PERFORMANCE OF FIVE SELECTED HYBRID RICE VARIETIES IN AMAN SEASON

SHOVON CHANDRA SARKAR

DEPARTMENT OF AGRICULTURAL BOTANY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA 1207

JUNE, 2014

PERFORMANCE OF FIVE SELECTED HYBRID RICE VARIETIES IN AMAN SEASON

BY

SHOVON CHANDRA SARKAR

Registration No. : 08-02835

A Thesis
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 (MS)
IN
AGRICULTURAL BOTANY

SEMESTER: JANUARY-JUNE, 2014

APPROVED BY:

Dr. Md. Moinul Haque
Professor
Department of Agricultural Botany
Sher-e-Bangla Agricultural University
Supervisor

Dr. Kamal Uddin Ahamed
Professor
Department of Agricultural Botany
Sher-e-Bangla Agricultural University
Co-Supervisor

Dr. Md. Ashabul Hoque
Associate Professor
Chairman
Examination Committee

DEDICATED

TO

MY BELOVED PARENTS

DEPARTMENT OF AGRICULTURAL BOTANY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

Memo No:

CERTIFICATE

This is to certify that the thesis entitled **“PERFORMANCE OF FIVE SELECTED HYBRID RICE VARITIES IN AMAN 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**. The result of a piece of bonafide research work carried out by **SHOVON CHANDRA SARKAR**, Registration number: **08-02835** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
Dhaka, Bangladesh

(Prof. Dr. Md. Moinul Haque)
Research Supervisor

ACKNOWLEDGEMENTS

All praises to Almightly God for His never-ending blessing, the author deems it is a great pleasure to express his profound gratitude to his respected parents, who entiled much hardship inspiring for prosecuting his studies.

The author likes to express his deepest sense of gratitude to his respected supervisor Dr. Md. Moinul haque, Professor, Department of Agricultural Botany, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh for his scholastic guidance, support, encouragement and valuable suggestions and constructive criticism throughout the study period and gratuitous labor in conducting and successfully completing the research work and in the preparation of the manuscript writing.

The author also expresses his gratefulness to his respected Co-Supervisor Dr. Kamal Uddin Ahamed, Professor, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, helpful comments and constant inspiration, inestimable help, valuable suggestions throughout the research work and in preparation of the thesis.

The author also expresses heartfelt thanks to all the teachers of the Department of Agricultural Botany, SAU, for their valuable suggestions, instructions, cordial help and encouragement during the period of the study.

The author expresses his sincere appreciation to his brothers, sisters, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study period.

The Author

PERFORMANCE OF FIVE SELECTED HYBRID RICE VARIETIES IN AMAN SEASON

ABSTRACT

The experiment was conducted in the Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, to observe the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan 2 in *Aman* season. Inbred BRRI dhan 33 was used as a check variety. The experiment was laid out in Randomized Complete Block Design with three replications. The studied hybrid varieties exhibited superiority in respect of growth characters such as tillers hill^{-1}, leaves hill^{-1}, TMD hill^{-1}, leaf area hill^{-1}, LAI, CGR, RGR and NAR over the inbred BRRI dhan 33. At reproductive stage highest TMD hill^{-1} was found in hybrid variety Tia (84.0 g) and inbred variety BRRI dhan 33 produced the lowest TMD hill^{-1}(70.10 g). Maximum leaf area hill^{-1} was found in Tia (1787cm^{2}) and minimum leaf area hill^{-1} was found in BRRI dhan 33 (1198cm^{2}).The average highest and the average lowest CGR and RGR were recorded in Tia (40.63 g m^{-2} d^{-1} and 17.9 mg g^{-1} d^{-1}) and BRRI dhan 33 (27.26 g m^{-2} d^{-1} and 13.35 mg g^{-1} d^{-1}). These hybrid varieties also showed higher yield attributes *viz*. effective tillers hill^{-1}, 1000-grain weight, biological yield and harvest index (HI) over the inbred. Consequently, the test hybrid varieties provided the higher grain yield compared to the inbred. The highest number of effective tiller hill^{-1} was recorded in Tia (13.38) followed by Shakti 2 (11.67) and the lowest number was found in BRRI dhan 33 (7.05). The maximum number of filled grains panicle^{-1} was recorded in Tia (222.30) and the minimum number was observed in BRRI hybrid dhan 2 (159.90). Aloron showed the highest 1000 grain weight (29.95 g) and BRRI dhan 33 showed the lowest (25.56 g). Thus, highest grain yield was achieved from Tia (7.82 t ha^{-1}), which was closely followed by Shakti 2 (7.65 t ha^{-1}). These two varieties produced 24.0% higher yield over the inbred BRRI dhan 33. Effective tillers hill^{-1} and higher filled grains panicle^{-1} mainly contributed to the higher grain yield of hybrid varieties.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
cm	=	Centimeter
Cont'd	=	Continued
cv.	=	Cultivar
DAT	=	Days after transplanting
^{o}C	=	Degree Centigrade
DF	=	Degree of freedom
EC	=	Emulsifiable Concentrate
et al.	=	And others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram
HI	=	Harvest Index
Hr	=	Hour
IRRI	=	International Rice Research institute
Kg	=	Kilogram
LV	=	Local variety
LSD	=	Least significant difference
M	=	Meter
m^2	=	Square meter
mm	=	Millimeter
viz.	=	Namely
N	=	Nitrogen
ns	=	Non significant
%	=	Per cent
$CV_{\%}$	=	Percentage of Coefficient of Variance
P	=	Phosphorus
K	=	Potassium
ppm	=	Parts per million
SAU	=	Sher-e- Bangla Agricultural University
S	=	Sulphur
Zn	=	Zinc

CHAPTER I

INTRODUCTION

Rice (*Oryza Sativa* L.) is the second most widely grown cereal in the world and it is the staple food for the half of the world's population. Asia is the leading producer of rice and most of the Asian gets 60% of their calories from rice. Bangladesh ranks 4th in both area and production and 6th in the production of per hectare yield of rice in the world. It is the staple food of about 160 million people of Bangladesh. Rice cultivation is favored by the hot, humid climate and large number of deltas across Asia's vast tropical and subtropical areas. Rice is extensively grown in Bangladesh in the three seasons namely, *Aus, Aman* and *Boro* which covers total 80% of the total cultivable area of the country (AIS, 2011). The population of Bangladesh is growing by two million every year and may increase by another 30 million over the next 20 years. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020. The increase rate of population is 1.42% (BBS, 2010) and the decreasing rate of agricultural land is 1% per annum limiting the horizontal expansion of 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 defines 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. crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) etc. These components are widely used by plant physiologists and provide some indices of the plant response 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), CGR, NAR and RGR ultimately reflection in high grain yield of rice (Thakur and Patel, 1998).

Hybrid rice is one of the options for increasing the yield ceiling in rice over the best modern varities. For the ever-increasing population of Bangladesh, the increasing demand for rice will have to meet with lesser amount of water, lesser number of labour and lesser amount of pesticides. Hybrid rice offers to break the yield ceiling of conventional semi-dwarf rice verities. Hybrid rice technology has been introduced through IRRI and BRRI and commercial seed companies of India and China during the last ten years and has already gained positive experience in the *Boro* season. In *Aman* season, however, available information regarding the yield and yield contribution characters, both morpho-physiological characteristics of hybrid rice verities are meager in Bangladesh. That is why, it is a prime need to conduct more research work to find out and develop sustainable technologies regarding hybrid rice cultivation under the prevailing local conditions in the *Aman* season. Julfiquar et al. 1998, observed that the modern inbred rice varities in Bangladesh had longer growth duration of 135-150 days in *Aman* season with a low daily yield, while high daily yield in hybrid rice was due to its short duration of 120-130 days. Therefore, it is postulated that if hybrid rice is introduced, crop duration can be reduced by 20-40 days.

In the year 2010, among the *Aman* rice varities high yielding modern varities covered 66.63% and yield was 2.49 t ha^{-1} and local varities covered 24.97% and yield was 1.58 t ha^{-1} (BBS, 2010). It is the farmers who have gradually replaced the local indigenous low yielding rice varities by high yielding ones and modern varities of rice developed by Bangladesh Rice Research Institute (BRRI) only because of getting 20 to 30% more yield unit land area (Shahjahan, 2007). In Bangladesh as well as in the world rice research is predominantly being conduct to develop modern high yielding and hybrid varieties.

However, some of the newly introduced hybrid rice varities are Shakti 2, BRRI hybrid dhan-2, Suborna 8, Tia, Aloron. So it is prime need to evaluate their performance in *Aman* season. Under these circumstances, the study was undertaken to compare the performance of aforementioned hybrid and inbred rice varieties in *Aman* season.

Therefore, the objectives of the study are as following-

I. To compare the growth, yield and yield contributing characters of hybrid rice varieties with popular inbred rice variety in *Aman* season.

II. To investigate the yield variation among the afore-mentioned five selected hybrid rice varities.

III. To identify the higher yield contributing characters responsible for hybrid rice varieties compared to the inbred.

CHAPTER II

REVIEW OF LITERATURE

Rice has wide adaptability in different environmental conditions. Yield of different rice varity is depend on the morphological parameters such as plant height, effective tiller hill^{-1}, number of spikelet's penicle^{-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 assimilate area also important to determine yield potentiality. Considering the above points, available literature was reviewed relevant to the present study are reviewed below with followings.

2.1 Morpho-Physiological parameters

2.1.1 Plant height

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- l 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. 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). 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 IR36 produced 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 Minahui-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 capacity, respectively (Mandavi *et al.*, 2004). Yuan (2001) suggested that plant is moderately compact type with moderate filleting capacity. Yang *et al*. (2011) observed that JND3 exhibited a higher tittering 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}

Cultivars with grater flag leaf area generally have high grain weight (Mahmood and Chowdhary, 2000). Islam (2006) showed that the increment of leaf area hill^{-1} varied significantly due to genotype at all growth stages. 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 at. 2004). 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. Sharma and Haloi (2001) conducted an experiment on scented rice and found that there was remarkable variation in leaf area. Paranhos *et al*., (1997) studied the development of leaf area and found that all the cultivars produced maximum leaf area during panicle initiation stage. Chandra and Das (2000) found that leaf area was significantly and positively associated with dry matter of culms and grain yield.

2.1.5 Leaf area index

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. 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. Wada *et al*., (2002) stated that a higher crop growth rate after anthesis mainly due to the high mean LAI during the ripening period. 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. Mahdevi *et al*., (2004) showed that all genotypes reached maximum LAI at pre-flowering except Dash and Tarom, which reached LAI at flowering. At pre-flowering Neda (high-yielding genotype) had greatest LAI comparing to other genotypes (LA1= 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. Ghosh and Singh (1998) observed a strong and positive correlation of LAI with grain yield. They also stated that LAI at flowering showed yield variation of 79% and delay in planting by 15 drastically affected LAI of rice.

