PERFORMANCE OF FIVE SELECTED HYBRID RICE VARIETIES IN *BORO* SEASON

By

MD. SALAH UDDIN
Registration No.: 05-01677

A Thesis
Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE
IN
AGRICULTURAL BOTANY

SEMESTER: JULY-DECEMBER, 2012

Approved by:

Md Moinul Haque
Associate Professor
Supervisor

Dr. Kamal Uddin Ahamed
Professor
Co-Supervisor

Dr. Mohammad Mahbub Islam
Chairman
Examination Committee
Department of Agricultural Botany
Sher-e-Bangla Agricultural University
Dhaka-1207

CERTIFICATE

This is to certify that thesis entitled, **"PERFORMANCE OF FIVE SELECTED HYBRID RICE VARIETIES IN BORO SEASON"** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of* **MASTER OF SCIENCE IN AGRICULTURAL BOTANY,** *embodies the result of a piece of bonafide research work carried out by* **MD. SALAH UDDIN, Registration No. 05-01677** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: December, 2011
Dhaka, Bangladesh

Md. Moinul Haque
Associate Professor
Supervisor

Dedicated To

My

Respectable

Parents

ACKNOWLEDGEMENTS

The author seems it a much privilege to express his enormous sense of gratitude to the almighty Allah for there ever ending blessings for the successful completion of the research work.

The author feels proud to express his deep sense of gratitude, sincere appreciation and immense indebtedness to his supervisor ***Associate Professor Md. Moinul Haque,*** *Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, for his continuous guidance, cooperation, constructive criticism and helpful suggestions, valuable opinion in carrying out the research work and preparation of this thesis, without his intense co-operation this work would not have been possible.*

The author feels proud to express his deepest respect, sincere appreciation and immense indebtedness to his co-supervisor ***Professor Dr. Kamal Uddin Ahamed,*** *Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, for his scholastic and continuous guidance, constructive criticism and valuable suggestions during the entire period of course and research work and preparation of this thesis.*

The author expresses his sincere respect to Professor Asim Kumar Bhadra, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka for valuable suggestions and cooperation during the study period. The author also expresses his heartfelt thanks to all the teachers of the Department of Agricultural Botany, SAU, for their valuable teaching, suggestions and encouragement during the period of the study.

The author expresses his sincere appreciation to his beloved father Md. Akim Uddin, mother Salma Akhter, wife Manira Akhter Rita and other members of the family, well wishers and friends for their inspiration, help and encouragement throughout the study.

The Author

PERFORMANCE OF FIVE SELECTED HYBRID RICE VARIETIES IN *BORO* SEASON

ABSTRACT

The experiment was carried out at the research farm of the Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, during December 2011 to May 2012 to evaluate the performance of five hybrid rice varieties namely Moyna, Sonarbangla-3, Heera-4, Jagoron and Panna-1. The experiment was laid out in Randomized Complete Block design with four replications. Inbred BRRI dhan-45 was used as a check variety. Growth characters yield and yield attributes were significantly different among the studied varieties. All the studied hybrid 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 and NAR over the inbred BRRI dhan-45. Additionally, these hybrids also showed better performance in yield related characters viz. effective tillers hill^{-1}, panicle length, 1000-grain weight, biological yield, harvest index (HI) over the same inbred. Consequently, the tested hybrid varieties produced the higher grain yield compared to BRRI dhan-45. Higher grain yield of the tested hybrids also related with higher dry matter production and partitioning. However, Heera-4 showed the best performance closely followed by Moyna. The hybrid varieties Heera-4 and Moyna had maximum CGR, RGR and NAR particularly in the reproductive stage (90 DAT) possibly for high sink demand and thus, these two varieties produced 43.5% higher yield over the inbred BRRI dhan-45. Yield components, effective tillers hill^{-1} and 1000 grain weight mainly contributed to the higher grain yield of hybrid varieties over the inbred BRRI dhan-45. These results suggested that the tested hybrid rice varieties had yield advantage over the inbred BRRI dhan-45 due to production and partitioning of more dry matter to the grain.

CONTENTS

CONTENTS (Cont'd)

CONTENTS (Cont'd)

CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Chapter 1

Introduction

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important cereals in the world. It is the staple food for more than half of the world population and grows in more than 100 countries. China, India, Indonesia, Bangladesh, Thailand and Vietnam produce about 80% of the world rice. Among the leading rice growing countries of the world, Bangladesh ranks fourth in rice area and production (BRRI, 2010). In Bangladesh rice accounts for 95% of the annual food grain production. It provides about 75% of the calories and 55% of the protein in the average daily diet of the people of the country (Bhuiyan et al. 2002). Bangladesh is rice dominated agro-based country. Agriculture contributes about 21.10% of the gross domestic product (GDP) of the country (Anon., 2008). In the year 2008-2009, the area and production of rice in the country were 11.28 million hectares and 31.31 million metric tons, respectively (BBS, 2010)

Agro-climatic conditions of our country are favorable for rice cultivation all around year. However, rice is grown in three seasons namely *Aus*, *Aman* and *Boro*. *Boro* rice has been gaining much importance in Bangladesh. The average per hectare yield of *Boro* rice is higher than that of *Aus* and *Aman* rice (BBRI, 1999). The total area, production and yield of *Boro* rice in Bangladesh are about 4706875 hectares, 18058962 (M.Tons) and 3.84 tha^{-1} (BBS, 2010) respectively. Among the three rice seasons of Bangladesh, it is the longest rice season, producing the highest grain yield (Gomosta *et al.*, 2006).

The increasing rate of population is 1.42% (BBS, 2010) and decreasing rate of agricultural land is 1% 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 (CGR), net assimilation rate (NAR) and relative growth rate (RGR) rate ultimately reflection in high grain yield of rice (Thakur and Patel, (1998).

Hybrid rice is one the option for increasing the yield ceiling in rice over the best modern varieties. The development of hybrid rice technology in Bangladesh began in 1993. Some elite maintainer lines identified are BR 29, BR8766-2-1, BR 4839-17-2-2-HR42, BR5690-62-23, BR5882-12-2-1, and BR5892-32-5-3. F_1 seed yield was higher during the *Boro* season than in the T. *Aman* season (Julfiquar *et al.*, 2006) .Hybrid rice in China and other countries has yielded 20-30% higher than the best inbred varieties.

However, some of the newly introduced hybrid rice varieties are Moyna, Sonarbangla-3, Heera-4, Jagoron, and Panna-1. So, it is prime need to evaluate their performance in *Boro* season. Under these circumstances, the study was undertaken to compare the performance of afore-mentioned hybrid and inbred rice varieties in *Boro* season.

Therefore, the objectives of the study are as following -

- To compare the growth parameters of hybrid rice varieties with popular inbred BRRI dhan-45 in *Boro* season.
- To investigate yield variation among the afore-mentioned five selected hybrid rice varieties.
- To find out the yield component(s) responsible for higher grain yield in hybrid rice varieties compared to the inbred.

Chapter 2

Review of Literature

REVIEW OF LITERATURE

Rice has wide adaptability to different environmental conditions, as it is evident from its worldwide distribution. Yield of a rice variety is determined by the morphological parameters such as plant height, effective tiller hill^{-1}, number of spikelets panicle^{-1}, percentage filled grain and grain size as well as by environmental factors. The physiological parameters like leaf area index, dry matter accumulation, translocation of assimilates are also important to determine yield potentiality. Some research findings regarding the morpho-physiological parameters and yield of hybrid rice relevant to the present study are reviewed below with followings.

2.1 Morpho-physiological parameters

2.1.1 Plant height

Honarnejad (1995) observed that plant height was 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 *Oryza rufipogon*. 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. (2004) 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 culm length of 70 cm. Hybrids have higher plant height as compared to HYV (Ghosh. 2001). BRRI (1995) reported that average plant height of BR30, BR22, BR23 and Iratom-24 were 120 cm, 125 cm, 120 cm and 80 cm, respectively.

2.1.2 Tillering dynamics

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 hill^{-1} (Song *et. al.*, 2009). The maximum tillering occurred at 738 GDD in all genotypes except Neda and Dasht that occurred at 920 GDD. Neda (improved genotype) and Ramazan Ali Tarom (traditional genotypes) had greatest and lowest tillering caopacity, 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 JND13.

2.1.3 Leaves hill^{-1}

Hassan (2001) showed that photosynthetically active leaves hill^{-1} 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. 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^{-1} (Baloch *et al.*, 2006).

2.1.4 Leaf area hill^{-1}

Mahdavi *et al.* (2004) 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. Flag leaf area was greatest in Minghui-63, hybrid was intermediate and *O. rufipogon* had the smallest area (Song *et al.*, 2004). Cultivars with grater flag leaf area generally have high grain weight (Mahmood and Chowdhary, 2000). 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.* (1997) studied the development of leaf area and found that all the cultivars produced maximum leaf area during panicle initiation stage.

2.1.5 Leaf area index

Wada *et al.* (2002) stated that a higher crop growth rate after anthesis mainly due to the high mean LAI during the ripening period. Yuan (2001) showed that LAI of the top three leaves is about 6. Whereas, Miah *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. 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. Reddy *et al.* (1995) reported that rice genotypes differed markedly in LAI, SLW and assimilation rate. Maximum assimilation rate was observed with LAI of 4-5. Assimilation rates decrease with higher LAI due to mutual shading. Ghosh and Singh (1998) observed a strong and positive correlation of LAI with grain yield. They also stated that LAI at flowing showed yield variation of 79% and delay in planting by 15 drastically affected LAI of rice. Mahdavi et al. (2004) showed that all genotypes reached maximum LAI at pre-flowering except Dash and Tarom, which reached maximum LAI at flowering. At pre-flowering Neda (high-yielding genotype) had greatest LAI comparing to other genotypes (LAI=5.70). Neda was a late-maturity genotype and due to longer vegetative phase had greatest LAI. Maximum LAI was correlated positively and strongly with grain yield.

2.1.6 Total dry matter hill^{-1}

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. 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). JianChang *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. They also showed that Onda had greater total dry matter among other genotypes (this genotypes also had highest grain yield). The maximum TDM produced earlier for improved genotypes than traditional genotypes (1445 and 1652 GDD, respectively). At flowering the dry matter was genotypes for Jahesh ad was lower of Ramazan Ali Tarom (923.93 g m^{-2} and 429 g m^{-2}, respectively).

2.1.7 Crop growth rate

Miah *et al.* (1996) 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). Horie (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. 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.

2.1.8 Relative growth rate

Zahad *et al.* (1980) 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. 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). Paranhos *et al.* (1997) found that CGR, RGR, And LAI differed significantly among cultivars. Chatta and Khan (1991) found that RGR had strong positive correlation with NAR.

