1}d^{-1}$) and at par with Tia (27.06 $gm^{-2}d^{-1}$). CGR declined at near maturity might be due to the decrease in LAI at the later stage. So, the CGR increased along with increases in LAT. This result is in consonance with the results of Yang et al. (2010). At vegetative stage (50-70 DAT), the CGR was observed to be maximum that indicated that plants allocated more it's dry matter for growth of leaf area. These results are consistent with the result of Miah *et al.* (1996) and Piranhas *et al.* (1997) who reported that varietal differences of CGR were significant at different growth stage.

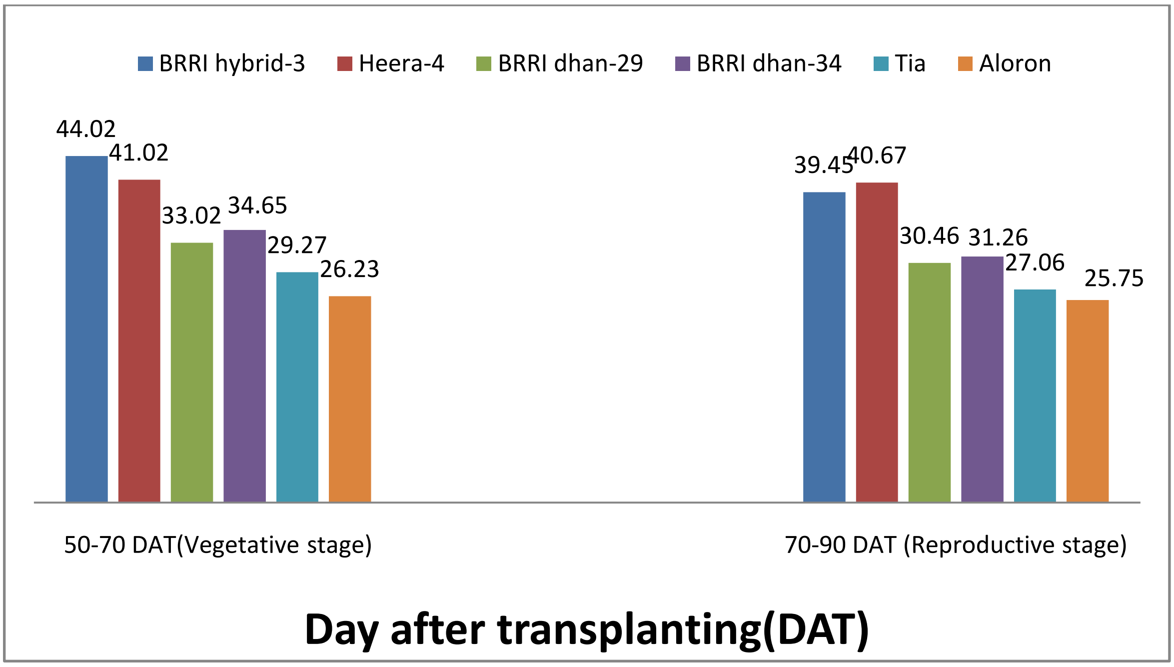

Figure 1. Crop growth rate (CGR) at 50-70 DAT) and 70-90 DAT in the test hybrid and inbred rice varieties at *Boro* season

4.1.11 Relative growth rate

The studied varieties showed the higher RGR at vegetative stage than the reproductive stage. BRRI hybrid-3 produced the highest RGR (21.78mg $g^{-1}d^{-1}$) at 50-70 DAT followed by Heera-4 (21.05 mg $g^{-1}d^{-1}$). Whereas Aloron and Tia showed the lower RGR (16.56 mg $g^{-1}d^{-}1$ and 17.34 mg $g^{-1}d^{-1}$). At reproductive stage (70-90 DAT) Heera-4(13.52 mg $g^{-1}d^{-1}$) and the lowest RGR value was found in Aloron (7.34 mg $g^{-1}d^{-1}$). RGR decreased in most of the field crops near maturity (Dutta and Mondal, 1998). Almost similar result was also observed by Sallauddin (2012) and in this experiment. The result of the present study are in agreement with .the result of Sarkar (2014), who stated that the higher RGR was existed during the vegetative stage and declined rapidly near maturity.