2. 1. 6 Total dry matter 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). Sharma and Haloi (2001) observed that the check variety Kunkuni Joha consistently maintained high rate of dry matter production at all growth stages and high dry matter accumulation at the panicle in initiation stage. 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 (these genotypes also had highest grain yield). The maximum TDM produced earlier for improved genotypes than traditional. 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). Chandra and Das (2000) reported that dry matter production of culms and leaves were significantly positively associated with grain yield and leaf area index.

2.1.7 Crop growth rate

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). 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). 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. Mandavi *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

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. 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. Mandavi *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. Paranhos *et al*., (1997) found that CGR, RGR, And LAI differed significantly among cultivars.

2.1.9 Net assimilation rate

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 phenological stage. 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. 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. Burondkar *et al*., (1998) reported that yield was positively correlated with CGR, RGR, NAR, TDB and some yield components.

2.1.10 Panicle length

Ghosh (2001) noted that hybrids, in general, gave higher values for panicle length compared to cultivars. Diaz *et al*. (2000) noted wide variation in panicle length, panicle type, grain panicle^{-1} and panicle weight and secondary branches panicle^{-1}.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) 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). 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. Kabir *et al*. (2004) reported that the cultivar chingura produced the highest panicle (26.86 cm) followed by Begunbitchi and Katijira varieties. 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. Malini *et al.* (2006) showed that the best hybrid was IR 68885A/ white ponni, which showed standard heterosis and heterobeltiosis for panicle length, spikelet’s panicle^{-1}, grains Panicle^{-1} straws yield and grain yield. Hossain *et al*. (2003) conduced increment with new rice cv. Sonar Bangla-1, BRRI dhan39 and Nijarshail, and reported that the cultivars were not different significantly in panicle length.

2.2 Yield parameters

2.2.1 Days to maturity

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^{-1} of CR203 (check), 5.1 MT ha^{-1} 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.

2.2.2 Effective tillers hill^{-1}

Hybrids recorded significant positive standard heterosis produced more productive tillers plants (Malini *et al*., 2006). Asraf *et al*. (1999) stated that transplanting of two and three seedlings of 35 d old nursery gave more promising results in terms of more productive tillers unit area. Number of productive tillers plant^{-1} is generally associated with higher productivity. Among yield is mainly a function of the number of panicle bearing tillers unit^{-1} area.

2.2.3 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).

2.2.4 Filled grain panicle^{-1}

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. 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^{-1}. Shrirame and Muly (2003) concluded that grain yield was significantly correlated with number of filled grains panicle^{-1}. Mishra and Pandey (1998) reported that panicle length, number of filled grains panicale^{-1} and 1000- seed weight had contributed for increased grain yield.

2.2.5 Unfilled grain panicle^{-1}

Singh and Gangwer (1989) conducted an experiment with rice cultivars C-14-8, CR-10009, IET-5656 and IET-6314 and reported that grain number panicle^{-1}, 1000-grain weight were higher for C-14-8 than those of any other three varieties. Rafey *et al*. (1989) carried out an experiment with three different rice cultivars and reported that weight of 1000 grain differed among the cultivars studied. Shamsuddin *et al*. (1988) also observed that panicle number hill^{-1} and 1000-grain weight differed significantly among the varieties. Kamal *et al*. (1988) evaluated BR3, IR20, and Pajam 2 and found that number of grain panicle^{-1} were 107.6, 123.0 and 170.9 respectively, for the varieties.

2.2.6 Thousand -grain weight

BRRI (1997) reported that weight of 1000- grains of Halio, Tilockachari, Nizershail and Latisail were 26.5 g, 27.7 g, 25.2 g and 25 g respectively. A 1000- grain weight of about 25 g is considered ideal for rice (Kush, 1994). 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 a*l., 1999).

2.2.7 Grain yield

Kamal *et al.* (1998) observed that modern variety BR 11 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). 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. 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 1/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). Sharama and Singh (2002) found that total dry matter and photosynthetic rate had very high direct and indirect effects on grain yield.

2.2.8 Straw yield

Patel (2000) studied the varietal performance of Kranti and 1R36 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 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 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.

2.2.10 Harvest index

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 its partitioning into plant and seed. 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. 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 55% for rice (Yuan, 2010). Jian Chang *et al*. (2006) found that super-high-yielding rice had more harvest index (51%) than the high- yielding rice.

CHAPTER III

MATERIALS AND METHODS

Materials and methods adopted for this study are presented in this chapter. Geographical position, physical conditions and soil status of the experiment 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

The study was conducted in the experimental farm, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the experimental site is $23^{0}74^{/}$N latitude and $90^{0}33^{/}$E longitude and at an elevation of 8.4 m from sea level (Anon., 1989). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.2 Soil

The soil belongs to “The Modhupur Tract”, AEZ 28(Appendix II). Top soil is silty clay in texture with distinct dark yellowish brown mottles in color. 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 climate of the experimental area is characterized by high temperature, high humidity and medium rainfall with occasional gusty winds during the *kharif* season (March-September) and a scanty rainfall associated with moderately low temperature in the *rabi* season (October-February). The weather information regarding temperature, rainfall, relative humidity and sunshine hours during the period of experiment was collected from the Weather station of Bangladesh, Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix II.

3.2 Experimental treatments and source of plant materials

Five hybrid varities and one check variety were used treatments for this study. These hybrid varities were selected as based on market demands.

Shakti 2: It is a hybrid varity developed in China, developed by BRAC and approved by the National seed board in 2010. It is recommended for *Aman* season. Plant type is semi dwarf (100-120 cm), growth duration is 105-130 days with average grain yield of 8.5-9.5 t ha^{-1}.

Suborna 8: This varity was developed in China imported by the Supreme Seed Company Pvt. Ltd. and approved by the National Seed Board of Bangladesh. Tia is well adapted the climatic condition of our country. The plant type is semi dwarf (95-105 cm), growth duration is 145-150 days and its average grain yield ranges from 8-9 t ha^{-1}.

Tia: Tia is hybrid rice developed in china. BRAC (Bangladesh Rural Advancement Committee) is the sole agent for this in Bangladesh. Semi dwarf type plant (90-100cm). The growth duration is 130-140 days and its average yield range up to 10 t ha^{-1}.

Aloron: It is a hybrid varity developed in China and marketed in Bangladesh by ACI Ltd. It is recommended for *Aman* season. Plant type is semi dwarf (100-120cm), growth duration is 105-130 days with average grain yield of 8.5-9.5 t ha^{-1}.

BRRI hybrid dhan 2: BRRI hybrid dhan2 is a hybrid variety was released in 2008 through Bangladesh Rice Research Institute suitable for *Aman* season. The average plant height is 100-110 cm. The growth duration is more than 150 days. This varity has a yield potential up to 8.0 t ha^{-1}.

BRRI dhan 33: These inbreed variety was developed by Bangladesh Rice Research Institute (BRRI), Gazipur. It is recommended for *Aman* season. Plant height is 90-105cm at the ripening stage. The grains are medium fine and white in color. It requires about 160 days on an average for completing its life cycle with an average grain yield is 4.6 t ha^{-1}.

All these hybrid and check varity were collected from a respective seed company, Dhaka and BRRI, Gazipur.

3.3 Land Preparation

The experimental land was first opened with a tractor and prepared thoroughly by ploughing and cross ploughing with a power tiller followed by country plough. Laddering helped breaking the clods and leveling the land followed every ploughing. Before transplanting each unit of plot was cleaned by removing the weeds, stubbles and crop residues. Finally each plot was prepared by puddling for transplanting seedlings.

3.4 Fertilizer management

Cowdung at the rate of 10 t ha^{-1} was applied at the first ploughing. The experimental plots were fertilized with 120, 60, 80 and 50 kg of Urea, TSP, MP and Gypsum, respectively. The whole amount of fertilizers for unit plot were calculated, measured and applied separately. One third urea and all other fertilizer were applied and incorporating 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 other at 50 DAT.

3.5 Experimental Design and layout

The experiment was laid out in a randomized complete block design (RCBD) with three replications, where the experimental area was divided into three blocks representing the replications to reduce soil hetero genetic effects. Each block was divided into 16 unit plots as treatments with raised bunds around. Thus the total numbers of plots were 48. The unit plot size was 3 m × 2.0 m and was separated from each other by 0.5 m ails. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m respectively.

3.6 Raising of Seedlings

The seedlings of rice were raised wet-bed methods. Seeds (95% germination) @ 25 kg ha^{-1} were soaked and incubated for 48 hour and sown on a well-prepared seedbed. During seedling growing, no fertilizers were used. Proper water and pest management practices were followed whenever required.

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

3.8 Transplanting of Seedling

The seedlings were transplanted in the puddle lands keeping row to row distance 25cm and plot to plot distance 15 cm respectively.

3.9 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.9.1 Irrigation

Necessary irrigations were provided to the plots as and when required during the growing period of rice crop.

3.9.2 Weeding

The plots were infested with some common weeds, which were removed by uprooting them from the field three times during the period of the cropping season.

3.9.3 Insect and pest control

There was no infection of diseases in the field but leaf roller (*Chaphalocrosis medinalis*) was observed in the field and used Malathion @ 1.12 L ha^{-1}.

3.10 Growth parameters

3.10.1 Sampling for growth analysis

Three hills $plot^{-1}$ were selected at 50 DAT (vegetative stage) and uprooted carefully for the 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 DAT and 90 DAT (reproductive stage) too.

3.10.2 Data collection

Data were collected on the following crop characters:

3.10.2.1 Plant height

The height of plant was counted in centimeter (cm) at the time of 50, 70 and 90 DAT (Days after transplanting) and at harvesting. The height was measured from the ground level to the tip of the plant of three hills and finally averaged.

3.10.2.2 Tillers $hill^{-1}$

The number of tillers $hill^{-1}$ was counted at the time of 50, 70 and 90 DAT and at harvesting by counting total tillers of three respective hills and finally averaged to $hill^{-1}$ basis.

3.10.2.3 Leaves hill^{-1}

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

3.10.2.4 Leaf area hill^{-1}

Leaf area was measured by an electronic area meter (LI 3000, USA) and their corresponding dry weight was recorded after drying at 72 ± 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

Leaf area index (LAI) measured at the time of 50, 70 and 90 DAT and at harvest. Data were recorded as the average of 03 plants selected at random the inner rows of each plots. The final data calculated multiplying by a correction factor 0.75 as per Yoshida (1981).

3.10.2.6 Root dry matter hill^{-1}

Root dry matter hill^{-1} was recorded at 50, 70 and 90 DAT and at harvest from 10 randomly collected root hill^{-1} of each plot from inner rows leaving the boarder row. Collected roots were oven dried at 70^0C for 72 hours then transferred into desecrator and allowed to cool down at room temperature; final weight was taken and converted into root dry matter content hill^{-1}.