2.1.9 Net assimilation rate

Lu *et al.* (2000) observed that decreased in the rate of photosynthesis in leaves cause parallel decrease in NAR and eventually low grain yield and they also obtained higher yield due to higher net assimilation rate. Similarly, Thakur and Patel (1985) stated that NAR is one of the factors responsible for higher paddy yield. Burondkar et al. (1998) reported that yield was positively correlated with CGR, RGR, NAR, TDM and some yield components. Khan (1991) found that NAR showed strong positive correlation with specific leaf weight and RGR. Singh (1994) observed a positive correlation between LAI and NAR towards higher paddy yield at all phonological stage. The NAR is used as a measure of the rate of photosynthesis minus respiration losses (Sun *et al.*, (1999) Oad *et al.* (2002) reported that rice growth, yield and physiological parameters, were interrelated, except for net assimilation rate.

2.2 Yield parameters

2.2.1 Effective tillers hill^{-1}

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

Kabir *et al.* (2004) reported that the cultivar chingura produced the highest panicle (26.86 cm) followed by Begunbitchi and Katijira varieties. 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. Chiandra 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 weight was found positive and highly significant. Diaz *et al.* (2000) noted wide variation in panicle length, panicle type, grain $panicle^{-1}$ and panicle weight and secondary branches $panicle^{-1}$. Malini *et al.* (2006) showed that the best hybrid was IR 68885A/ white ponni, which showed standard heterosis and heterobeltiosis for panicle length, spikelets $panicle^{-1}$, grains $panicle^{-1}$strawa yield and grain yield. The panicle length of the genotype CR 874-59 was observed to be higthest 28.8 cm) followed by CR 2008-129 26.9 cm) (patnaik and Mohanty.2006) wheres, 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). Myungkyu *et al.* (2005) studied with four rice varieties having different panicle characters and found that there were more primary rachis branches (PRBS) $panicle^{-1}$ and grain setting in Sindongjinbyeo and Iksan 767 but secondary rachis branches (SRBS) per PRB was fewer than in Saegyewabyo. While Dongin-1 and Saegyewabyo revealed more grains setting on SRB and lower ripened grain ratio. Dixit *et al.* (2004) 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 $hill^{-1}$ (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 Filled grain $panicle^{-1}$

Srivasta and Triphati (1998) found that the increase in grain yield in local cheek variety in comparison to hybrid might be attributed to the increased fertile grain/ panicle. Mishra and Pandey (1998) reported that panicle length, number of filled grains $panicale^{-1}$ and 1000- seed weight had contributed for increased grain yield. Jian

Ching *et al.* (2006) found that super-high-yielding rice had more spikelets panicle^{-1} and higher filled-grain percentage (>90%) than the high-yielding rice. Shrirame and Muly (2003) concluded that grain yield was significantly correlated with number of filled grains panicle^{-1}.

2.2.5 Thousand-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 (Asraf *et al.*, 1999). 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. 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 IR 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 (135-150 d) 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 (Swaina *et al.*, 2007). Patnaik and Mohanty (2006) showed that there was a wide variation in the maturity duration of varieties.

2.2.7 Biological yield

Park (1988) conducted an experiment to assess relationship between biological yield and harvest index. He observed that biological yield and harvest index both were closely related to sink size, source activity and sink source ratio.

2.2.8 Grain yield

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. Sharama 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 modern 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 spikelets m^{-2} due to a large number of spikelts $panicle^{-1}$ and high harvest index rather than biomass production (Yang *et al*., 2007).CR 978-8-2 recorded the highest grain yield of 4.925 t ha^{-1} followed by the check variety Sarna (4.864 t ha^{-1}) and CR 874-59 (4.675 t ha^{-1}) (Patnaik and Mohanty, 2006). The highest yield of 9.2 t ha^{-1} was obtained from selected I/J line IR 5865-2B-12-2-2, which was equal to that of indica hybrid CNHR3 and significantly higher than that of modern variety IR 36 (Roy, 2006). A rice cultivar Takanari showed the highest grain yield among the genotypes across the two years, and successfully produced over 11 t ha^{-1} of grain yield (Takai *et al*., 2006).

2.2.9 Straw yield

Patel (2000) studied the varietal performance of Kranti and IR36 and observed that kranti produced significantly higher straw yield than IR 36. The mean straw yield increases with Kranti over IR36 was 10%. Rejaul (2005) stated that straw yield was significantly affected due to varieties. The highest straw yield (5.64 t ha^{-1} was observed in BRRI dhan29. The tiller plants and total tillers $hill^{-1}$, might be contributed for higher straw yield of BRRI dhan29. The lowest straw yield (.5.43 t ha^{-1} was obtained from BRRI dhan28.

2.2.10 Harvest index

Cui *et al.* (1998) reported that significantly higher yield and harvest index in II group (Asian rice varieties) than that of the J group (Japanese rice varieties). Butogele *et al.* (1996) observed that medium grain cultivars had a higher harvest index and physiological efficiency. Harvest index is a measure of the efficiency of conversion of photosynthates into economic yield of a crop (Dutta and Mondal, 1998). High yield is determined by physiological process leading to a high net accumulation of photosynthates and it's partitioning into plant and seed. Jian Chang *et al.* (2006) found that super-high-yielding rice had more harvest index (51%) than the high - yielding rice. Shriame and Muley (2003) found that grain yield exhibited a very strong positive correlation with harvest index. 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).

Chapter 3

Materials and Methods

MATERIALS AND METHODS

Materials and methods adopted for this study are presented in this chapter. Geographical position, physical conditions and soil status of the experimental site are mentioned here. Experimental procedure or technique, methods of data collection on relevant parameters and management practices are also clearly described in this chapter.

3.1 Description of the experimental site

3.1.1 Location

This research work was conducted at the research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. The location of the site is $23^0 74'$N latitude and $90^0 35'$E longitude with an elevation of 8.2 meter from sea level.

3.1.2 Soil

The soil belongs to "The Modhupur Tract", AEZ 28 (Appendix I). Top soil is silty clay in texture with distinct dark yellowish brown mottles in colour. The soil pH is 5.6 and has organic carbon 0.45%. The experimental area is flat having available irrigation and drainage system. The selected plot is medium high land. The details have been presented in Appendix III.

3.1.3 Climate

The geographic location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February 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 and has been presented in Appendix II.

3.1 Experimental treatments and plant materials

Based on farmers demand five hybrid rice varieties were selected. These five and one inbred varieties were used as treatments for this study *viz*:

Moyna: Tia is hybrid rice development at China .It is recommended for *Boro* season of Bangladesh. The average plant height is 90-100 cm. The growth duration is 130-140 days. This variety has a yield potential up to 10 t ha^{-1}.

Sonarbangla-3: This hybrid variety has been imported from China and approved by the National Seed Board of Bangladesh. The variety is recommended for the *Boro* season. The plant type is semi dwarf (95-105 cm), growth duration is 145-150 days and its average grain yield ranges from 9 to 10 t ha^{-1}.

Jagoron: It is a hybrid rice variety and developed in China. BRAC (Bangladesh Rural Advancement Committee) is the sole agent for this variety in Bangladesh. The variety has the ability to produce grain yield 8.5 to 9.5 t ha^{-1}, growth duration 104 to 130 days, plant height is semi dwarf (100 to 120 cm) , and suitable in irrigated soil.

Heera-4: 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}

Panna-1: It is another hybrid rice variety developed in China and marketed in Bangladesh by ACI Ltd. It was recommended for *Boro* season (November to February). The grains are medium fine and white in color. It requires about 145 days on an average for completing its life cycle with an average grain yield of 8.0 t ha^{-1}.

BRRI dhan-45: This inbred variety was developed by Bangladesh Rice Research Institute (BRRI), Gazipur, it is released as a variety in the year of 2009. It is recommended for *Boro* season (November to February). Average plant height is 100 cm at the ripening stage. The grains are medium fine and white in color. It requires about 145 days on an average for completing its life cycle with an average grain yield is 7.5 t ha^{-1} (BRRI, 2010).

All these hybrid rice and check variety-were collected from a respective seed company, Dhaka and BRRI, Gazipur

3.3 Land preparation

The experimental land was opened with a power tiller and later on it was ploughed and cross- ploughed three times followed by laddering to level the land. The corners of the land were spaded. Clods were broken into smaller pieces using hammer. Before final land preparation sufficient water was added to the field for proper pudding. During final land preparation required amount of fertilizers was applied and all the weeds and stubbles were removed from the field to make the land ready for transplanting.

3.4 Fertilizer application

The land was fertilized with 120, 60, 80 and 50 kg ha^{-1} of urea, TSP, MP and Gypsum, respectively. The whole amount of fertilizers for unit plot were calculated, measured and applied separately. One third of urea and all other fertilizers were applied and incorporated into the soil at the time of final land preparation and the rest amount of urea was top dressed in two equal splits, one at 25 DAT (days after transplanting) and the other at 50 DAT.

3.5 Experimental design and layout

The experiment was laid out in a Randomized complete Block Design (RCBD) with four replications. Each replication represented a block in the experiment. Each block was divided into six unit pots, each of 5 m × 4 m in size. Thus, the experiment was comprised of 24 unit plots. The spaces between two adjacent blocks and two unit plots were 1.0 m and 0.5 m, respectively.

3.6 Raising of seedlings

Seedlings were raised in well prepared seedbed at the side of research field. Before sowing of seeds in the seedbed were soaked for 24 hours and then the soaked seeds were kept in the jute bags till the sprouting (3days) of the seeds. The sprouted seeds were sown in the wet seedbed on 03 December, 2011. Due care was taken to protect the seedbed from damages by birds and pests.

3.7 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 seedbeds were uprooted carefully to safeguard the seedling from mechanical injury in the roots and the seedlings were kept in soft mud under shade.

3.8 Transplanting of seedlings

On 02 January of 2012, 30 days old seedlings of all studied hybrid rice and check variety were transplanted in the puddle land keeping row to row distance 25 cm and plant to plant distance 15 cm.

3.9 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.

3.10 Growth parameters

3.10.1 Sampling for growth analysis

Five 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.

3.10.2 Data collection

Data were recorded on the following crop characters:

3.10.2.1 Plant height

Plant height was considered from ground level to the apex of the longest leaf at vegetative phase and to the panicle at reproductive phase, respectively.

3.10.2.2 Tillers hill^{-1}

Tillers hill^{-1} from the sampled plants of each plot was counted at different growth stage viz. 50 (vegetative stage), 70 and 90 DAT (reproductive stage) and at harvesting.

3.10.2.3 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.