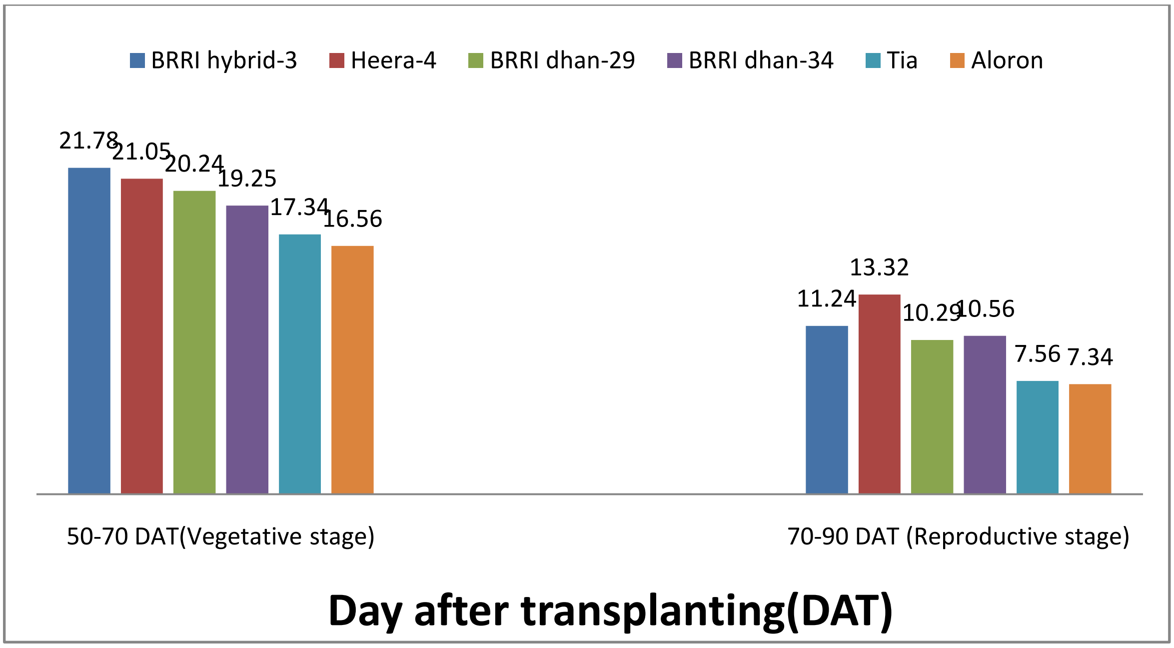

Figure 2. Relative growth rate (RGR) at 50-70 DAT and 70-90 DAT stages in the hybrid and inbred rice varieties in *Boro* season.

4.2 Yield attributes

4.2.1 Panicles hill^{-1}

Panicles (effective tillers) hill^{-1} exhibited significant difference among the test rice varieties (Table 6). The highest number of effective tillers hill^{-1} (14.30) was recorded in Heera-4 followed by Tia (12.65). Whereas, the lowest number of panicles hill^{-1} was recorded in Aloron (10.17) which was closely followed by BRRI hybrid-3(10.25).

4.2.2 Non- effective tillers hill^{-1}

There was a significant difference noticed among Non- effective tillers hill^{-1} of the studied varieties (Table-6) The highest non-effective tillers hill^{-1} as obtained in BRRI hybrid-3(4.38) followed by BRRI dhan-34(3.33). on the other hand, the minimum number of non-effective tillers hill^{-1} was recorded from Aloron (1.67) it was statistically identical with Tia (2.04).