3.10.2.7 Stem dry matter hill^{-1}

Stem dry matter hill^{-1} was recorded at 50, 70 and 90 DAT and at harvest from 10 randomly collected stems hill^{-1} of each plot from inner rows leaving the boarder row. Collected stems were oven dried at 70^0C for 72 hours then transferred into desecrator and allowed to cool down at room temperature; final weight was taken and converted into stem dry matter content hill^{-1}.

3.10.2.8 Leaf dry matter hill^{-1}

Leaf dry matter hill^{-1} was recorded at 50, 70 and 90 DAT and at harvest from 10 randomly collected leaf hill^{-1} of each plot from inner rows leaving the boarder row. Collected leaves were oven dried at 70^0C for 72 hours then transferred into desecrator and allowed to cool down at room temperature; final weight was taken and converted into leaf dry matter content hill^{-1}.

3.10.2.9 Total dry matter hill^{-1}

Total dry matter hill^{-1} was recorded at 50, 70 and 90 DAT and at harvest by adding stem dry matter and leaves dry matters hill^{-1}.

3.10.2.10 Crop growth rate (CGR)

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)

3.10.2.11 Relative growth rate (RGR)

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

$$RGR = \frac{L_n W_2 - L_n W_1}{T_2 - T_1} \text{ mg g}^{-1} \text{ d}^{-1}$$

Where,

W_1 = Total dry matter at time T_1 (g)

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

L_n = Natural logarithm

3.10.2.12 Net assimilation rate (NAR)

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

$$NAR = \frac{W_2-W_1}{T_2-T_1} \times \frac{L_nLA_2-L_nLA_1}{LA_2-LA_1} \text{ g m}^{-2} \text{ d}^{-1}$$

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)

L_n = Natural logarithm

3.10.2.13 Panicle length

The length of panicle was measured with a meter scale from 10 selected plants and the average value was recorded as per plant.

3.11 Yield parameters

3.11.1 Harvest and processing

Depending on the maturity of tasted rice varities, they were harvested on different days. Harvesting was done when 80 to 90% of the grains become golden yellow on 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 square meter which was prefixed at the corner of each plot. The harvested crops 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 Days to maturity

Days to maturity were recorded by counting the number of days required to harvest in each plot.

3.11.2.2 Effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tiller during harvesting. Data on effective tillers hill^{-1} were counted from 10 selected hills and average value was recorded.

3.11.2.3 Non-effective tillers hill^{-1}

The total number of non-effective tiller hill^{-1} was counted as the number of non-panicle bearing tiller during harvesting. Data on non effective tiller hill^{-1} were counted from 10 selected hills and average value was recorded.

3.11.2.4 Total tillers hill^{-1}

The total number of tiller hill^{-1} was counted as the number of effective tillers hill^{-1} and non-effective tillers hill^{-1}. Data on total tillers hill^{-1} were counted from 10 selected hills and average value was recorded.

3.11.2.5 Filled grains panicle^{-1}

The total numbers of filled grain was collected randomly from selected 10 plants of a plot on the basis of grain in the spikelet and then average numbers of filled grains panicle^{-1} was recorded.

3.11.2.6 Unfilled grains panicle^{-1}

The total numbers of unfilled grain was collected randomly from selected 10 plants of a plot on the basis of not grain in the spikelet and then average numbers of unfilled grains panicle^{-1} was recorded.

3.11.2.7 Total grains panicle^{-1}

The total numbers of grain was collected randomly from selected 10 plants of a plot by adding filled and unfilled grain and then average numbers of grains panicle^{-1} was recorded.

3.11.2.8 Weight of 1000 grain

One thousand clean oven dried (72 ± 2° C for 72 hours with 14% moisture) grains were counted from seed stock obtained from hill^{-1} in each plot and weighed by using an electronic balance.

3.11.2.9 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central 1 m^2 area and five sample plants were added to the respective unit plot yield to record the final grain yield plot^{-1} and finally converted to ton hectare^{-1} (t ha^{-1}).

3.11.2.10 Straw yield

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of central 1 m^2 area and five sample plants were added to the respective unit plot yield to record the final straw yield plot^{-1} and finally converted to ton hectare^{-1} (t ha^{-1}).

3.11.2.11 Biological yield

Grain yield and straw yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Straw yield.

3.11.2.12 Harvest index

Harvest index (HI) was calculated from the grain and straw yield of rice for each plot and expressed in percentage.

$$\text{HI} = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (total dry weight)}} \times 100$$

3.12 Statistical analysis

The data obtained for different parameters were statistically analyzed to obtain the level of significance using the computer MSTAT package program developed by Russel (1986). The significance of the differences among the treatment means were estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULT AND DISCUSSION

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

4.1 Growth parameters

4.1.1 Plant height

Plant height of the cultivars was measured at different stages was varied significantly among the hybrid and inbred rice varieties (Fig. 1). Plant height increased progressively with the advancement of time and growth stages. At vegetative stage (50 days after transplanting), the tallest plant was recorded in Tia (78.46 cm) followed by Shakti 2 (75.87 cm) and the shortest was recorded in Aloron (63.88 cm) followed by BRRI hybrid dhan 2 (66.88 cm). At reproductive stages (70 and 90 DAT),), the highest plant highest was observed in Tia (101.32 and 108.3 cm, respectively) and the lowest height was recorded in BRRI dhan 33 (83.33 and 87.62 cm, respectively). At the time of final harvest, Tia had the highest plant height (110.10 cm) followed by Suborna 8 (108 cm) and the shortest was in BRRI dhan 33 (87.6 cm) followed by BRRI hybrid dhan 2 (94.24 cm) with same statistical rank. Rest of the hybrid rice showed intermediate status. Om *et al*. (1998) and Kabir *et al.* (2004) also observed variation in plant height due to varietal differences. It appears that the highest plant height was found in Tia and lowest plant height was obtained in BRRI dhan 33.

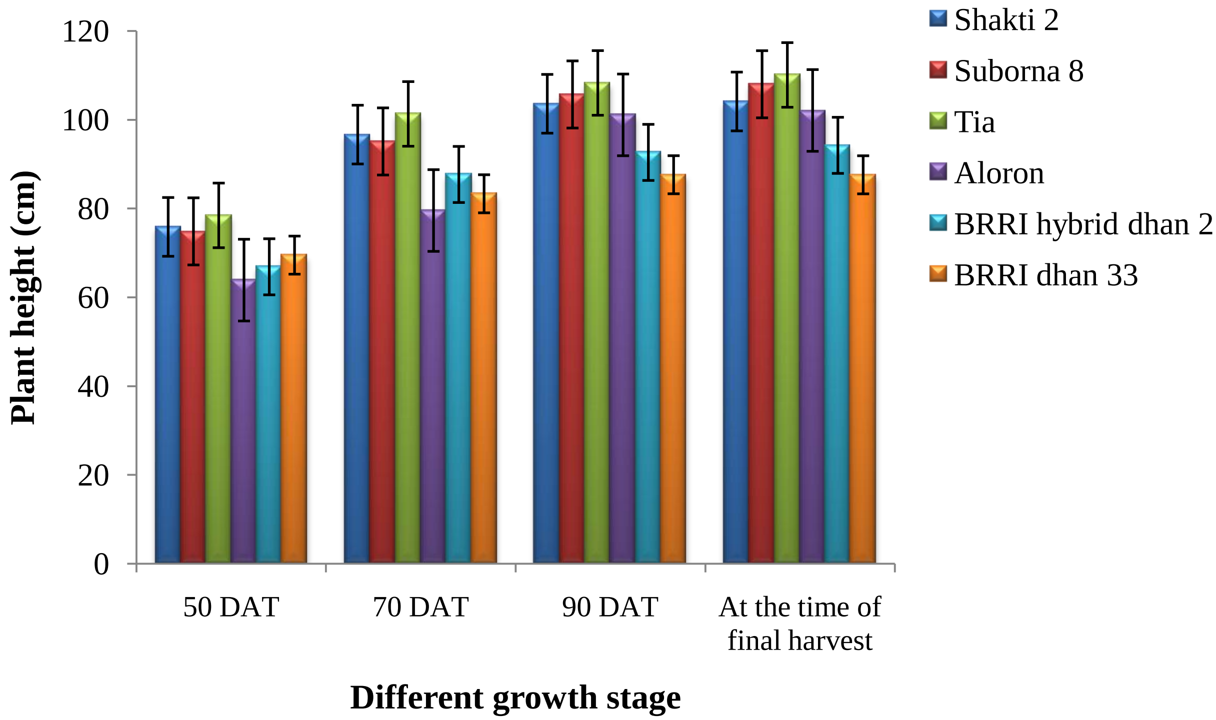


Figure 1. Plant height at different days after transplanting (DAT) in hybrid and inbred rice varieties. *Vertical bar represents SE (n=3)*

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 (Fig. 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 DAT) stage, the maximum number of tillers hill^{-1} was recorded in the Tia (16.23) that was significantly different from other hybrid rice varieties and the lowest number of tillers hill^{-1} at vegetative stages (50 DAT) was observed in BRRI hybrid dhan 2 (11.66). At reproductive (70 and 90 DAT) stages the maximum number of tillers hill^{-1} was observed in the Tia (21.34 and 21.45 respectively) and the lowest number of total tiller was recorded in the BRRI hybrid dhan 2 (16 and 15.76 respectively). At final harvest, Tia had the maximum number of tillers hill^{-1} (19.1) and the lowest was in BRRI hybrid dhan 2 (14.34). With the decrease of tillers hill^{-1}, yield also decease considerably (Hogue, 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 panicles plant^{-1} with 6 to 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).