3.10.2.4 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 $\pm 2^0$ C for 72 hours. Sub-sampling was done when the sample volume was excess and difficult to handle. Finally, leaf area was calculated hill^{-1}

3.10.2.5 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-

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

Where,

LA = Leaf area (cm^2)

A= Unit land area (cm^2)

3.10.2.6 Total dry matter hill^{-1}

Root dry weight, leaf dry weight and stem dry weight were added to get the total dry matter and then the other growth parameters were calculated as follows.

3.10.2.7 Crop growth rate

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

$$CGR = \frac{1}{A} \times \frac{W_2 - W_1}{T_2 - T_1} \text{ g m}^{-2} \text{ d}^{-1}$$

Where,

W_1= Total plant dry matter at time T_1 (g)

W_2 = Total plant dry matter at time T_2 (g)

A = Ground area (m^2)

3.10.2.8 Relative growth rate

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

$$RGR = \frac{LnW_2 - LnW_1}{T_2 - T_1} \text{ g g}^{-1} \text{ d}^{-1}$$

Where,

W_1 = Total plant dry matter at time T_1 (g)

W_2 = Total plant dry matter at time T_2 (g)

Ln = Natural logarithm

3.10.2.9 Net assimilation rate

Increase of plant material per unit of leaf area per unit of time

$$NAR = \frac{W_2 - W_1}{T_2 - T_1} \times \frac{LnLA_2 - LnLA_1}{LA_2 - LA_1} \text{ g m}^{-2} \text{ d}^{-1}$$

Where,

LA_1 = Leaf area at time T_1 (m^2); LA_2 = Leaf area at time T_2 (m^2)

W_1 = Total plant dry matter at time T_1 (g)

W_2 = Total plant dry matter at time T_2 (g)

LA_1 = Leaf area at time T_1 (m^2)

LA_2 = Leaf area at time T_2 (m^2)

Ln = Natural logarithm

3.11 Yield parameters

3.11.1 Harvesting and processing

Depending on the maturity of tested hybrid and inbred rice varieties, they were harvested on different days. Harvesting was done when 80 to 90% of the grains become golden in color. 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).

3.11.2 Data collection

Data were recorded on the following yield parameters:

3.11.2.1 Effective tillers hill^{-1}

Effective tillers hill^{-1} from the sampled plants of each plot was counted at final harvesting.

3.11.2.2 Non-effective tillers hill^{-1}

Non-effective tillers hill^{-1} from the sampled plants of each plot was counted at final harvesting.

3.11.2.3 Panicle length

Measurement was taken from the neck node to the apex of each panicle.

3.11.2.4 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.

3.11.2.5 Thousand grain weight

One thousand clean oven dried (72 ± 2^0 C for 72 hours) grains were counted from seed stock obtained from hill^{-1} in each plot and weighed by using an electronic balance.

3.11.2.6 Crop duration

Crop duration was calculated from seeding to maturity when 75-80% grains was golden in colour.

3.11.2.7 Biological yield

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

Biological yield = Grain yield + Straw yield.

3.11.2.8 Yield

Grain yield was recorded for one sq. meter and then converted to express as t ha^{-1}.

3.11.2.9 Harvest index

Harvest index is the relationship between economic (grain yield) yield and biological yield (Gardener et al., 1985). It was calculated by using the following formula:

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

3.12 Statistical analysis

The data collected on different parameters under the excrement were statistically analyzed to obtain the level of significance using the computer MSTAT package program developed by Russel (1986). The differences between pairs of means were compared by Duncan's multiple range test (DMRT) as stated by Gomez and Gomez (1984).

Chapter 4

Results and Discussion

RESULTS AND DISCUSSION

This chapter comprises of the presentation and discussion of the results obtained from the experiment. The results were presented under following subheadings in tabular and graphical form to strengthen the discussion and interpretation conveniently.

4.1 Growth parameters

4.1.1 Plant height

Plant height at different stages was varied significantly among the hybrid and inbred rice varieties (Table 1). Plant height increased progressively with the advancement of time and growth stage. At vegetative stage (50 days after transplanting), the tallest plant was recorded in Heera-4 (79.5 cm) followed by Moyna (76.87 cm) and the shortest was recorded in Jagoron (64.87 cm) followed by Panna-1 (67.87 cm). At reproductive stages (70 and 90 DAT), the highest plant highest was observed in Heera-4 (102 and 109.3 cm, respectively) and the lowest height was recorded in BRRI dhan-45 (83.33 and 88.67 cm, respectively). At final harvest, Heera -4 had the highest plant height (111 cm) followed by Somarbangla-3 (109 cm) and the shortest was in BRRI dhan-45 (89.7 cm) preceded by Panna-1 (96.0 cm) with same statistical rank. Rest of the hybrid rice showed intermediate status. BRRI (1995), DRR (1996), Om *et al.* (1998) and Kabir *et al.* (2004) also observed variation in plant height due to varietal differences. It appears that Heera-4 was the tallest and BRRI dhan-45 was the shortest plant.

Table 1. Plant height at different days after transplanting (DAT) in hybrid and inbred rice varieties.

Treatments	Plant height (cm)			
	50 DAT	70 DAT	90 DAT	At final harvest
Moyna	76.87	97.67ab	103.70ab	105.00ab
Sonarbangla-3	75.87a	96.00b	106.7ab	109.00ab
Heera-4	79.50a	102.00a	109.30a	111.00a
Jagoron	64.87c	80.00d	101.00b	103.00b
Panna-1	67.87bc	88.67c	93.66c	95.00c
BRRIdhan-45	70.50b	83.33cd	88.67c	89.70d

Values with common letter (s) within a column do not differ significantly at 5% level of probability as per DMRT.

4.1.2 Tillers hill^{-1}

There was a significant variation in the total number of tillers hill^{-1} among the hybrid and inbred rice varieties at all growth stages (Table 2). Result showed that number of total tillers hill^{-1} increased with the advancement of vegetative growth stages. But at reproductive stages, number of total tillers hill^{-1} decreased in all the studied hybrid rice. At vegetative (50) stage, the maximum number of tillers hill^{-1} was produced by Heera-4 that was significantly different from other hybrid rice varieties. The lowest number of tillers hill^{-1} at vegetative stages was observed in Panna-1. At reproductive (70 and 90 DAT) stages the maximum number of tillers hill^{-1} was recorded in the Heera-4 and the lowest number of total tiller was recorded in the Panna-1. With the decrease of tillers hill^{-1}, yield also decease considerable (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) reported that significant variation observed among the cultivars. It was shown that hybrid produced a significantly higher number of tillers than their parental species (Song *et al.*, 2009).

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

Treatments	Tillers hill^{-1}			
	50 DAT	70 DAT	90 DAT	At final harvest
Moyna	12.50d	16.50b	15.67bc	14.88b
Sonarbangla-3	13.66bc	16.66bc	16.00bc	14.00bc
Heera-4	15.33a	20.33a	20.50a	18.00a
Jagoron	12.66cd	16.66b	16.00bc	14.00bc
Panna-1	10.66e	15.00c	14.75c	13.33c
BRRIdhan-45	14.50ab	16.87b	17.13b	14.13bc

Values with common letter (s) within a column do not differ significantly at 5% level of probability as per DMRT.

4.1.3 Leaves hill^{-1}

Significant difference on total number of leaves hill^{-1} in the rice varieties was observed from vegetative (50 DAT) to reproductive (90 DAT) stage (Table 3). The total number of leaves was continued to increase up to 70 DAT and thereafter declined. At vegetative stage (50 DAT), the highest number of leaves was observed in Heera-4 (77.66) followed by Sonarbangla-3 (66.0). At 70 DAT, the highest number of leaves was observed in Heera-4 (93.33) followed by Moyna (86.33) and they were statistically different at 5% level of probability. At reproduced stage (90 DAT), the highest number of leaves (90.33) was recorded from Heera-4 and Panna-1 produced the lowest number of leaves (63.33). In contrast, at 50 and 70 DAT, Panna-1 produced the lowest number of leaves (50.66 and 67.33, respectively) followed by BRRI dhan-45 (57.67 and 72.00, respectively). Rest of the hybrid rice showed intermediate values. So, the result indicate that Heera-4 produced the highest number of leaves and Panna-1 produced the highest number of leaves and also indicate that number of leaves increase up to a certain growth stage till the end of vegetative stage and then declined. The variation in total number of leaves might concern with the genetical variation, physiological functions and growth characters of the studied rice.

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

Treatments	Leaves hill^{-1}		
	50 DAT	70 DAT	90DAT
Moyna	64.66bc	86.33b	82.00b
Sonarbangla-3	66.00b	75.33c	71.33c
Panna-1	50.66e	67.33d	63.33d
Jagoron	61.00cd	72.33cd	68.66c
Heera-4	77.66a	93.33a	90.33a
BRRIdhan-45	57.67d	72.00cd	63.33cd

Values with common letter (s) within a column do not differ significantly at 5% level of probability as per DMRT.

4.1.4 Leaf area hill^{-1}

The development of leaf area (LA) over time in tested rice varieties was significantly varied during the vegetative and reproductive growth phases (Table 4). Results revealed that LA increased with age till the end of vegetative stage and thereafter declined. The increment of leaf area $hill^{-1}$ varied significantly among the rice varieties. At vegetative stage (50 and 70 DAT), the highest leaf area $hill^{-1}$ was produced by Heera-4 (1311 and 2081 cm^2, respectively) that was significantly different from others followed by Moyna (1236 and 1895 cm^2, respectively). The lowest leaf was observed in BRRI dhan-45 (1424 cm^2) proceeded by Panna-1 (1523 cm^2) at 70 DAT. At 90 DAT, the highest and the lowest leaf area $hill^{-1}$ were recorded in Heera-4 (1966 cm^2) and BRRI dhan-45 (1412 cm^2), respectively. The result obtained from the present study is consistent with the result of Sharma and Haloi (2001) in scented rice, who stated that variation in LA could be attributed to the changes in number of leaves. The result is also supported by the result of Chandra and Das (2010) in rice. The result indicated that hybrid rice varieties produced the higher leaf area than the check variety and the variation in leaf area might occur due to the variation in number of leaves (Table 3).