4.2.3 Panicle length

Panicle length exhibited remarkable variation in different test rice varieties (Table 6). The longest panicle was recorded in the hybrid Heera-4 (26.33 cm) followed by BRRI dhan-29 (24.66) and then BRRI-34 (24.00 cm). The shortest panicle was found in Aloron (19.56 cm), it was statistically same as Tia (23.14). This result is consistent with the result of Sarkar (2014) who reported that panicle length was significantly varied among rice varieties. Moinul (2014) reported that hybrid rice varieties usually have extra-heavy panicle.

4.2.4 Unfilled spikelets panicle^{-1}

Number of unfilled spikelets panicle^{-1} varied significantly among the studied rice varieties (Table 6).Tia provided the maximum number unfilled spikelets panicle^{-1} (19.23) followed by Aloron (16.45) while, the lowest by number of unfilled unfilled spikelets panicle^{-1} was recorded in BRRI dhan-34(7.33) followed by BRRI dhan-29(11.66). The test rice varieties significantly differed in respect of unfilled spikelets panicle^{-1}. Similar result was also reported by Sarkar (2012) who observed a wide range of variability in unfilled spikelets panicle^{-1} in different rice varieties.

4.2.5 Grains panicle^{-1}

Grains panicle^{-1} was showed considerable different among the test rice varieties (Table 6). Heera-4 provided the maximum the number of grains panicle^{-1} (142.30) followed by BRRI dhan-29 (140.00). Whereas, BRRI dhan-34 gave the lowest number of grains panicle^{-1}(109.70).

4.2.6 1000-grain weight

1000-grain weight was significantly differed among the hybrid and inbred rice varieties (Table 6). Heera-4 showed the highest 1000- grain weight (28.83 g). Whereas, BRRI dhan-34 showed the lowest l000- grain weight (23.01 g). 1000-grain weight is a varietal characteristic controlled by genetic makeup (Yoshida, 1981).

4.2.7 Crop duration

Crop duration varied significantly among the test hybrid and inbred rice varieties (Table 6). Result indicated that all the varieties required shorter days to maturity than BRRI dhan-29 (159 d). Tia taken the lowest days to maturity (131 d) This result was in consonance with Anonymous (2004) who reported that hybrid rice took more days to maturity than that of local varieties due to delay in tillering, flowering and grain maturity which might be help them accumulated more dry matter.

4.2.8 Biological yield (BY)

Biological yield was markedly differed among the studied rice varieties (Table 6). The highest BY was achieved in Heera-4 (14.11 t ha^{-1}) closely followed by BRRI dhan-29 (13.92 t ha^{-1}). While the lowest biological yield was recorded in Aloron (12.67th^{-1}). This result is different from the findings of Sallauddin (2012) and Sarkar (2014) who reported that hybrid rice varieties produced more biological yield than inbred one.

4.2.9 Grain Yield

Grain yield showed remarkable variation among the hybrid and inbred rice varieties (Table 6). Heera-4 produced the highest grain yield (8.24 t ha^{-1}) whereas the lowest grain yield (5.82 t ha^{-1}) was obtained from BRRI dhan 34, which was about 34%, lowers than that of Heera-4. This result indicated that the hybrid variety Heera-4 had remarkable superiority to grain yield over the other rice varieties except BRRI dhan -29 (7.20 t ha^{-1}).

4.2.10 Harvest index

Harvest index (HI) differed considerable among the hybrid and inbred rice varieties (Table 6). Heera-4 showed significantly the highest harvest index (58.40%). It means dry matter partitioning to economic yield was superior in Heera-4 to the other rice. Aloron recorded significantly the lowest harvest index (47.56%). Result reflected that the hybrid Heera and BRRI hybrid dhan-3 provied higher harvest index. This finding was in agreement with Sarkar (2014) and Sallauddin (2012).