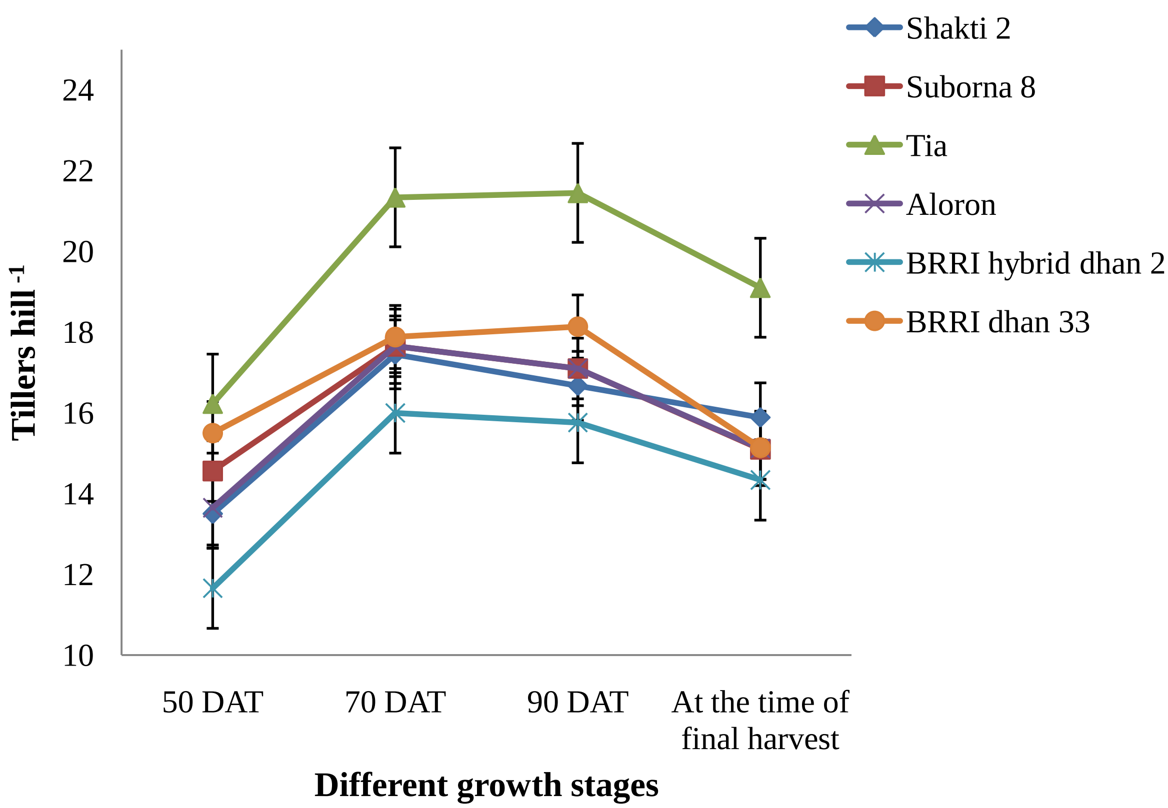


Figure 2. Tillers hill^{-1} at different days after transplanting (DAT) in hybrid and inbred rice varieties. *Vertical bar represents SE (n=3)*

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 (Fig. 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 Tia (78.67) followed by Suborna 8 (67.00). At 70 DAT, the highest number of leaves was observed in Tia (94.35) followed by Shakti 2 (87.34) and they were statistically different at 5% level of probability. At reproduced stage (90 DAT), the highest number of leaves was recorded from Tia (91.34) and BRRI hybrid dhan 2 produced the lowest number of leaves (64.34). In contrast, at 50 and 70 DAT, BRRI hybrid dhan 2 produced the lowest number of leaves (51.56 and 67.35, respectively) followed by BRRI dhan 33 (58.68 and 73.00, respectively). Rest of the hybrid rice showed intermediate values. So, the result indicate that Tia produced the highest number of leaves and BRRI hybrid dhan 2 produced the lowest 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.

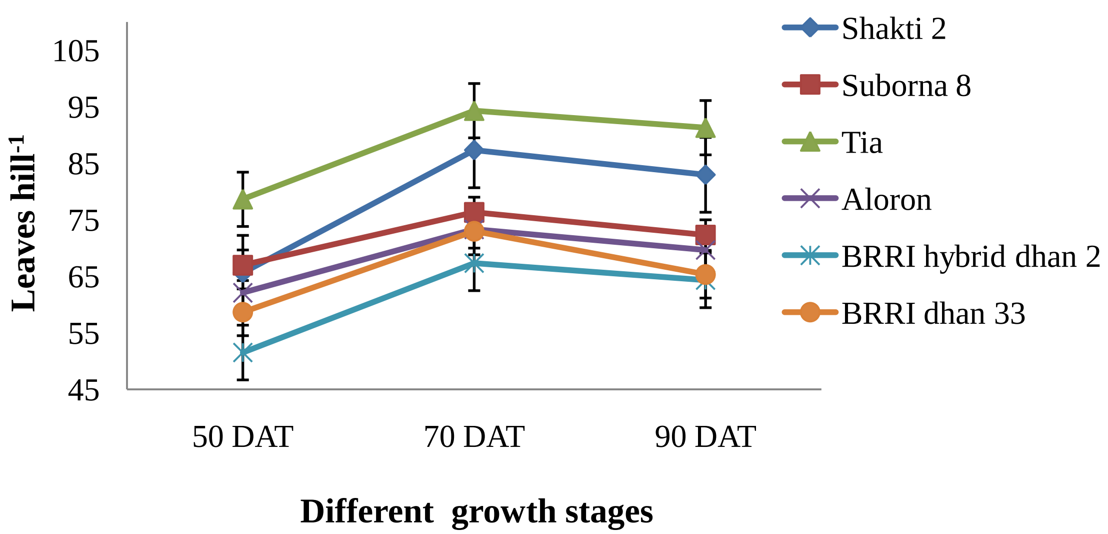


Figure 3. Leaves hill^{-1} at different days after transplanting (DAT) in hybrid and inbred rice varieties. *Vertical bar represents SE (n=3)*

4.1.4 Leaf area hill $^{-1}$

The development of leaf area (LA) over time in test rice varieties was significantly varied during the vegetative and reproductive growth phases (Fig. 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 Tia (1312 and 2082 cm^2 respectively) that was significantly different from others followed by Shakti 2 (1237 and 1896 cm^2 respectively). The lowest leaf was observed in BRRI dhan 33 (756 and 1425 cm^2 respectively) followed by BRRI hybrid dhan 2 (897 and1524 cm^2 respectively) at vegetative stage. At 90 DAT, the highest and the lowest leaf area hill^{-1} were recorded in Tia (1967 cm^2) and BRRI dhan 33 (1413 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 Leaf area (LA) could be attributed to the changes in number of leaves. The result is also supported by the result of Chandra and Das (2007) 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.

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 area index (LAI) in the studied rice varieties was observed from vegetative (50 DAT) to reproductive (90 DAT) stages (Fig. 5). The LAI continued to increase till start of reproductive stage and thereafter decreased. At vegetative stages (50 DAT), the maximum LAI was observed in Tia (3.38) followed by Shakti 2 (3.23). At 70 DAT, the maximum LAI was observed in Tia (4.91) followed by Shakti 2 (4.55). In contrast, at 50 and 70 DAT, BRRI dhan 33 showed

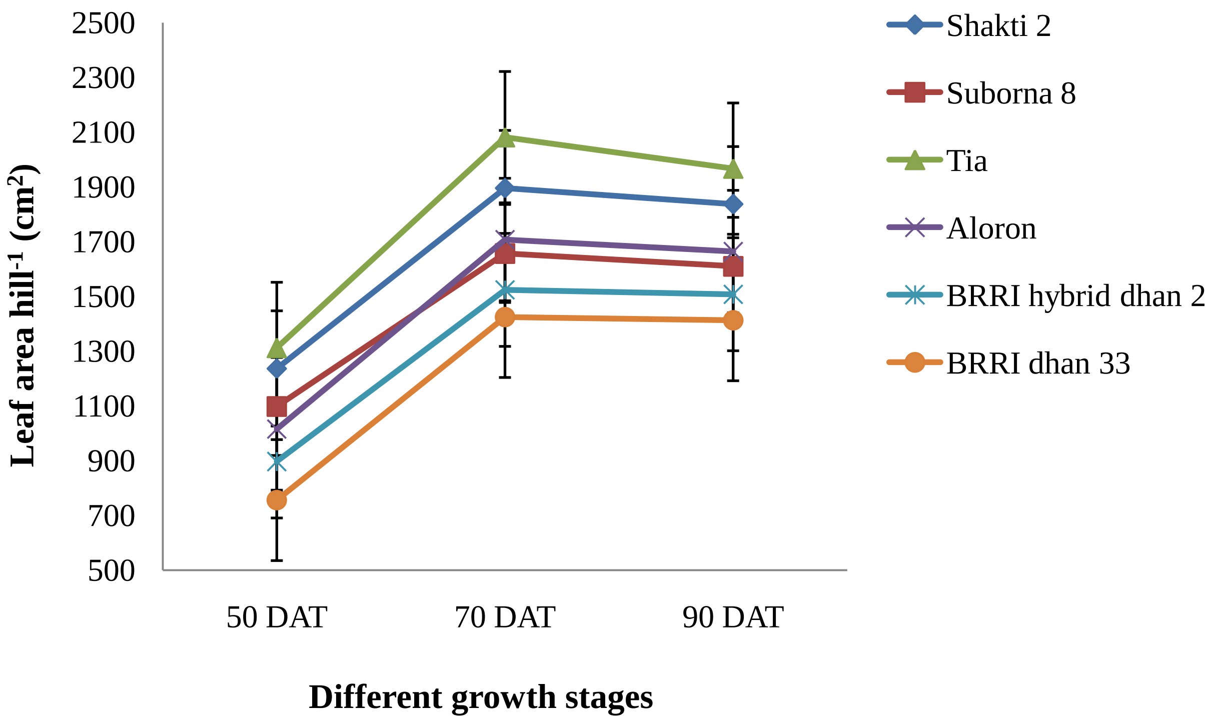


Figure 4. Leaf area hill^{-1} at different days after transplanting (DAT) in hybrid and inbred rice varieties. *Vertical bar represents SE (n=3)*

the lowest LAI (2.28 and 3.62, respectively) over their growth period. Rest or the hybrid rice showed intermediate values. On the other hand, at reproductive stage (90 DAT) the hybrid rice variety Tia and inbred BRRI dhan 33 showed the highest and the lowest LAI, (4.72 and 3.59) 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 senescence. The high yielding varieties possessed higher LAI values throughout the whole growth period which led to the higher biomass production and yield (Reddy *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 consequently higher number of leaves hill^{-1} (Fig. 4).