4.1.5 Leaf area index (LAI)

Leaf area index express as the ratio of leaf to the ground area occupied by the crop. Significant difference on leaf index (LAI) in the studied rice varieties was observed from vegetative (50 DAT) to reproductive (90 DAT) stages (Table 4). The LAI continued to increase till start of reproductive stage and thereafter decreased. At vegetative stages (50 DAT), the maximum LAI was observed in Heera-4 (2.62) followed by Moyna (2.47). At 70 DAT, the maximum LAI was observed in Heera-4 (4.16) followed by Moyna (3.79). In contrast, at 50 and 70 DAT, BRRI dhan-45 showed the lowest LAI (1.52 and 2.85, respectively) over their growth period. Rest of the hybrid rice showed intermediate values. On the other hand, at reproductive stage (90 DAT) the hybrid rice variety Heera-4 and inbred BRRI dhan-45 showed the highest and the lowest LAI, respectively. The results obtained from the present study are consistent with the result of 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 LAI values throughout the whole growth period which led to the higher biomass production and yield (Ready *et al.*, 1995). The result indicated that hybrid rice produced higher LAI than the check variety and the increase in LAI with time could be attributed to increase in number of tillers hill^{-1} (Table 2) consequently higher number of leaves hill^{-1}(Table 3).

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

Treatment	Leaf area hill^{-1} (cm^2)			Leaf area index (LAI)		
	50 DAT	70 DAT	90 DAT	50 DAT	70 DAT	90 DAT
Moyna	1236b	1895b	1836b	3.22b	4.54b	4.42ab
Sonarbangla-3	1097c	1656c	1609cd	2.94c	4.07cd	3.97c
Heera-4	1311a	2081a	1966a	3.37a	4.91a	4.71a
Jagoron	1015d	1707c	1663c	2.77cd	4.16c	4.07bc
Panna-1	896d	1523d	1507de	2.54cd	3.8de	3.79cd
BRRIdhan-45	755e	1424d	1412e	2.27d	3.6e	3.57d

Values with common letter (s) within a column do not differ significantly at 5% level of probability as per DMRT.

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 BRRI dhan-45. 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}

Stem dry matter is an important factor for plant growth and development. There was significant difference observed in stem dry matter among the hybrid and inbred rice varieties at different growth stages (Table 5). At vegetative stages (50 DAT) maximum stem dry matter was observed in Heera-4 and the lowest was found in BRRI dhan-45. At reproductive stage (70 and 90 DAT) the maximum stem dry matter was found in Heera-4 and the lowest was found in inbred, BRRI dhan-45. Result revealed that stem dry matter was gradually increased with time.

4.1.8 Leaf dry matter hill^{-1}

There was a significant variation observed in leaf dry matter among the rice cultivars at virus growth stages (Table 5). At vegetative stages (50 DAT) maximum leaf dry matter was observed in Heera-4 and the lowest was found in BRRI dhan-45. At reproductive stage (70 and 90 DAT) the maximum leaf dry matter was found in Heera-4 and the lowest was found in the inbred variety. Result revealed that leaf dry matter was gradually increased with time.

4.1.9 Total dry matter hill^{-1}

Total dry matter production was significantly varied among hybrid and inbred rice varieties (Table 5). This result revealed that dry matter production increased with age of rice plant. Result further revealed that dry matter accumulation in plant was low at 50 DAT and thereafter increased rapidly. At 90 DAT, Heera-4 showed the highest dry matter hill^{-1} (81.50 g) followed by Moyna (80.50 g). On the other hand, BRRI dhan-45 produced the lowest TDM (67.60 g) preceded by Panna-1 (71.37 g) and they were significantly different. At 50 and 70 DAT, the highest TAD hill^{-1} was observed in Heera-4 (24.83 and 53.50 g, respectively) and the lowest TDM hill^{-1} was recorded in BRRI dhan-45 (18.13 g and 42.06 g, respectively).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 Hoque (2004) who reported that TDM increased with increasing plant age up to physiological maturity and high yielding rice always maintained higher TDM hill^{-1}. The results indicated that hybrid rice produced higher TDM than BRRI dhan-45. Increased dry matter in hybrid rice was possibly due to greater leaf area hill^{-1} (Table 4).

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

Treatments	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
Moyna	5.20a	7.30b	12.80b	14.03b	32.53c	52.90b	6.20b	13.50b	14.50b	23.40ab	52.43a	80.50a
Sonarbangla-3	4.40b	5.70d	12.50c	12.10d	30.02d	49.20d	5.20d	12.20d	13.70d	22.46ab	47.66bc	73.20bc
Heera-4	5.30a	7.40a	13.20a	14.13a	34.70a	53.20a	6.40a	13.83a	15.40a	24.83a	53.50a	81.50a
Jagoron	3.50c	7.20c	10.50e	13.96c	32.70b	52.20c	6.10c	12.70c	14.30c	22.83ab	51.60ab	76.40ab
Panna-1	4.40b	5.56e	11.20d	9.53e	26.16e	44.57e	5.10e	11.30e	13.60e	21.03bc	44.73cd	71.37bc
BRRIdhan-45	3.40c	5.40f	10.40f	9.13f	23.83f	43.60f	4.60f	11.20f	12.80f	18.13c	42.06d	67.60c

Values with common letter (s) within a column do not different significantly at 5% level of probability as per DMRT.

4.1.10 Crop growth rate

The influence of the rice varieties on CGR was measured during the vegetative (50 - 70 DAT) and reproductive (70 -90 DAT) growth phases (Fig. 1) At vegetative stage (50 -70 DAT), the hybrid rice Moyna showed the highest CGR value (43.71 g m^{-2} d^{-1}) followed by Heera-4 (41.9 g m^{-2} d^{-1}). In contrast, the lowest CGR was observed in BRRI dhan-45 (29.27 g m^{-2} d^{-1}) followed by Panna-1(30.35g m^{-2} d^{-1}). At reproductive stage (70 -90 DAT), the highest CGR was observed in Heera-4 (40.67 g m^{-2} d^{-1}) followed by Moyna (39.46 g m^{-2} d^{-1}). The lowest CGR value at 70-90 DAT was observed in BRRIdhan-45 (26.75 g m^{-2} d^{-1}) preceded by Panna-1 (28.05 g m^{-2} d^{-1}). Decline of CGR at the latter stage might be attributed to the decrease in LAI at the latter stage (Table 4). So, the CGR increased along with increases in LAI. This result is in agreement with the finding of Yang *et al.* (2010). At vegetative stage (50-70 DAT), the CGR value was found to be maximum which indicated that plants expended it's assimilate 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. From the result, it appears that CGR was the highest in hybrid rice and the lowest in BRRI dhan-45.

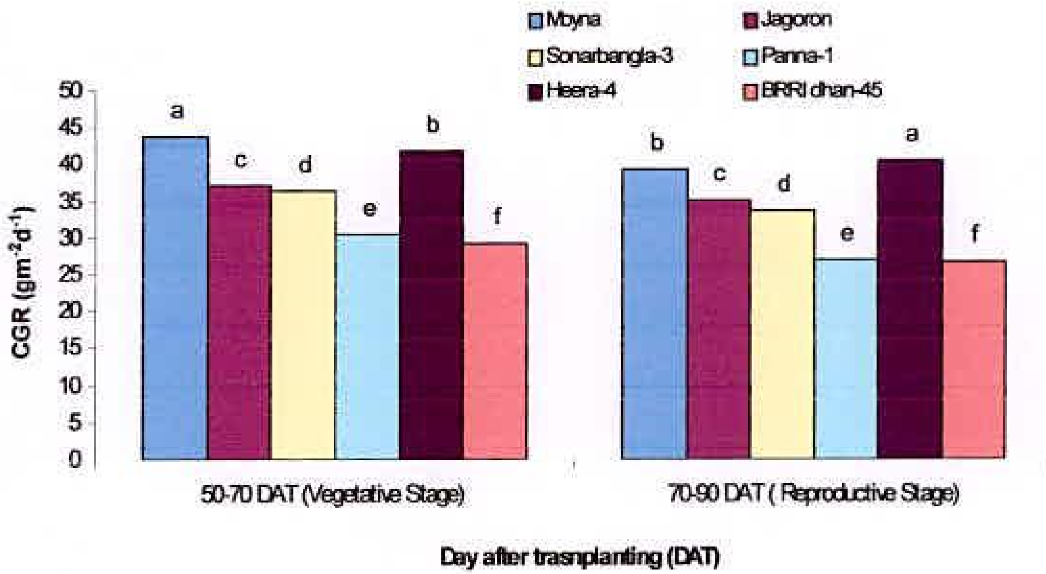


Fig 1. Crop growth rate (CGR) at vegetative (50-70 DAT) and reproductive (70-90 DAT) stages in the tested hybrid and inbred rice varieties. ***Common letter (s) does not differ significantly at 5% level of probability.***

4.1.11 Relative growth rate

The relative growth rate (RGR) in tested hybrid and inbred varieties was measured during the vegetative (50-70 DAT) and reproductive (70-90 DAT) growth phases (Fig.2). It was observed an inverse relationship between RGR and plant age. Varietal differences in RGR were found significant at all growth stages. The RGR showed the higher values at vegetative stage (50 -70 DAT) than the reproductive stage (70-90 DAT) .The result revealed that the Moyna produced the highest RGR value (21.85 mg g^{-1} d^{-1}) at 50-70 DAT followed by Heera-4 (21.05 mg g^{-1} d^{-1}) and there was significant difference between them. In contrast, the lowest RGR value was observed in BRRI dhan-45 (17.66 mg g^{-1} d^{-1}) at 50-70 DAT. At 70-90 DAT, the highest RGR was found in Heera-4 (13.52 mg g^{-1} d^{-1}) and the lowest RGR value was found BRRI dhan-45 (7.08 mg g^{-1} d^{-1}). Generally, with the advancement of the plant age, the RGR decreased in most of the field crops (Dutta and Mondal, 1998). The rapid decline of RGR at the latter stage possibly due to the efforts towards reproductive development by the plant population. Similar result was also observed in the present experiment. The result of the present study are in agreement with the result of Aktar (2005), who stated that the maximum RGR was observed during the vegetative stage an declined rapidly with the advancement of growth stages.