Table.6 Yield components and grain yield of hybrid and inbred rice varieties in *Boro* season

.Rice Variety	Panicles $hill^{-1}$	Non-effective tillers $hill^{-1}$	Panicle length	Unfilled spikelets $panicle^{-1}$	Grains $panicle^{-1}$	1000 grain weight (g)	Crop duration (d)	Biological yield ($t\ ha^{-1}$)	Grain yield ($t\ ha^{-1}$)	Harvest index (%)
Tia	12.65b	2.04b	23.14b	19.23a	139.12ab	23.01bc	131c	11.91b	5.82b	48.86b
Aloron	10.17d	1.67b	19.56c	16.45b	132.34b	26.96ab	143b	12.67ab	6.05b	47.56b
Heera-4	14.30a	2.30a	26.33a	13.35c	142.30a	28.83a	148b	14.11a	8.24a	58.40a
BRRI hybrid-3	10.25d	4.38a	23.33b	14.72bc	133.00b	24.10b	151ab	12.21ab	6.65ab	54.46ab
BRRI dhan-29	11.34c	2.65b	24.66b	11.66c	140.00a	25.06b	159a	13.92ab	7.20ab	51.72b
BRRI dhan-34	11.69c	3.33ab	24.00b	7.33d	109.70c	21.41c	149b	11.53b	5.57b	48.30b
$LSD_{(0.05)}$	0.71	1.29	1.58	2.68	6.96	2.42	9.50	2.10	1.95	4.22
CV(%)	5.26	8.54	3.23	14.10	2.97	3.61	6.47	17.32	18.65	12.80

Values with common letter(s) within a column do not differ significantly at 5% level of probability analyzed by LSD.

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was carried out at the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka during *Boro* season from November, 2013 to May, 2014, with a view to study the morpho-physiological behaviour and yield performance of four hybrid and two inbred rice varieties. The experiment was arranged in a randomized Complete Block Design (RCBD) with four replications. One seedling of thirty two days old was transplanted in each hill maintaining pacing 20 cm X 20 cm. The unit plot size was 4 x 2.5 m^2. All intercultural operations were practiced as and when required. Collected data were analyzed following the statistical procedure.

The studied hybrid and inbred varieties exhibited remarkable variation in different growth and yield characters such as plant height, tillers $hill^{-1}$ leaves hill-^{1}, TDM, leaf area, LAI, CGR, RGR, and yield attributes like effective tillers hill', unfilled and filled grains panicle', panicle length, 1000- grain weight, crop duration, biological yield, grain yield and HI. The hybrid rice hybtid Heera-4 and inbred BRRI dhan-29 showed superiority in respect of growth parameters like tillers $hill^{-1}$, leaf area $hill^{-1}$, leaf area $hill^{-1}$, LAI, CGR, RGR over the rest varieties. In all test varieties, number of total tillers $hill^{-1}$ and number of leaves increased up to heading stage and then declined.

BRRI dhan-29 had highest height (111.00 cm) followed by BRRI hybrid-3(109.00cm) and the shortest was in Aloron (81.56cm) proceeded by BRRI dhan-34 (95.00cm). At 70 and 90 DAT, maximum number of tillers $hill^{-1}$ was achieved from Heera-4 (20.67 and 20.65). Yield also deceased considerable with the decrease of tillers hill^{-1} (Hoque, 2004). At 90 DAT, the maximum number of leaves hill^{-1} (90.32) was recorded from Heera-4. In 50 and 70 DAT, the highest leaf area hill^{-1} was produced by Heera-4 (2081 cm^2 and 1966 cm^2). At 70 and 90 DAT, the maximum stem and leaf dry matter was achieved in Heera-4 and the minimum was found in Aloron. At 90 DAT, Heera-4 (81.50g) provided the highest dry matter hill^{-1} followed by BRRI hybrid-3(80.55g) while Aloron produced the lowest TDM (63.45g). At vegetative stage, (50 -70 DAT), the BRRI hybrid-3 exhibited the highest CGR (44.02 gm^{-2}d^{-1}) followed by Heera-4(41.9 gm^{-2}d^{-1}) .While the minimum CGR were found in Tia (29.27 gm^{-2}d$^{-1)}$ and Aloron (26.23 gm^{-2}d^{-1}). At reproductive stage (70 -90 DAT), the highest CGR was recorded in Heera-4 (40.67 gm^{-2}d^{-1}) closely followed by BRRI hybrid-3(39.45 gm^{-2}d^{-1}).The minimum CGR at 70-90 DAT was observed in Aoron (25.75gm^{-1}d^{-1}) and followed by Tia (27.06 gm^{-2}d^{-1}). At reproductive stage (70-90 DAT) Heera-4(13.52 mg g^{-1}d^{-1}) and the lowest RGR value was found in Aloron (7.34 mg g^{-1}d^{-1}). The highest number of effective tillers hill^{-1} (14.30) was recorded in Heera-4 followed by Tia (12.65). Whereas, the lowest number of panicles hill^{-1} was recorded in Aloron (10.17) which was closely followed by BRRI hybrid-3(10.25). Heera-4 provided the maximum the number of grains panicle^{-1} (142.30) followed by BRRI dhan-29 (140.00). Whereas, BRRI dhan-34 gave the lowest number of grains panicle^{-1} (109.70). Heera-4 showed the highest 1000- grain weight (28.83 g). Whereas, BRRI dhan-34 showed the lowest l000- grain weight (23.01 g). All the varieties required shorter days to maturity than BRRI dhan-29 (159 d). Tia taken the lowest days to maturity (131 d). The highest BY was achieved in Heera-4 (14.11 t ha^{-1}) closely followed by BRRI dhan-29