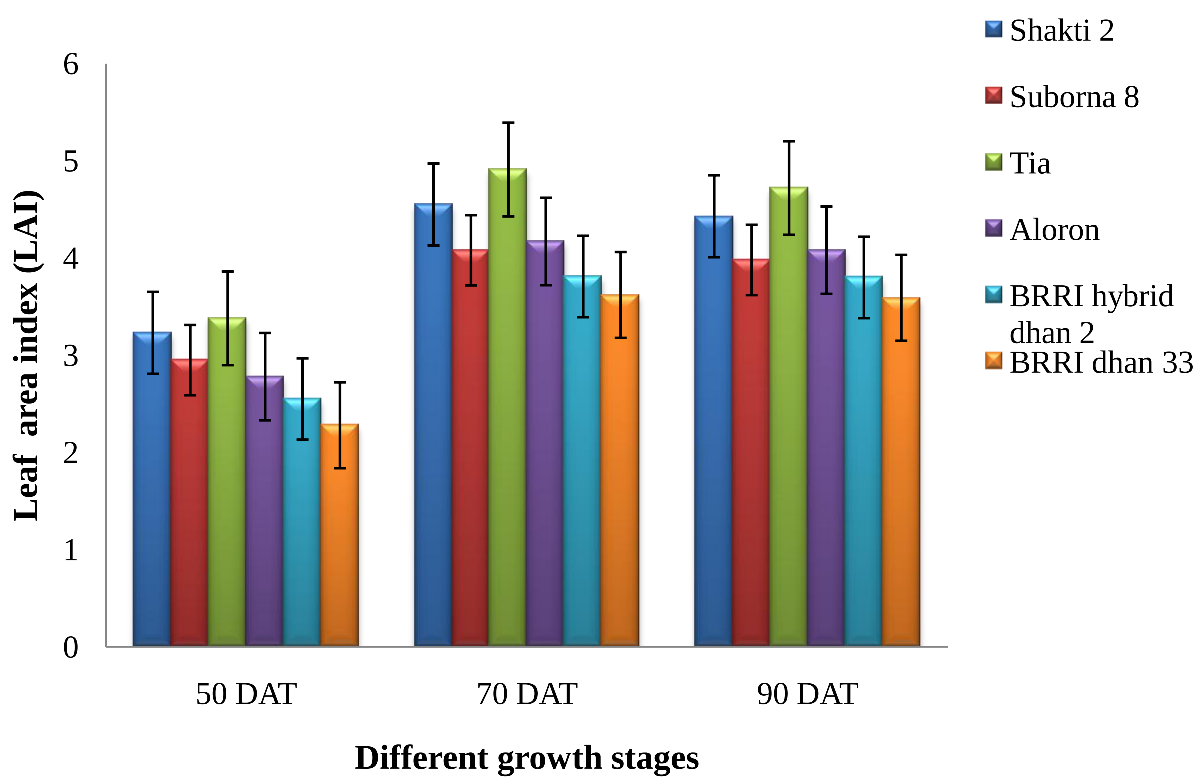


Figure 5. Leaf area Index (LAI) at different days after transplanting (DAT) in hybrid and inbred rice varieties. *Vertical bar represents SE (n=3)*

4.1.6 Root dry matter hill $^{-1}$

There was a significant variation observed in root dry matter production among test rice varieties at different growth stages (Table 1). At vegetative stages (50 DAT) maximum root dry matter was observed in Tia (6.3 g) and the lowest was found in BRRI dhan 33 (4.4 g). At reproductive stage (70 and 90 DAT) the maximum root dry matter was again found in Tia and the lowest was found in the inbred variety BRRI dhan 33. 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 1). At vegetative stages (50 DAT) maximum stem dry matter was observed in Tia and the lowest was found in BRRI dhan 33. At reproductive stage (70 and 90 DAT) the maximum stern dry matter was again found in Tia and the lowest was found in the inbred variety. 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 different growth stages (Table 1). At vegetative stages (50 DAT) maximum leaf dry matter was observed in Tia and the lowest was found in BRRI dhan 33. At reproductive stage (70 and 90 DAT) the maximum leaf dry matter was found in Tia (6.9 g) and the lowest was found in the inbred variety BRRI dhan 33. Result revealed that leafs 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 (Fig. 6). 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, Tia showed the highest dry matter hill^{-1} (84.0 g) followed by Tia (83.0 g). On the other hand, BRRI dhan 33 produced the lowest TDM hill^{-1} (70.10 g) preceded by BRRI hybrid dhan 2 (73.87 g) and they were significantly different. At 50 and 70 DAT, the highest TDM hill^{-1} was observed in Tia (27.33 and 56 g, respectively) and the lowest TDM was recorded in BRRI dhan 33 (20.63 g and 44.56 g, respectively).The increase of

Table 1. Dry matter accumulation of hybrid and inbred rice varieties at different days after transplanting (DAT) in *Aman* Season.

Treatments	Root dry matter hill $^{-1}$ (g)			Stem dry matter hill $^{-1}$ (g)			Leaf dry matter hill $^{-1}$ (g)		
	50 DAT	70 DAT	90 DAT	50 DAT	70 DAT	90 DAT	50 DAT	70 DAT	90 DAT
Shakti 2	6.2a	8.3b	13.8b	15.03b	33.53c	53.9b	6.7b	14.0b	15.0b
Suborna 8	5.4b	6.7d	13.5c	13.10d	31.02d	50.2d	5.7d	12.70d	14.2d
Tia	6.3a	8.4a	14.2a	15.13a	35.7a	54.2a	6.9a	14.33a	15.9a
Aloron	4.51c	8.2c	11.5e	14.96c	33.7b	53.2c	6.6c	13.2c	14.8c
BRRI hybrid dhan 2	5.5b	6.56e	12.2d	10.53e	27.16e	45.58e	5.6e	11.8e	14.1e
BRRI dhan 33	4.4c	6.4f	11.4f	10.13f	24.83f	44.5f	5.1f	11.7f	13.3f
CV (%)	8.65	7.26	6.1	9.87	7.04	8.92	8.87	7.48	9.3

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

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 the inbred variety. Increased dry matter in hybrid rice was possibly due to greater leaf area hill^{-1} (Fig. 4).

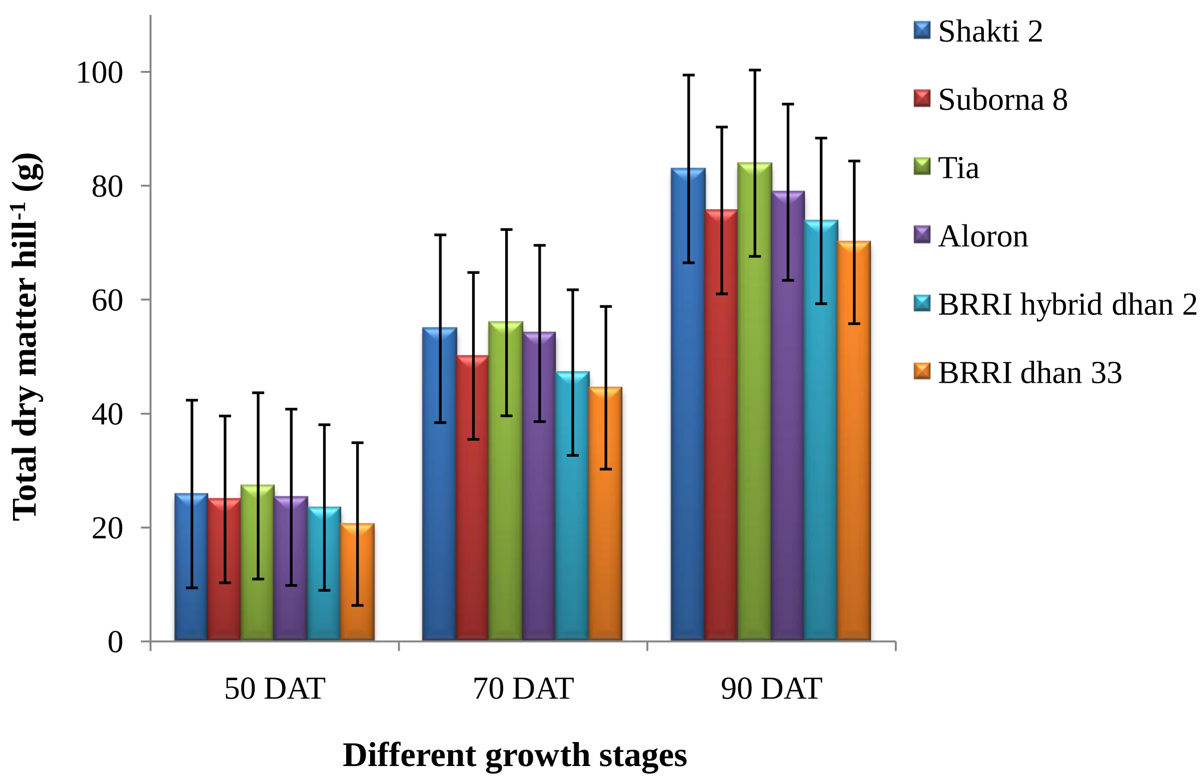


Figure 6. Total dry matter hill^{-1} (TDM) at different days after transplanting (DAT) in hybrid and inbred rice varieties. *Vertical bar represents SE (n=3)*

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. 7). At vegetative stage (50 -70 DAT), the hybrid rice Shakti 2 showed the highest CGR value (44.71 g m^{-2} d^{-1}) followed by Tia (42.9 g m^{-2} d^{-1}). In contrast, the lowest CGR was observed in BRRI dhan 33 (28.27 g m^{-2} d^{-1}) followed by BRRI hybrid dhan 2 (31.25g m^{-2} d^{-1}). At reproductive stage (70 -90 DAT), the highest CGR was observed in Tia (38.36g m^{-2} d^{-1}) followed by Shakti 2 (34.4 g m^{-2} d^{-1}) The lowest CGR value at 70-90 DAT was observed in BRRIdhan 29 (26.25 g m^{-2} d^{-1}1) preceded by BRRI hybrid dhan 2 (29.05 g m^{-2} d^{-1}). Decline of CGR at the latter stage might he attributed to the decrease in LAI at the latter stage (Table 2). So, the CGR increased along with increases in LAI. This result is in agreement with the finding of Yang *et al*. (2011). 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 found lowest in the inbred variety BRRI dhan 33.

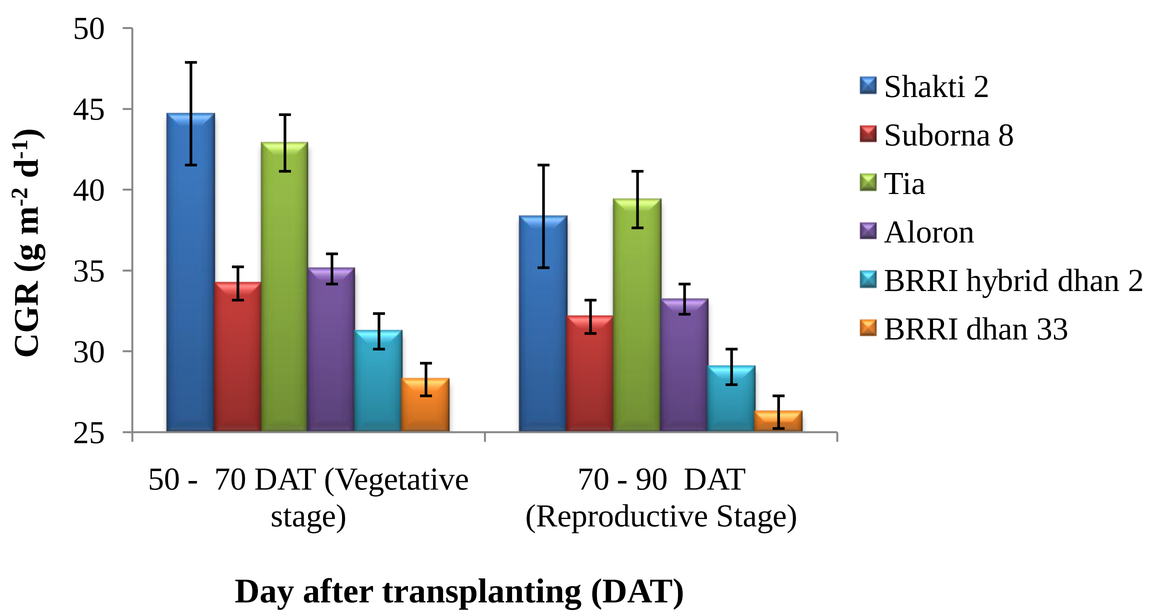


Figure 7. Crop growth rate (CGR) at different days after transplanting (DAT) in hybrid and inbred rice varieties. *Vertical bar represents SE (n=3)*

4.1.11 Relative growth rate

The relative growth rate (RGR) in test hybrid and inbred varieties was measured during the vegetative (50-70 DAT) and reproductive (70-90 DAT) growth phases (Fig. 8). It was observed an inverse relationship between RGR and plant age. The RGR showed the higher values at vegetative stages (50 -70 DAT) than the reproductive stage (70-90 DAT). The result revealed that the Shakti 2 produced the highest RGR value (22.75 mg g^{-1} d^{-1}) at 50-70 DAT followed by Tia (21.95 mg g^{-1} d^{-1}) and there was significant difference between them. In contrast, the lowest RGR value was observed in BRRI dhan 33 (18.65 mg g^{-1} $d^{-1)}$ at 50-70 DAT. At 70-90 DAT, the highest RGR was found in Tia (13.85 mg g^{-1} d^{-1}) and the lowest RGR value was found BRRI dhan 33 (8.05 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 results 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 and declined rapidly with the advancement of growth stages.