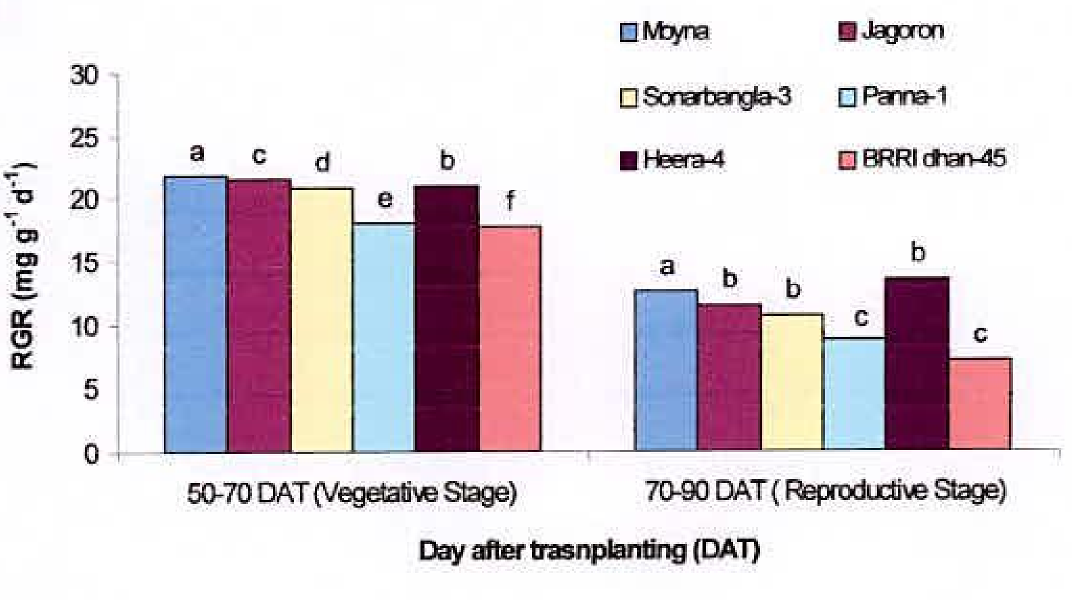


Fig 2. Relative growth rate (RGR) at vegetative (50-70 DAT) and reproductive (70-90 DAT) stages in the tested hybrid and inbred rice varieties. ***Common letter (s) does not differ significantly at 5% level of probability.***

4.1.12 Net assimilation rate

Significant variation in NAR was found in vegetative stage (50-70 DAT), to reproductive stage (70-90 DAT) (Fig. 3). At vegetative stage (50-70 DAT), the highest NAR (6.7 g m^{-2} d^{-1}) was observed in Moyna followed by Heera-4 (6.5 g m^{-2} d^{-1}) and the lowest (5.1 g m^{-2} d^{-1}) was observed in BRRI dhan-45 preceded by Panna-1 (5.4 g m^{-2} d^{-1}). At reproductive stage (70-90 DAT), the highest NAR (4.6 g m^{-2} d^{-1}) was recorded in Heera-4 followed by Moyna (4.4 g m^{-2} d^{-1}) with the same statistical rank while the lowest NAR value was recorded in BRRI dhan-45 (3.2 g m^{-2} d^{-1}). Considering both growth stages, Heera-4 was found to be superior compared to the other studied varieties .This result is agreed with result of Hoque (2004) who reported that high yielding rice had greater NAR than the low yielding ones. The decrease of NAR at later growth stage might possibly be for mutual shading and increased number of older leaves, which could have lowered photosynthetic efficiency (Reddy et al., 1995).

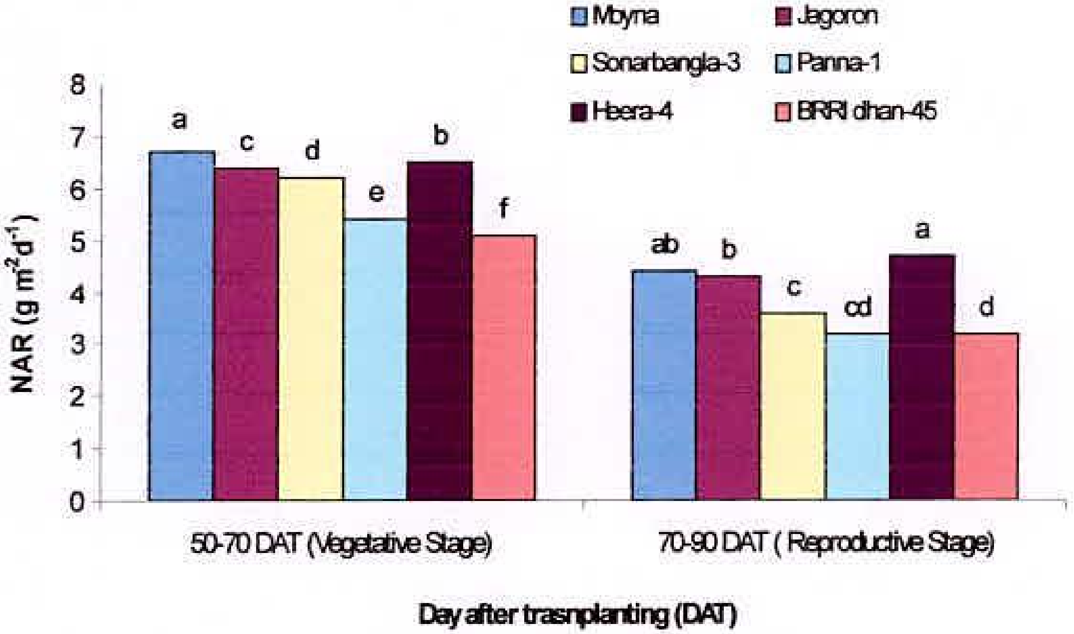


Fig 3. Net assimilation rate (NAR) at vegetative (50-70 DAT) and reproductive (70-90 DAT) stages in the tested hybrid and inbred rice varieties. ***Common letter (s) does not differ significantly at 5% level of probability.***

4.2 Yield parameters

4.2.1 Effective tillers hill^{-1}

Number of effective tillers hill^{-1} had shown significant variation among the studied rice varieties (Table 6). The highest number of effective tillers hill^{-1} (15.34) was recorded in Heera-4 followed by Moyna (12.67). This result revealed that there was significant difference in number of effective tillers hill^{-1} between them. In contrast, the lowest number of effective tillers hill^{-1} was observed in BRRI dhan-45 (10.0) preceded by Panna-1 (11.34). Result further revealed that hybrid rice produced greater number of effective tillers hill^{-1} than BRRI dhan-45. It means yield is positively correlated with effective tillers number hill^{-1}. The above result of variability in effective tillers hill^{-1} are also in agreement with many workers (Yang *et al.*, 2010; Shrirame and Muley, 2003; Munshi, 2005).

4.2.2 Non- effective tillers hill^{-1}

Non- effective tillers hill^{-1} had shown significant difference among the studied varieties (Table 6). The highest number of non-effective tillers hill^{-1} (4.66) was recorded in BRRI dhan-45 followed by Panna-1 (3.33). This result revealed that there was significant difference in number of non- effective tillers hill^{-1} between them. In contrast, the lowest number of non- effective tillers hill^{-1} was observed in Heera-4 (2.30) followed by Moyna (2.33). Result further revealed that hybrid rice produced lower number of non- effective tillers hill^{-1} than the inbred.

4.2.3 Panicle length

Significant variation in panicle length was noticed in different hybrid rice (Table 6). The longest panicle was observed in Heera-4 (26.33 cm) followed by Jagoron (26.30 cm) and Moyna (25.33 cm). The shortest panicle was observed in BRRI dhan-45 (23.33 cm) preceded by Panna-1 (24.00 cm). From the result, it appears that panicle length was longer in hybrid rice than the inbred due to genetic make up. This result is consistent with findings of Chakma (2006) who reported that panicle length was significantly varied in varieties. Salam *et al.* (1990) reported that higher yield in rice can be achieved from panicle length.

4.2.4 Unfilled grains panicle^{-1}

Number of unfilled grains panicle^{-1} varied significantly among the rice (Table 6). Moyna produced the highest number of unfilled grains panicle^{-1} (20.33) followed by Jagoron (16.33) and they differed significantly. On the other hand, the lowest by number of unfilled grains panicle^{-1} was recorded in Panna-1 (7.33) followed by Sonarbangla-3 (11.66) and Heera-4 (13.3). It was found from this experiment that hybrid rice significantly differed in respect number of unfilled grains panicle^{-1}. Similar result was also reported by Dutta *et al.* (2002) in aromatic fine grain rice, who observed a wide range of variability in number of unfilled grains panicle^{-1}. Chowdhary *et al.* (1993) reported differences in number of unfilled grains panicle^{-1} due to varietal character.

4.2.5 Filled grains panicle^{-1}

Filled grains panicle^{-1} was markedly different among the tested varieties (Table 6). Heera-4 produced the highest number of filled grains panicle^{-1} (222.30) followed by Moyna (210.30). This result showed that there was no significant difference between Heera-4 and Moyna. On the other hand, Panna-1 produced the lowest Number of filled grains panicle^{-1} (159.70) preceded by BRRI dhan-45 (193.0) and they differed significantly. This result is in agreement with the result of Dutta *et al.* (2002) who observed that yield was affected by the filled grains panicle^{-1}

4.2.6 Thousand-grain weight

Thousand-grain weight was significantly differed among the tested varieties (Table 6). Panna-1 showed the highest 1000- grain weight (31.83 g) due to heavier grain followed by Sonarbangla-3 (28.06 g) which were significantly different from each other. On the other hand, BRRI dhan-45 showed the lowest1000- grain weight (22.1 g) due to lighter grain which showing significant difference with Moyna (27.1 g). Mondal *et al.* (2005) studied with 17 modern cultivars of transplanted *Aman* rice and reported that 1000-grain weight differed significantly among the cultivars studied, which supported the present experimental result. Fujia *et al.* (1984) observed that length, which and thickness of rice grains were positively correlated with 1000- grain weight. The variation in1000- grain weight might be due to genetic make up of particular rice and sink strength.

4.2.7 Crop duration

Days to maturity exhibited significant difference among the tested hybrid and inbred rice varieties (Table 6). Result indicated that all the varieties required shorter days to maturity than Heera-4. Heera-4 required the highest days to maturity (129.0 d) followed by Moyna (124 d) and they were significantly different from each other. On the other hand, BRRI dhan-45 required the lowest days to maturity (118 d) followed by Panna-1 (120 d). This result was in full agreement with Anonymous (2004) who reported that hybrid rice took more days to complete their life-cycle than those of local varieties due to delay in tillering, flowering and grain maturity which might be help them produce more dry matter and higher yield.

4.2.8 Biological yield

The total biomass production was found statistically different among the tested rice varieties (Table 6). The highest biological yield hill^{-1} was recorded in Heera-4 (12.11 t ha^{-1}) followed by Moyna (12.03 t ha^{-1}). In contrast, the lowest biological yield was recorded in BRRI dhan-45 (10.21 t ha^{-1}) preceded by Panna-1 (10.53 t ha^{-1}). Result revealed that hybrid rice produced more biological yield than BRRI dhan-45. Munshi (2005) and Chowdhury *et al.* (1995) reported that grain yield was positively correlated with biological yield in rice.