(13.92 t ha^{-1}), while the lowest biological yield was recorded in Aloron (12.67th^{-1}). Heera-4 produced the highest grain yield (8.24 t ha^{-1}) whereas the lowest grain yield (5.82 t ha^{-1}) was obtained from BRRI dhan 34, which was about 34%, lowers than that of Heera-4. Heera-4 showed significantly the highest harvest index (58.40%). It means dry matter partitioning to economic yield was superior in Heera-4 to the other rice. Aloron recorded significantly the lowest harvest index (47.56%).

Conclusions:

Based on the result of the present study, the conclusion may be drawn as:

- Heera-4 and BRRI hybrid dhan- 3 exhibited and higher crop growth rate and higher LAI at vegetative and reproductive stages compared to the rest varieties in *Boro* season.
- Among the test varieties, hybrid Heera-4 produced the highest grain yield (8.24 t ha $^{-1}$) followed by inbred BRRI dhan-29 (7.20 t ha $^{-1}$)

However, it needs more trials under farmer’s field conditions at different agro-ecological zones of Bangladesh for the conformation of the results.

Chapter VI

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CHAPTER VI

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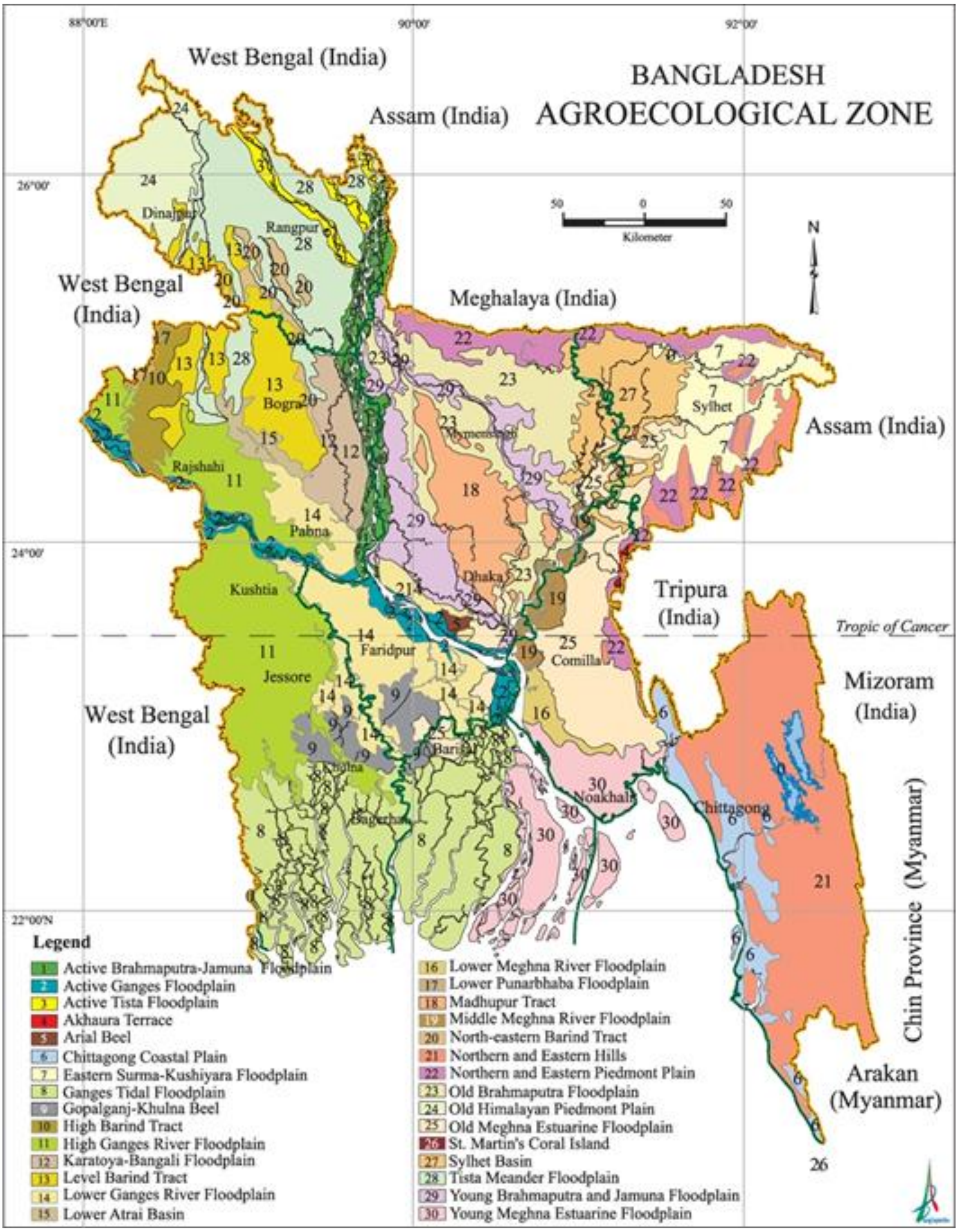
Chapter VII

Appendices

APPENDICES