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. 9). At vegetative stage (50-70 DAT), the highest NAR (7.2 g m^{-2} d^{-1}) was observed in Shakti 2 followed by Tia (6.9 g m^{-2} d^{-1}) and the lowest (5.3 g m^{-2} d^{-1}) was observed in BRRI dhan 33 preceded by BRRI hybrid dhan 2 (5.1 g m^{-2} d^{-1}). At reproductive stage (70-90 DAT); the highest NAR (4.8 g m^{-2} d^{-1}) was recorded in Tia followed by Shakti 2 (4.6 g m^{-2} d^{-1}) with the same statistical rank while the lowest NAR value was recorded in BRRI dhan 33 (3.3 g m^{-2} d^{-1}). Considering both growth stages, Tia was found to be superior

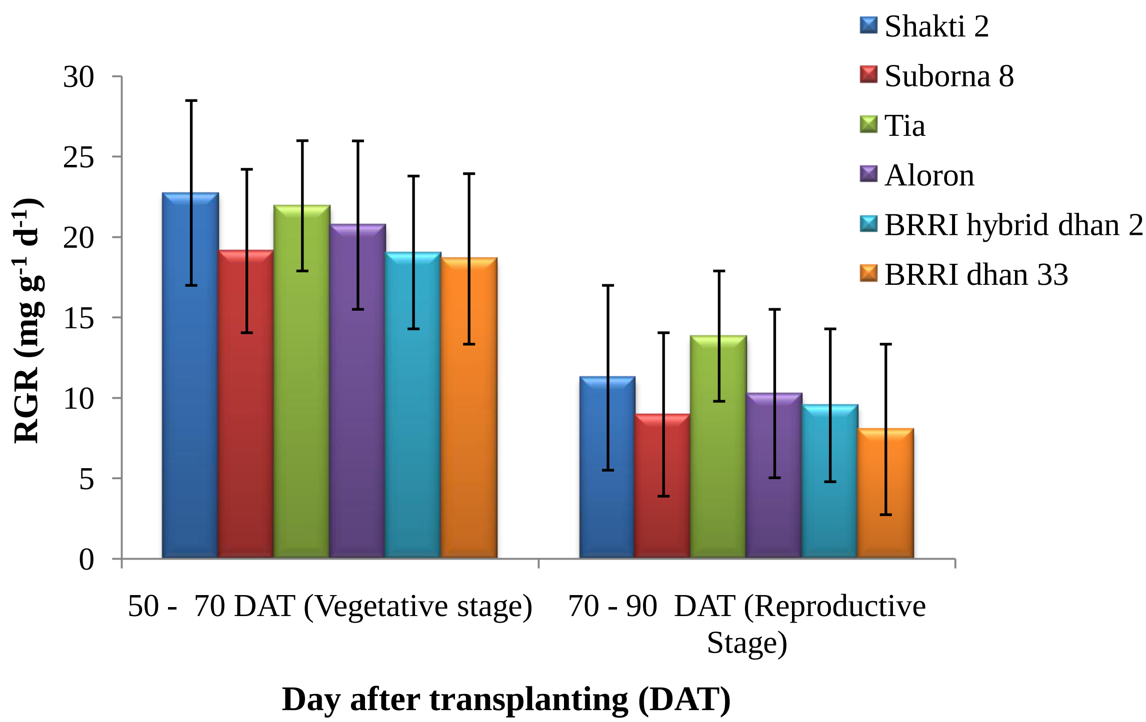


Figure 8. Relative growth rate (RGR) at different days after transplanting (DAT) in hybrid and inbred rice varieties. *Vertical bar represents SE (n=3)*

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).

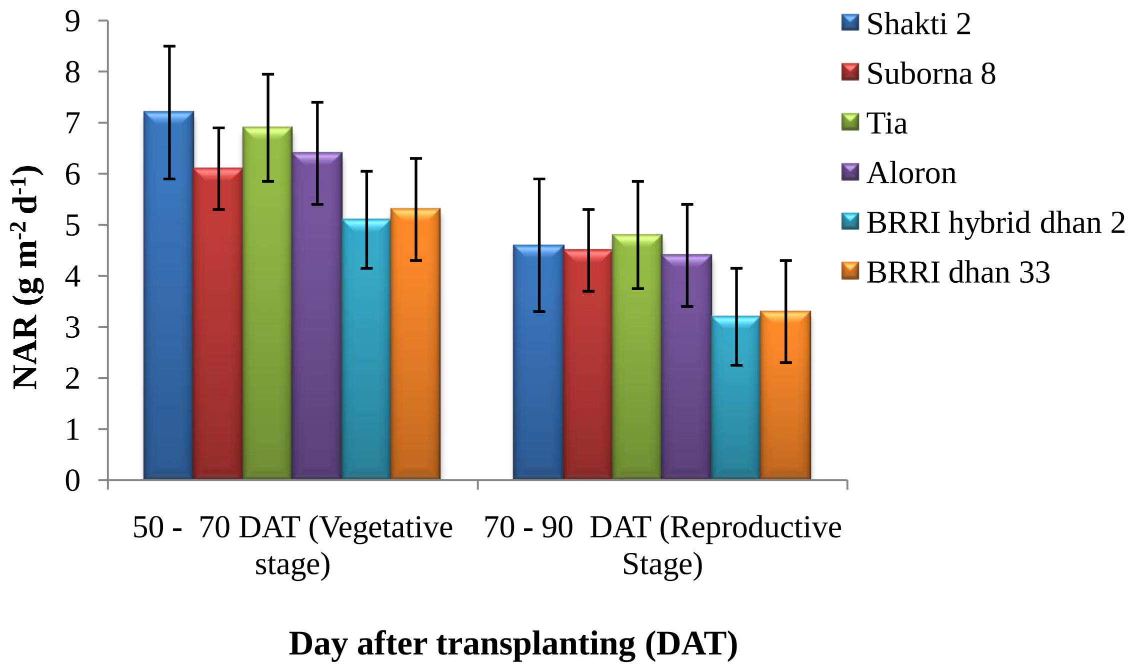


Figure 9. Net assimilation rate (NAR) at different days after transplanting (DAT) in hybrid and inbred rice varieties. *Vertical bar represents SE (n=3)*

4.1.13 Panicle length

Significant variation in panicle length was noticed in different hybrid rice (Fig. 10). The longest panicle was observed in Tia (26.34 cm) followed by Aloron (26.32 cm) and Shakti 2 (26.26 cm). The shortest panicle was observed in BRRI dhan 33 (24.33 cm) preceded by BRRI hybrid dhan 2 (25.00 cm). From the result, it appears that panicle length was longer in hybrid rice than the inbred due to genetic makeup. 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.

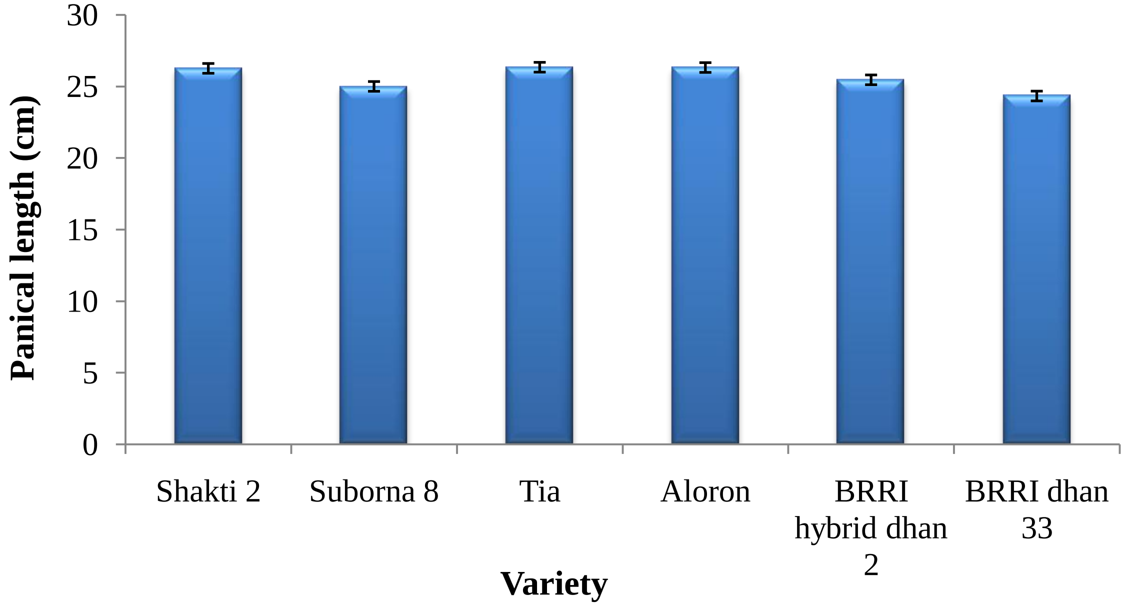


Figure 10. Panicle length of five selected hybrid and inbred rice varieties. *Vertical bar represents SE (n=3)*

4.2 Yield parameters

4.2.1 Days to maturity

Days to maturity of rice showed statistically significant variation due to different variety (Fig.11). The maximum days to maturity (138.86) were observed from Shakti 2. which were statistically similar (135.29) with Suborna 8 and closely followed (128.26) Tia, while the minimum days (115.68) was found from Aloron. Similar results also reported by Masum *et al.* (2008); and Chowdhury *et al.* (1993) from their earlier experiment.