4.2.9 Grain Yield

There was a remarkable difference in respect of grain yield ha^{-1} (Table 6). Heera-4 produced the highest grain yield (6.24 ha^{-1}) followed by Moyna (6.03 t ha^{-1}) and they were significantly different. On the other hand, BRRI dhan-45 the lowest grain yield (4.27 ha^{-1}) which is about 43.5% lowers than that of Heera-4. They yield was higher in Heera-4 including other hybrid rice might be attributed to the production of higher LAI,CGR,NAR,TDM, higher number of effective tillers hill^{-1} and higher number of filled grains panicle^{-1}. Mondal *et al.* (2005) and Pruneddu and Spanu (2001) reported that the hybrid rice produced higher number of effective tillers hill^{-1} and higher number of filled grains panicle^{-1} also showed higher grain yield ha^{-1}. This result indicated that the hybrid variety Heera-4 had remarkable superiority to growth, yield attributes and grain yield over the other rice varieties.

4.2.10 Harvest index

Harvest index (HI) varied significantly among the hybrid and inbred rice varieties (Table 6). Heera-4 recorded significantly the highest harvest index (51.75%). It means dry matter partitioning to economic yield was superior in Heera-4 to the other rice. BRRI dhan-45 recorded significantly the lowest harvest index (41.70%). It means dry matter partitioning to economic yield was inferior in BRRI dhan-45 to the other rice. From this present study, it appears that hybrid rice maintained higher harvest index. Chandra and Das (2010), Cui *et al.* (2000) and Ready *et al.* (1994) also found higher harvest index in the hybrid varieties compared to the inbred.

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

Treatments	Effective tillers hill^{-1}	Non-effective tillers hill^{-1}	Panicle length (cm)	Unfilled grain panicle^{-1}	Filled grain panicle^{-1}	1000-grain weight (g)	Crop duration (d)	Biological yield (t ha^{-1})	Grain yield (t ha^{-1})	Harvest index (%)
Moyna	12.67b	2.33c	25.33ab	20.33a	210.30a	27.10b	154ab	12.03a	6.03ab	50.06a
Jagoron	11.67c	2.33c	26.30a	16.33b	204.00a	27.90b	152b	11.66ab	5.66b	48.43ab
Sonarbangla-3	11.34d	2.66c	24.66abc	11.66d	200.00a	28.06b	153ab	10.92bc	4.92c	44.90bc
Panna-1	11.34d	3.33b	24.00bc	7.33e	159.70b	31.83a	140b	10.53c	4.57cd	43.26c
Heera-4	15.34a	2.30c	26.33a	13.33cd	222.30a	27.20b	159a	12.11a	6.24a	51.75a
BRRIdhan-45	10.00e	4.66a	23.33c	14.66bc	193.00a	22.10c	148b	10.21c	4.27d	41.70c

Values with common letter (s) within a column do not different significantly at 5% level of probability as per DMRT.

Chapter 5

Summary and Conclusion

SUMMARY AND CONCLUSION

The experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Dhaka during the period from December, 2011 to May 2012 to study the growth and yield performance of five selected hybrid rice varieties. The experiment was laid out in a randomized Complete Block Design (RCBD) with four replications. One seedling of thirty days old was transplanted in each hill maintaining pacing 25 cm X 15 cm. The unit plot size was 4 x 5 m^2. All the necessary intercultural operation including weeding, top dressing, irrigation and pesticide applications, etc were done as and when necessary. Collected data were analyzed following the standard procedure and method.

Plant height, tillershill^{-1} leaves hill^{-1}, TDM, leaf area, LAI, CGR, RGR, NAR, and yield attributes like effective tillers hill^{-1}, unfilled and filled grains panicle^{-1}, panicle length, 1000-grian weight, crop duration, biological yield, grain yield and HI were significantly varied among the studied hybrid and inbred varieties. The hybrid rice Heera-4 showed superiority in respect of growth parameters like tillers hill^{-1}, leaf area hill^{-1}, TDM hill^{-1}, leaf area hill^{-1}, LAI, CGR, RGR, and NAR over the rest varieties. In all tested varieties, number of total tillers hill^{-1} gradually increased with the progress of growth stage. Number of leaves increased up to a certain growth stage (till the end of vegetative stage) and then declined. Leaf area hill^{-1} and leaf index area increased with age till start of reproductive stage and thereafter decreased. Dry matter accumulation in plant was low at 50 DAT and thereafter increased rapidly. In the early growth stage, CGR, NAR, and RGR increased rapidly but in the latter growth stage, they declined. Again, Heera-4 also showed the highest yield contributing characters like effective tillers hill^{-1} (15.34), panicle length (26.33 cm), crop duration (159.00 d), biological yield (12.11 t ha^{-1}),HI (51.88 %) to the check variety, BRRI dhan-45 (10.0, 23.33 cm, 148 d, 10.213 t ha^{-1} and 41.82 %, respectively). However, all the tested hybrid rice varieties produced higher grain yield compared to BRRI dhan-45. Yield components, effective tillers hill^{-1} and 1000-grain weight mainly contributed to the higher grain yield of the hybrid varieties over the inbred BRRI dhan-45. Among the studied hybrid, Heera-4 and Moyna performed better in respect of grain yield (6.24 and 6.03 t ha^{-1}, respectively) than that of inbred BRRI dhan-45

(4.27 t ha^{-1}). Results indicated that Heera-4 and Moyna produced higher grain yield because of higher total dry matter production, net assimilation rate (NAR), crop growth rate (CGR), harvest index (HI) and finally they have 43.5% yield advantage over the inbred BRRI dhan-45.

Therefore, Heera-4 and Moyna has the improved growth attributes among the afore-mentioned five hybrid rice varieties and ultimately lead to the higher dry matter production. All the tested hybrids diverted more dry matter to the grain compared to inbred BRRI dhan-45. Panicles $hill^{-1}$ and 1000-grain weight are the determinants for the higher grain yield of the studied hybrids over the inbred BRRI dhan-45. Although it needs more trials under farmer's field conditions at different agro-ecological zones of Bangladesh for the conformation of the results.

References

REFERENCES

Ahalawal, I.P.S. and Sarif, C.S.1983. Growth analysis in pigeon pea (*Cajanus cajan* L.) under differing management condition. *Indian J. Agron.*, 28(3): 363-369.

Aktar, M.B. 2005. Morpho-physiological evaluation and characterization in four *Aman* rice genotypes. M.S. Thesis, Dept., Crop Bot., Bangladesh Agric. Univ., Mymensingh.

Alim, A. 1982. Bangladesh Rice. Alim Publication, Dhaka.

Anonymous. 2004. Annual Report for 2003-2004 of Bangladesh Institute of Nuclear Agriculture. P.O .Box No. 4, Mymensingh, Bangladesh.

Anonymous. 2008. Development and use of hybrid rice technology. Annual Report 1998-1999 and work-plant for 1999-2000. Directorate of Rice Res., Hyderabad India. pp. 103-105.

Asharf, A., Khalid, A. and Ali, K. 1999. Effect of seeding age and density on growth and yield of rice in saline soil. *Pak. J. Biol. Sci.*, 2 (30): 860-862.

BBS (Bangladesh Bureau of Statistics). 2006. Statistical Year Book of Bangladesh. Ministry of planning, Government of the people's Republic of Bangladesh, Dhaka. P. 142.

BBS. 2010. Statistical Year Book of Bangladesh Bureau of Statistics. Min. Plan. Govt. People's Repub. Bangladesh. p. 450.

Bhuia, M.S.U., Hossain , S.M.A. and Kabir, S.K.G. 2002. Nitrogen fertilizer in rice cv. BR 10 after green manuring. *Bangladesh J. Agril. Sci.* 16(1): 89-92.

Briggs, K.G. and A. Aylenfisu. 1980. Relationships between morphological characters above the flag leaf node and grain yield in spring wheat. *Crop Sic.*, 20: 350-354.

BRRI (Bangladesh Rice Research Institute). 1995. *Adhunic Dhaner Chash.* Bangladesh Rice Res. Inst., Joyderpur, Gazipur. pp. 52-53.

BRRI (Bangladesh Rice Research Institute). 1997. Annual Report for 1996. Bangladesh Rice Res. Inst., Joyderpur, Gazipur. pp. 8-15.

BRRI (Bangladesh Rice Research Institute). 1999. Adhunik Dhaner Chash. Bangladesh Rice Res. Ins., Joyderpur, Gazipur, Bangladesh pp. 5-9

BRRI (Bangladesh Rice Research Institute). 2010. Adhunik Dhaner Chash. Bangladesh Rice Res. Ins., Joyderpur, Gazipur, Bangladesh pp. 7-8.

Brondkar, M.M., Chavan, S.A., Jadav, B.B. and Birari, S.P. 1998. Physiological basis for varietal difference in yield of early rice varieties. *J. Maharashtra Agric. Univ.,* 13(3): 343-344.

Butogele, A.J.R, Biollch, P.K., Kavar, J.L, Macchiavelli, R.E. and Lindau, C.W. 1996. Rice variety difference in dry matter and nitrogen accumulation as related to plant stature and maturity group. *J. Plant Nutr.,* 20(9): 1203-1224.

Chakma, S. 2006. Influence of spacing on the growth and yield attributes of modern *Boro* rice varieties.M.S. Thesis, Dept. Crop Bot., Bangladesh Agric.Univ., Mymensingh.

Chandra, K. and Das, A.K. 2007. Correlation and intercorrelation of physiological parameters in rice under rainfed transplanted condition. *Crop Res . Hisar Assam Agril. Univ.,* 19 (2): 251-254.

Chatta, T.M. and Khan, M.A. 1991. Study on relationship between physiological parameters of India. *Pak. J. Sci. Indus. Res.*, 34(1): 37-39.

Chowdhary, M. J.U., Sarkar, A. U., Sarkar, M.A.R. and Kashem, M.A. 1999. Effect of variety and number of seedling hill^{-1} on the yield and its components on late transplanted *Aman* rice. *Bangladesh J. Agri. Sic.,* 20(2): 311-316.

Cui, J., Kusutani, A , Q., Toyata, M., Asanuma , K. and Cui, J. 2000. Studies on the varietal difference of harvest index and morphological characteristics of rice. *Japanese J. Crop Sci.,* 63 (3) 359-364.

Cui, J., Nakamura, T., Kusutani, A. and Toyota, M. 1998. Studies on the harvest index in rice cultivars varietal difference in harvest index. *Tech. Bull. Fac. Agric. Kagawa Univ.*, 50(1): 9-15.

DAFE (Department of Agriculture and Forestry Extension). 2003. Evaluation of introduced hybrid rice combinations and some Vietnam hybrids. *Technology Journal of Agriculture and Rural Development, Vietnam*. No.3. pp 257-259.

Diaz, S.H., Castro, R. and Morejon, R. 2000. Morpho- agronomic characterization of varieties of rice.Institute Nacional de Ciencias Agricolas, Gaveta Postal, San Jose, de las Lajas ,La Habana, Cuba, 21:3, 81-86.