Appendix I. Experimental location on the map of agro-ecological zonea of Bangladesh.



Appendix II. Monthly recorded air temperature, relative humidity, rainfall and sunshine of the experimental site during the period from August to 2013 to January 2014

Month	Air tempt(^{0}c)		RH(%)	Total rainfall (mm)	Sunshine (hrs)
	Max	Min			
August	26.54	13.87	80.75	00.00	6.68
September	24.42	13.96	78.79	00.00	7.00
October	27.35	15.42	78.89	33.00	8.13
November	24.33	12.56	75.35	34.34	7.56
December	25.53	12.79	79.78	00.00	6.69
January	23.40	13.87	79.00	00.00	5.61

Source: Bangladesh Meteorological Department climate & weather division) Agargaon, Dhaka- 1207

Appendix III. Physical and chemical properties of soil of the experimental plot

Properties	Value
A. Physical	
% Sand (0.2-0.02mm)	26
% Silt (0.02-0.002mm)	45
% Clay (< 0.002mm)	29
Textural class	Silty clay
B. Chemical	
Soil pH	5.6
Organic carbon (%)	0.46
Organic matter (%)	0.76
Total nitrogen (%)	0.07
Phosohorus (µg/g soil)	22.07
Sulphur (µg/g soil)	25.98
Megnasium (meq/100 g soil)	1.00
Boron (µg/g soil)	0.48
Copper (µg/g soil)	3.54
Zinc (µg/g soil)	3.33
Potassium (µg/g soil)	0.30

Source: Soil Resources Development Institution,Khamarbari,Dhaka-1207

PLATES

Plate 1: Image of Transplanting of seedlings