4.2.2 Effective tillers hill^{-1}

Number of effective tillers hill^{-1} had shown significant variation among the studied rice varieties (Table 5). The highest number of effective tillers hill^{-1} (13.38) was recorded in Tia followed by Shakti 2 (11.67). This result revealed that there was

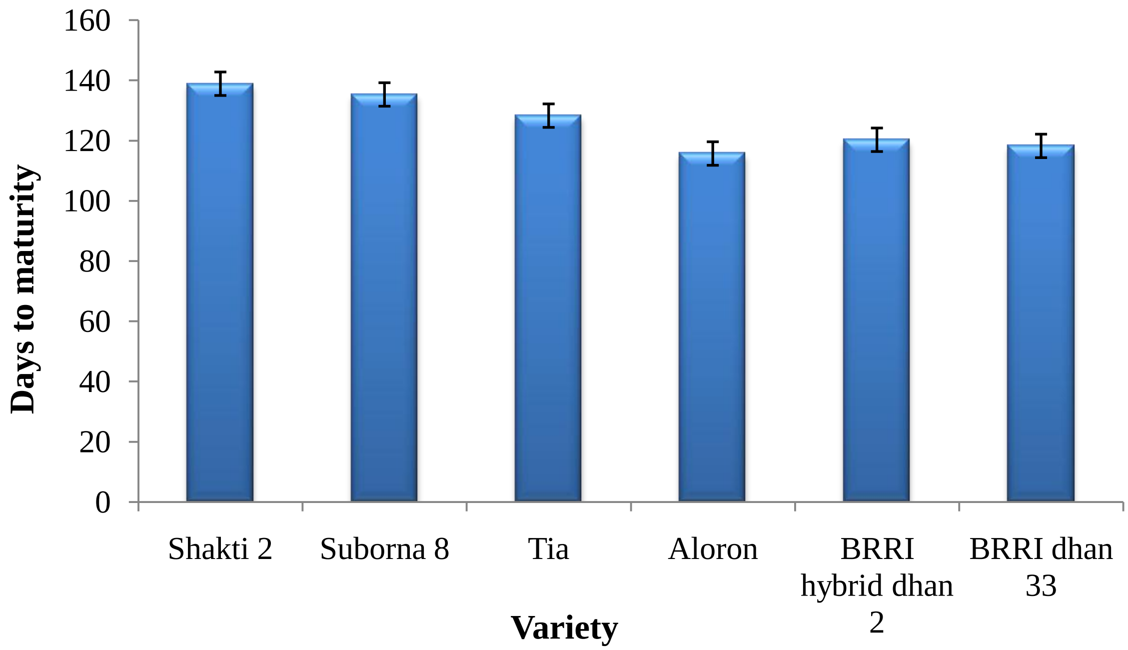


Figure 11. Days to maturity of five selected hybrid and inbred rice varieties.

Vertical bar represents SE (n=3)

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 33 (7.05) preceded by BRRI hybrid dhan 2 (8.32). Result further revealed that hybrid rice produced greater number of effective tillers hill^{-1} than inbred varieties. It means yield is positively correlated with effective tillers number The above result of variability in effective tillers hill^{-1} are also in agreement with many workers (Yang el al., 2010; Shrirame and Muley, 2003; Munshi, 2005).

4.2.3 Non- effective tillers hill^{-1}

Non- effective tillers hill^{-1} had shown significant difference among the studied varieties (Table 2). The highest number of non-effective tillers (5.25) was recorded in BRRI dhan 33 followed by BRRI hybrid dhan 2 (3.15). 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 Shakti 2 (2.30) followed by Tia (2.33). Result further revealed that hybrid rice produced lower number of non- effective tillers hill^{-1} than the inbred.

4.2.4 Filled grains panicle^{-1}

Filled grains panicle^{-1} was markedly different among the test varieties (Table 2). Tia produced the highest number of filled grains panicle^{-1} (222.30) followed by Shakti 2 (212.30). This result showed that there was no significant difference between Tia and Shakti 2. On the other hand, BRRI hybrid dhan 2 produced the lowest Number of filled grains panicle^{-1} (159.90) preceded by BRRI dhan 33 (192.05) 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}.

4.2.5 Unfilled grains panicle^{-1}

Number of unfilled grains panicle^{-1} varied significantly among the rice (Table 2). Shakti 2 produced the highest number of unfilled grains panicle^{-1} (20.33) followed by Jagoron (17.33) and they differed significantly. On the other hand, the lowest by number of unfilled grains panicle^{-1} was recorded in BRRI hybrid dhan 2 (8.33) followed by Aloron (11.98) and Tia (13.33). 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.

4.2.6 Thousand grain weight

Thousand-grain weight was significantly differed among the test varieties (Table 2). Aloron showed the highest 1000 – grain weight (29.95 g) due to heavier grain followed by Suborna 8 (28.65 g) which were significantly different from each other. On the other hand, BRRI dhan 33 showed the lowest 1000 grain weight (22.56 g) due to lighter grain which showing significant difference with Shakti 2 (27.75g). Mondal *et al.* (2005) studied with 17 modern cultivars of transplant *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 and thickness of rice grains were positively correlated with 1000- grain weight. The variation in 1000- grain weight might be due to genetic makeup of particular rice and sink strength.

4.2.7 Grain yield

There was a remarkable difference in respect of grain yield ha^{-1} (Table 3). Tia produced the highest grain yield (7.82 t ha^{-1}) followed by Shakti 2 (7.65 t ha^{-1}) and they were significantly different. On the other hand, BRRI dhan 33 had the lowest grain yield (4.36 t ha^{-1}). The yield was higher in Tia including other hybrid r. e might be attributed to the production of higher LAI,CGR,NAR,TDM, higher number of effective tillers $hill^{-1}$ and higher number or 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 Tia had remarkable superiority to growth, yield attributes and grain yield over the other rice varieties.

Table 2. Yield contributing characters for selected hybrid and inbred rice variety in *Aman* season.

Treatments	Effective tillers hill^{-1}	Non-effective tillers hill^{-1}	Filled grain panicle^{-1}	Unfilled grain panicle^{-1}	1000- grain weight (g)
Shakti 2	11.67b	2.30d	212.30a	20.33a	27.75b
Suborna 8	8.95c	2.85c	205.20b	17.33b	28.65b
Tia	13.38a	2.35d	222.30a	13.33cd	28.05b
Aloron	8.50d	3.05b	202.00b	11.98d	29.95a
BRRI hybrid dhan 2	8.32d	3.15b	159.90e	8.33e	27.88b
BRRI dhan 33	7.05e	5.25a	192.05c	15.25bc	25.56c
CV (%)	8.57	3.03	5.56	7.43	9.97

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

4.2.8 Straw yield

The yield of straw was observed to differ significantly due to varieties (Table 3). It is evident from the experimental results Shakti 2 produced significantly higher (8.42 t ha^{-1}) straw yield followed by Tia (7.85 t ha^{-1}). The lowest straw yield was found in BRRI dhan 33 (5.74 t ha^{-1}). The result was in agreement with the findings of Panda and Leeuwrik (1971) who reported that the straw yield could be assigned to plant height.

4.2.9 Biological yield

The total biomass production was found statistically different among the test rice varieties (Table 3). The highest biological yield $hill^{-1}$ was recorded in Shakti 2 (16.07 t ha^{-1}) followed by Tia (15.67 t ha^{-1}). In contrast, the lowest biological yield was recorded in BRRI dhan 33 (10.10 t ha^{-1}) preceded by Aloron (11.36 t ha^{-1}). Result revealed that hybrid rice produced more biological yield than BRRI dhan 33. Munshi (2005) and Chowdhury *et al.* (1999) reported that grain yield was positively correlated with biological yield in rice.

4.2.10 Harvest index

Harvest index (HI) varied significantly among the hybrid and inbred rice varieties (Fig. 12). Tia recorded significantly the highest harvest index (49.91%). It means dry matter partitioning to economic yield was superior in Tia to the other rice. BRRI dhan 33 recorded significantly the lowest harvest index (43.17%). It means dry matter partitioning to economic yield was inferior in BRRI dhan 33 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.* (1995) also found higher harvest index in the hybrid varieties compared to the inbred.

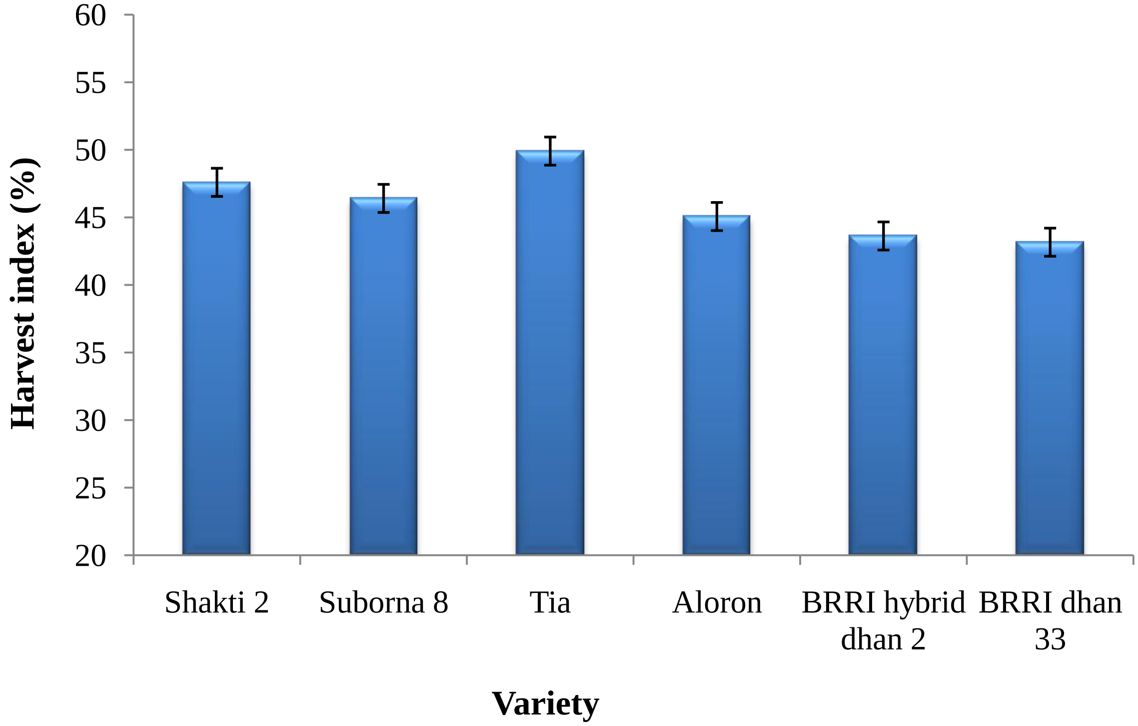


Figure 12. Harvest index of five selected hybrid and inbred rice varieties.