Dixit, A.J., Thorat, S.T., Gaikuad , V.V. and Jadhaw , M.V. 2008.Yield attributes and yield of parental lines of Salydri hybrid rice as influenced by sowing dates. *J. Agrometero.* 6(Special Issue): 95-97.

DRR (Directorate of Rice Research). 1996. Final Report (1991-96). Development and use of hybrid rice ` technology. Directorate of Rice Res., Rajendranagar, Hyderabad, India. pp. 1- 42.

Dutta, R.K. and Mondal, M.M.A. 1998. Evaluation of lentil genotypes in relation to growth characteristics, assimilate distribution and yield potential. LENS Newsl., 25: 51-55.

Dutta, R.K., Mia, M.A.B. and Khanum, S. 2002. Plant architecture and growth characteristics of fine grain aromatic rice and their relation with grain yield. Int. Rice Comm. Newsl., 51: 51-55.

Evans, L.T. and Fischer, R.A. 1999. *Crop Sci.,* 39:1544-1551.

FAO (Food and Agricultural Organization). 2000. Production Yearbook Vol.52. UN, Rome, Italy, p. 64.

FAO (Food and Agricultural Organization). 2002. Production Yearbook .No.61. Published by FAO, Rome, Italy, p.54.

Fujita, K., Coronel, V.P. and Yoshida, S. 1984. Grain filling characteristics of rice varieties (*Oryza sativa*) differing in grain size under controlled environmental conditions. *Soil Sci. Plant Nutri.,* 30(3): 445- 454.

Gardner, F.P., Pearace, R.B. and Mistecell, R.I. 1985. Physiology of Crop Plants. Iowa State Univ. Press., Iowa. P.66.

Ghosh, M. 2001. Performance of hybrid and high-yielding rice varieties in Teraj region of West Bengal. *J. Int. Academicians,* 5(4): 578-581.

Gomosta, A.R., Quayyum, H.A. and Mahbub, A.A. 2006. Tillering duration and yielding ability of rice varieties in the winter rice season of Bangladesh. Rice research for food security and poverty alleviation-Proceeding of the International Rice research Conference.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research. 2nd end, John Wiley and sons, New York .

Hassan, M.M. 2001 Studies of Morpho-physiological characteristics of some selected *Aman* rice varieties. M.S. Thesis, Dept., Crop Bot., Bangladesh Agric. Univ., Mymensingh.

Honarnejad, R. 1995. Study on correlation among some morphological characters in six Iranian rice genotypes. *Seed and Plant,* 11: 4, 37-52 (pe.), 6 (en).

Hoque, M.N. 2004. Morpho-physiological studies in aromatic and modern rice cultivars. M.S. Thesis, Dept. Bot., Bangladesh Agric. Univ., Mymensingh.

Horie, T. 2006. Increasing yield potential in irrigated rice: breaking the yield barrier. Rice research for food security and poverty alleviation-Proceeding of the International Rice Research Conference.

Hossain, M.S., Sarkar, M.A.R and Ahmed, M. 2003.Performance of separated tillers of transplant *Aman* rice at various management practices. *Bangladesh J. Agri. Sci.*, 30(1): 1-7.

IRRI (International Rice Research Institute). 1993. Rice Research in a time of change-IRRI's medium- term plan for 1994-95. Int. Rice Res., Los Banos, Philippines. P.79

BRRI. 2010. Annual Report for 2010. Bangladesh Rice Res. Inst., Joydebpur, Gazipur. p. 31.

Islam, M.R. 2006. Physiological evaluation and characterization of fine grain romatic rice genotypes .M.S. Thesis, Dept. Crop Bot., Bangladesh Agric. Univ., Mymensingh.

Jian Chang Y., D.Yong, W. Chang Fu. L.LiJun, W. ZhiQin. Z., QingSen 2006. Growth and developmentcharacteristics of super high yielding mid season japonica rice. *Scientia Agricultura Sinica.* 39(7): 1336-1345.

Julfiquar, A. W., Virmani, S.S., Haque, M.M., Mazid, M.A. and Kamal, M.M. 2006. Hybrid rice in Bangladesh: opportunities and challenges. Rice Research for food security and poverty alleviation–Proceedings of the International Rice Conference.

Kabir, M.B., Kabir, M.R., Jahan, M.S. and Das, G.G. 2004. Yield performance of three aromatic fine rice in a coastal medium high land. *Asian J. Plant Sci.* 3(5): 561-563.

Kamal, A.M.A., Azam, M.A. and Islam , M.A. 1998. Effect of cultivar and NPK combination of the yield contributing characters of rice. *Bangladesh J. Agril. Sci.,* 15(1): 105-110.

Khan , M.A.H. 1991. The effects of carbon dioxide enrichment on the pattern of growth and development in rice and mustard. Ph.D. Dissertation. Royal Vet. And Agric. Univ., Copenhagen. P. 104.

Khisha, K. 2002. An evaluation of Madagascar System of Rice production in aman season with three high potential rice varieties. M.S. Thesis, Dept. Agron. Bangladesh Agril. Univ., Mymensingh pp. 36-63.

Kush, G.S. 1994. Increasing the genetic yield of rice: prospect and approaches. Int. Rice Comm. Newsletter, 43:1-8.

Liao, Y., Chen, Z. M., He, X, Y., Chen, S. J. and Chen , Y. 2010. Sink, source and Flow characteristics of rice variety Yuexiangzhan with high harvest index. Chinese J. Rice Sci., 15(1); 73-76.

Lockhart, J.A.R. and Wiseman, A.J.L. 1988. Introduction to Crop Husbandry. Oxford, UK, Wheaton & Co. Ltd., Pergamon Press. pp 70-180.

Lu,Q., Jiang, D., Weng, X.Y. and Xi, H.F. 2000. The effect of potassium nutrition on dry matter production and photosynthesis of different genotypes of rice. *J. Zhejiang Agric . Univ.,* 25(3): 267-270 (in Chinese).

Mahdavi, F., Eamaili, M. A., Pirdashti, H. and Fallah, A. 2004. Study on the physiological and morphological indices among the modern and old rice (*Oryza sativa* L) genotypes. New directions for a diver's plant: Proceedings of the 4th International Crop Science Congress, Brisbane, Australia.

Malini, N., Sundaram, T., Ramakrishnan, H. and Saravanan, S. 2006. Prediction of hybrid vigour for yield attributes among synthesized hybrids in rice (*Oryza sativa* L). Res. J. Agric. Biol. Sci., 2(4): 166-170.

Mao, C. 2006. Improving seed production to speed up the global commercialization of hybrid rice .Rice research for food security and poverty alleviation- Proceedings of the International Rice Research Conference.

Marable, B. 2005. Properties of rice growing in abandoned paddies in Sri Lanka. *Crop- fertility and Volunteurism.* 295-303.

Mia, M.A.B. 2001. Effect of variety and spacing on the growth , yield and yield attributes of aromatic rice. M.S. Thesis, Dept. Agron., Bangladesh Agric. Univ., Mymensingh. P. 49.

Mia, M.N.H., Yoshida, T.,Yamamoto, Y. and Nitta, Y. 1996. Characteristics of dry matter production and partitioning of dry matter to panicles in high yielding semidwarf indica and japonica indica hybrid rice varieties. *Japanese J. Crop Sci.,* 65 (40: 672-685.

Mishra, M. and Pandey, M.P. 1998. Heterosis breeding in rice for irrigated sub-humid tropics in north India. Oryza, 35: 8-14.

Mondal, M.M.A., Islam, A.F.M.S. and Siddique, M.A. 2005. Performance of 17 modern transplant aman cultivar in the north region of Bangladesh. *Bangladesh J. Crop . Sci.,* 16: 23-29.

Munshi, R.U. 2005.A comparative morphophysiological study between two local and two modern rice cultivars. M.S. Thesis, Dept. Crop Botany, Bangladesh Agri. Univ., Mymensingh.

Myungkyu, O.H., Kim, B., Shin, M., Choung, J., Kim, K.Y., KO, J.C., Ko.J., Lee, J. and Choi, I.S. 2005.Yearly variation of panicle characters in Japonica rice (*Oryza sativa* L) *Korean J. Breed.* 37(1): 43-48.

Nuruzzaman, M., Yamamoto, Y., Nitta, Y., Yoshid, T. and Miyazaki, A. 2000.Varietal difference intillering ability of fourteen japonica and indica rice varieties. *Soil Sci. Plant Nutr.,* 46(2): 381-391.

Oad, F.C., Samo, M.A., Oad, N.L., Chandio, G.Q. and Sta Cuz, P.2002. Relationshipof physiologicalgrowth and yield contributing parameters of localized rice ratoon crop. *Pakistan J. Appl.Sci.,* 2(4): 429-432.

Om, H., Latua, S.K. and Dhiman , S.D. 1998 .Effect of nitrogen and seed rate in nursery raising and nitrogen on growth and yield of hybrid rice (*Oryza sativa*). *Indian J. Agron.,* 42(1): 68-70.

Paranhos, J.T., Marchezan, E. and Dutta, L.M.C. 1997. Morphological parameters of three irrigated rice cultivars. Int. Rice Res. Newsl., 17(5): 9.

Park, S.T. 1998. Biological yield and harvest index in relation to major cultivation methods in rice. Research Reports of the Rural Development Administration. Rice. Korea Republic, 30: 3, 46-58.

Patel, J.R. 2000. Effect of water regime, variety and blue green algae on rice (*Oryza sativa*). *Indian J. Agron.* 45 (1): 103-106.

Patnaik, S.S.C. and Mohanty, S.K. 2006. Improving productivity of rainfed shallow favorable lowland and irrigated rice production system. CRRI Annual Report. P. 17.

Pheloung, P.C. and Siddique, K.H.M. 1991. Contribution of system dry matter to grain yield in wheat cultivars. *Aust. J. Plant Physiol.,* 18(1).

Pirdashti, H. 1998. Study of dry matter and nitrogen remobilization and determining of rice (*Oryza sativa*) cultivars growth indicaes in different sowing dates. MS thesis. Agriculture Collage, Tarbiat Modarres University. P. 158.

Pruneddu, G. and Spanu, A. 2001.Varetal comparison of rice in Sardinia. Dipartimentodi Science Agroomiche Genetica vegetable Agraria, Universita degli, Italy Informatore- Agraria, 57(5): 47-49.

Purseglove, J.W. 1985. Tropical Crops: Monocotyledons. Vol.1 and 2 comb. English Language Book Society, Longman, England. P.168.

Rahman, M.A. 2002. Effect of age of seedling and plant spacing on the growth, tillering ability and yield of HYV rice. M.S. Thesis, Dept. Crop Bot., Bangladesh Agric. Univ., Mymensingh. P. 53.

Rao, R.N and Patnaik, S.S.C. 2006. Developing hybrid rice technology for irrigated and rainfed lowland ecologies. CRRI Annual Report 2005-06. pp 56-59.

Rao, S.D. 1992. Flag leaf a selection criterion for exploiting potential yields in rice *Indian J. Plant Physiol.*, 35(3): 265-268.

Reddy, Y.A.N., Prasad, T.G. and Kumar , M.U. 1995. Relationship between leaf area index, specific leaf weight and assimilation rate in rice genotypes. *Madaras Agril. J.*, 82(111): 616-617.

Rejaul, K.M.2005. Effect of weeding regime and variety on the yield components and yield of boro rice. M. S. Thesis, Dept. Crop Bot., Bangladesh Agric. Univ., Mymensingh.

Roy, S.K.B. 2006 Increasing yield in irrigate boro rice through indica/ japonica improved lines in West Bangla, India. Rice Research for food security and poverty alleviation-Proceedings of the International. Rice Research Conference.

Salam, M.A., Khorshed, A. and chowdhury. S.I. 1990. Morpho-physiological aspects of Binasail for its improved yield potential over the parent Nizersail. *Bangladesh J. Nuclear Agric.*, 5(5): 15-21.

Shams, B.S. 2002. Effect of elevated temperature on the growth and yield parameters of modern *Boro* rice varieties. M.S. Thesis Dept. Crop Bot., Bangladesh Agric. Univ., Mymensingh. pp1-2.

Sharma, A.P. and Singh, S.P. 2002. Relationship of physiological attributes with grain yield in rice. *Agric. Sci. Digest.*, 20(3): 166-171.

Sharma,S.K. and Haloi, B. 2001. Characterization of crop growth variables in some selected rice cultivars of Assam. *Indian J. Plant Physiol.,* 6(2): 166-171.

Shriame, M.D. and Muley, M.D. 2003 .Variability and correlation studies in rice. *Indian J. Soils and Crops.* 13(1): 165-167.

Singh, V.P. 1994. Correlation studies in rice. Agric. Sci. Digest., 14(3-4): 185-188.Song, Z.P., Lu, B.R., Wang, B. and Chen, J. K. 2004. Fitness estimation through performance comparison of F_1 hybrid with their parental species Oryza rulipogon and 0.Sativa. *Ann. Bot.*, 93: 311-316.

Song, X., Agata, W. and Kawamitsu, Y. 2009. Studies on dry matter and grain production of Fi hybrid rice in China. II. Characteristics of dry matter production. Japan J. Crop Sci. 59(1): 29-33.

Srivasta, G.K and Triphati, RS. 1998. Respones of hybrid and composition of rice to number of seedling and planting geometry. *Ann. Agril. Res.,* 19(2): 235-236.

Sun, Y. F., Liang, J.M., Ye, J. and Zhu,W.Y.1999. Cultivation of super-high yielding rice plants. *China Rice,* 5: 38-39

Swaina, D.K., Herathb, S., Bhaskarc, B.C., Krishnanc, P., Raoc, K.S., Nayakc, S.K. and Dashc, R.N. 2007. Developing ORYZA IN for medium and long duration rice variety selection under non-water stress conditions *Agron. J.,* 99: 428- 440.

Takai, T., Matsuura, S., Nishio, T., Ohsumi, A., Shiraiwa, T. and Horie, T. 2006.Rice yield potential is closely related to crop growth - rate during late reproductive period. *Field Crops Res.*, 96: 328-335.

Tanaka,A. 1980. Physiological examination of very high yielding rice crops. Research issues for ultra-high yielding rice crop. Secretarial of Research Council of Agriculture, Forestry and Fisheries (mimeo). pp 64-74.

Thakur, D.S. and Patel, S.R.1998. Growth and sink potential of rice as influenced bythe split applicationof potassium with FYM in inceptisols of eastern central India. *J. Potassium Res.,* 14(1/4): 73-77.

Wada, Y., Yun, S., Sasaki, H., Maeda, T., Miura, K. and Watanabe, K. 2002. Dry matter production and nitrogen absorption of japonica-indica hybrid rice cultivars grown under upland conditions-a comparison with japonica cultivars *Japanese J. Crop Sci.,* 7(1): 28-35.

Wen, H.N. and Yang, Z.G. 1991. Studies of the cultivation method with transplanting single seedlings per hill in late rice. *Zhejiang Nongye Kexue* ,6: 264-268 (in Chinese).

Yang, F., Wang, X.L., Mia, J.Y. and Ling, F.L. 2011. A comparative analysis of yield component factors of the two rice varieties of JND3 and JND13 . *J. Jilin Agril. Univ.,* 23(4): 21-24.

Yang, W., Peng, S., Laza, R.C., Visperas, R.M. and Dionisio–Sese, M.L. 2007. Grain yield and yield attributes of new plant type and hybrid rice. *Crop Sci.,* 47: 1393-1400.

Yuan, L.P. 2010.Breeding of super hybrid rice. In: Peng S, Hardy B, editors. Rice Research for food Security and Poverty Alleviation. Los Banos (Philippines): International Rice Research Institute. pp 143-149.

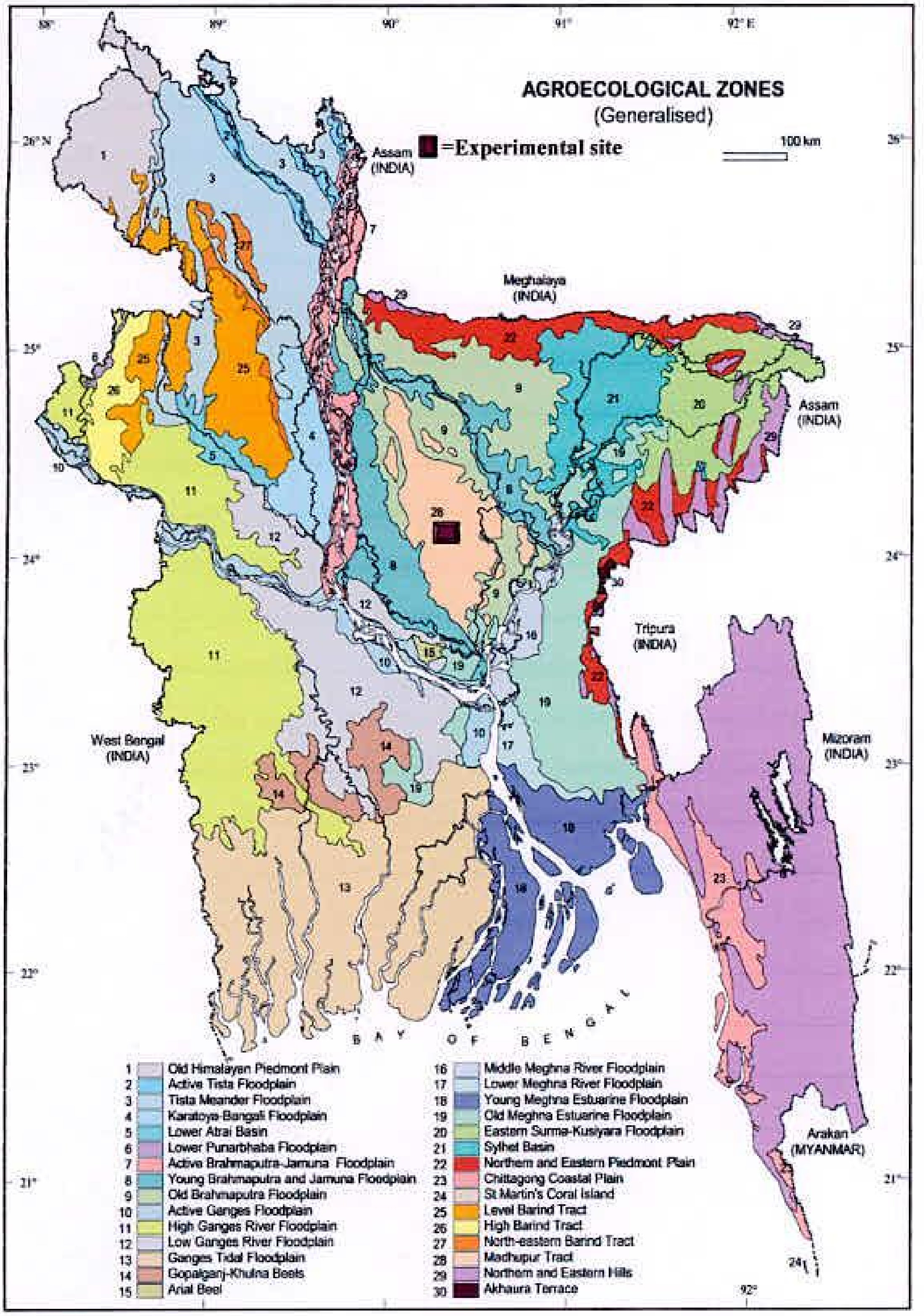
Yoshida, S., 1981. Fundamentals of Rice Crop Science. Intl. Rice Res. Inst., Los Banos, Leguna, Philippines. pp 48 -269.

Zahad, A. A., Ashore , A.M. and Hadudy, K. H. 1980. Comparative analysis of growth, development and yield of five field bean cultivars. Z. Acker Flnazenbau, 249: 113

Appendices

APPENDICES

Appendix I. Experimental location on the map of Agro-ecological zones of Bangladesh



Appendix II. Monthly recorded air temperature, relative humidity, rainfall and sunshine of the experimental site during the period from December 2011 to May 2012

Month	*Air temp. (°c)		*RH(%)	*Total Rainfall (mm)	*Sunshine (hrs)
	Max	Min.			
December	26.54	13.87	80.75	00.00	6.69
January	23.40	12.96	79.00	00.00	7.00
February	27.34	16.41	73.90	35.00	8.18
March	29.61	20.57	80.60	12.00	7.66
April	30.56	22.14	78.57	82.00	7.42
May	32.83	23.38	82.43	58.00	5.61

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka –1207

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

Properties	Value
A. Physical	
% Sand (0.2-0.02 mm)	26
% Silt (0.02-0.002 mm)	45
% Clay (< 0.002 mm)	29
Textural class	Silty clay
B. Chemical	
Soil pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.07
Phosphorus (µg/g soil)	22.08
Sulphur (µg/g soil)	25.98
Magnesium (meq/100 g soil)	1.00
Boron (µg/g soil)	0.48
Copper (µg/g soil)	3.54
Zinc (µg/g soil)	3.32
Potassium (µg/g soil)	0.30

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka-1215