Vertical bar represents SE (n=3)

Table 3. Yield of selected hybrid and inbred rice varieties in *Aman* season.

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
Shakti 2	7.65a	8.42a	16.07a
Suborna 8	5.43b	6.27b	11.70c
Tia	7.82a	7.85a	15.67a
Aloron	5.12b	6.24b	11.36c
BRRI hybrid dhan 2	5.64b	7.20a	12.84ab
BRRI dhan 33	4.36c	5.74c	10.10d
CV (%)	6.86	5.99	8.3

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

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Agricultural Botany field of Sher-e-Bangla Agricultural University, Dhaka during the period from July to December, 2013 with a view to finding out the growth and yield performance of five selected hybrid rice varieties in *Aman* season. The experimental treatments included five hybrid rice varieties *viz.* Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan 2 and BRRI dhan 33 as the modern inbred rice variety. The experiment was laid out in a randomized Complete Block Design (RCBD) with three replications. One seedling of thirty days old was transplanted in each hill maintaining pacing 25 cm X 15 cm. The unit plot size was 3 x 2 m^2. All the necessary intercultural operation including weeding, top dressing, irrigation and pesticide applications etc. were done according to the necessity. Collected data were analyzed following the standard procedure and method.

Plant height, tillers $hill^{-1}$, leaves $hill^{-1}$, TDM, leaf area, LAI, CGR, RGR, NAR, panicle length and yield attributes like days to maturity, effective tillers $hill^{-1}$, filled and unfilled grains $panicle^{-1}$, 1000- grain weight, biological yield, grain yield and Harvest Index (HI) were significantly varied among the studied hybrid and inbred varieties. The hybrid rice variety, Tia showed superiority in respect of growth parameters like tillers $hill^{-1}$ (16.23, 21.34 and 21.45 at different DAT), leaf area $hill^{-1}$ (78.67, 94.35 and 91.34 cm^2 at different DAT), TDM $hill^{-1}$ (27.33, 56.00 and 84.00 g at different DAT), LAI (3.38, 4.91 and 4.72 at different DAT), CGR (41.90 and 39.4 g m^{-2} d^{-1} at different growth stage), RGR (21.95 and 13.85 mg g^{-1} d^{-1} at different growth stage), and NAR (6.9 and 4.8 g m^{-2} d^{-1} at different growth stage) 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 area index 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 was found higher but in the latter growth stage, they declined. Again, Tia also showed the highest yield contributing characters like effective tillers $hill^{-1}$ (16.38), panicle length (26.34 cm) grain yield (8.32 t ha^{-1}), HI (49.91 %) to the check variety, BRRI dhan 33 (10.05, 24.33cm, 4.36 t ha^{-1} and 43.17 %, respectively). However, all the tested hybrid rice varieties produced higher grain yield compared to BRRI dhan 33. 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 33. Among the studied hybrid, Tia and Shakti 2 performed better in respect of biological yield (16.67 and 17.07 t ha^{-1}, respectively) than that of inbred BRRI dhan 33 (10.10 t ha^{-1}). Results indicated that Tia and Shakti 2 produced higher biological yield because of higher total dry matter production, net assimilation rate (NAR), crop growth rate (CGR), harvest index (HI) and finally they have 24.0% yield advantage over the inbred BRRI dhan 33.

Therefore, it is concluded that Tia was superior in *Aman* season in consideration of growth and yield attributes among the afore-mentioned five hybrid and one popular inbred rice varieties. Tia ultimately leads to the higher dry matter production. All the test hybrids converted more dry matter into the grain compared to inbred variety, BRRI dhan 33. Panicles $hill^{-1}$ and 1000-grain weight are the determinants for the higher grain yield of the studied hybrids over the inbred BRRI dhan 33.

Considering the results of the present experiment, it could be concluded that-

1. Hybrids are better than inbred rice varieties to ensure higher yield. Specially, Tia should be chosen to cultivate during *Aman season.*
2. Such experiments are needed to conduct in different agro-ecological zones (AEZ) of Bangladesh for the confirmation of the results.

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**: 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.0 .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*., **30** (2): 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.

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.

BRRI (Bangladesh Rice Research Institute). (1995). Adhunik 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.

BRRI. (2010). Annual Report for 2010. Bangladesh Rice Res. Inst., Joydcbpur, Gazipur. P. 31.

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 modem 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.(1948). 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 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., Asanurna , 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. Agromelero.* **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). (2002). Production Yearbook .No.**61**. Published by FAO, Rome, Italy, p.54.

FAO (Food and Agricultural Organization). (2006). Production Yearbook Vol.**52**. UN, Rome, Italy, p. 64.

Fujita, K., Coronel, V.P. and Yoshida, S. (1984). Grain filling characteristics of rice varieties (*Oryza sativa* L) 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.

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

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.

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.

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 development characteristics of super high yielding mid season japonica rice. *Scientia Agricultura* **39**(7): 1336-1345.

Julfiquar, A. W., Virmani, S.S., Hague, 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., Japan, 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. (1988). Effect of cultivar and NPK combinations on the yield contributing characters of rice. *Bangladesh J. Agril. Sci.*, **15**(1): 105-110.

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).

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

Mandavi, 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.

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 semidwarl 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, 0.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 physiological growth 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 saliva*). *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.

Rafey, A., Khan, P. A. and Srivastava, V. C. (1989). Effect of Nitrogen on growth, yield and nutrient uptake of upland rice. *Indian J. Agron*. **34**(2):133-135.

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.

Shamsuddin, A. M., Islam, M. A. and Hossain, A. (1988). Comparative study on the yield and agronomic characters of nine cultivars of aus rice. *Bangladesh J. Agril. Sci*., **15**(1): 121-124.

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, S. and Gangwer, B. (1989). Comparative studies on production potentials in traditional tall and improved rice cultivars. *J. Andaman Sci. Assoc*., **5**(1): 81-82.

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 F1 hybrid with their parental species Oryza rulipogon and O.Sativa. *Ann. Bot.*, **93**: 31 1 -3 1 6.

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., Nislaio, T., Ohsurni, A., Shiraiwa, T. and Horie, (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 by the split application of potassium with FYM in inceptisols of eastern central. *India. J. Potassium Res.*, **14**(1/4): 73-77.

Wada, Y., Yun, S.. Sasaki, II., 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.,* (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.

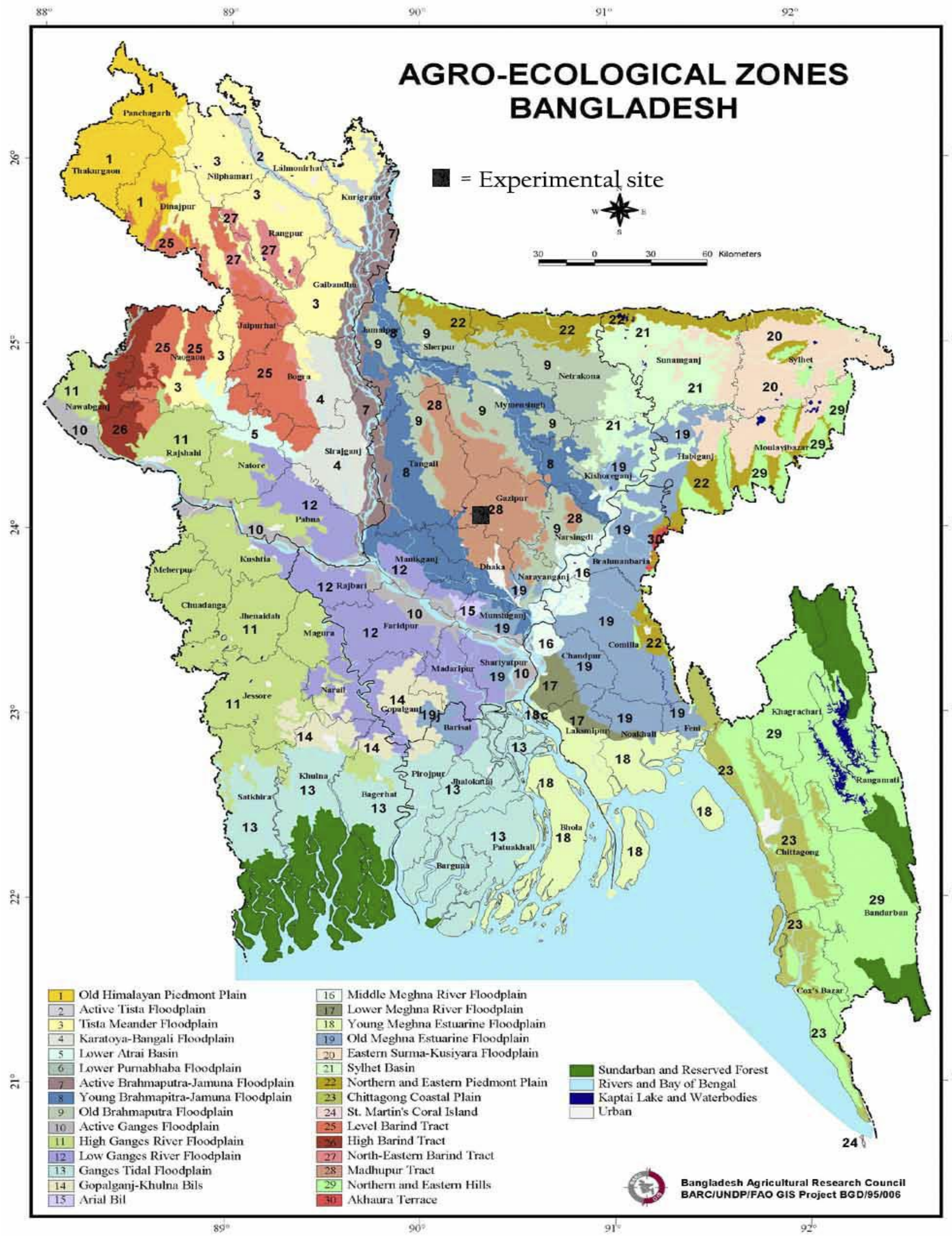
Yoshida, S., (1981). Fundamentals of Rice Crop Science. Intl. Rice Res. Inst., Los Banos, Leguna, Philippines. pp 48 -269.

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.

Zahad, A. A., Ashore , A.M. and I ladudy, K. 114(1980) Comparative analysis of growth, development and yield of live field bean cultivars. Z. Acker Flnazenbau, 249: 113.

APPENDICES

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



Appendix II. Characteristics of the soil of experimental field

A. Morphological characteristics of the soil of experimental field

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

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

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

Appendix III. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from July to December 2013

Month (2013)	Air temperature (^{0}C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
June	35.4	22.5	80	577
July	36.0	24.6	83	563
August	36.0	23.6	81	319
September	34.8	24.4	81	279
October	26.5	19.4	81	22

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212