A COMPARATIVE STUDY ON HYBRID AND INBRED RICE GROWN IN *AMAN* SEASON

MD. DILUAR HOSEN

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

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BY

MD. DILUAR HOSEN

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Approved by:

……………..……………….	**……………..…………….………..**
Prof. Dr. Md. Moinul Haque	**Prof. Dr. Kamal Uddin Ahmed**
Supervisor	Co-supervisor

…………..……………..…………
Assoc. Prof. Dr. Md. Ashabul Hoque
Chairman
Examination Committee

DEPARTMENT OF AGRICULTURAL BOTANY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
Phone: 9134789

CERTIFICATE

This is to certify that the thesis entitled **“A COMPARATIVE STUDY ON HYBRID AND INBRED RICE GROWN 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 (M.S.)** in **AGRICULTURAL BOTANY,** embodies the results of a piece of bona fide research work carried out by **MD. DILUAR HOSEN,** Registration No. **09-03533** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

Dated: 14.08.2016

Dhaka, Bangladesh

(Prof. Dr. Md. Moinul Haque)
Supervisor

Dedicated To

My Beloved Parents

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ABSTRACT

A field experiment was conducted with four hybrids (Gold, Moyna, Shuborna 3 and BRRI hybriddhan 4) and three inbred rice varieties (BRRIdhan 56, BRRI dhan 57 and BRRIdhan 62) in the Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, with a view to evaluating their performances. The experiment was laid out in Randomized Complete Block Design with three replications. Significant variation was found among the selected inbred and hybrid rice varieties in respect of their different growth and yield characters. Among the seven rice varieties, inbred BRRIdhan 62 was found inferior considering above characters. All the hybrid varieties contained higher amount of chlorophyll in their flag leaf at flowering to maturity compared to the inbred. BRRI hybriddhan 4 exhibited superiority over the rest hybrid and inbred varieties in different growth parameters like plant height, tillers hill^{-1}, leaves hill^{-1}, total dry matter hill^{-1}, leaf area hill^{-1}, leaf area index, crop growth rate and panicle length. BRRI hybriddhan 4 also showed superiority in case of yield parameters such as panicles hill^{-1}(14.27), filled grains panicle^{-1}(168.43), 1000- grain weight (26.07 g), biological yield (13.33 t ha^{-1}) and grain yield (6.13 t ha^{-1}). Rest of the hybrid varieties *viz.* Shuborna 3 (5.60 t ha^{-1}), Gold (5.15 t ha^{-1}) and Moyna (4.86 t ha^{-1}) also provided higher grain yield compared to BRRIdhan 56 (4.63 t ha^{-1}) and BRRIdhan 57 (4.25 tha^{-1}). Panicles hill^{-1}, filled grains panicle^{-1} and 1000- grain weight mainly contributed to the higher grain yield of the hybrid varieties over the inbred.

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ABBRIVIATION	ELABORATION/ FULL WORD(S)
AEZ	Agro-Ecological Zone
BARC	Bangladesh Agricultural Research Council
BINA	Bangladesh Institute of Nuclear Agriculture
BRRI	Bangladesh Rice Research Institute
Cont'd	Continued
cv.	Cultivar
DAT	Days after transplanting
^{0}C	Degree Centigrade
DF	Degree of freedom
EC	Emulsifiable Concentrate
et al.	and others
etc.	Etcetera
g	Gram
BBS	Bangladesh Bureau of Statistics
cm	Centimeter
etc.	Etcetera
FAO	Food and Agriculture Organization
HI	Harvest Index
Hr	Hours
IRRI	International Rice Research Institute
Kg	Kilogram
LV	Local variety
LSD	Least significant difference
M	Meter

ABBRIVIATION	ELABORATION/ FULL WORD(S)
mm	Millimeter
viz.	Namely
N	Nitrogen
ns	Non-significant
%	Percent
CV%	Percentage of Coefficient of Variance
P	Phosphorus
K	Potassium
ppm	Parts per million
S	Sulphur
Zn	Zinc
MP	Muriate of Potash
m^2	Square meter
UNDP	United Nations Development Program

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important crops in tropical and subtropical world. It is the main sources of food for approximately half of the world population and hence the most important crop on the earth (Goff, 1999). Asia is the prominent producer of rice and about 60% of the Asian gets their calorie from rice. Rice provides 20-80% dietary energy and near about 12-17% of dietary protein for Asians (Azeez, 1986). Annual per capita consumption of rice in Bangladesh is the highest in the world (Nasiruddin, 1993). It provides about 70% of an average citizen's total calorie intake (BRRI, 2010). It has been found that rice contributes 76% of the caloric and 66% of the protein intake (BNNC, 2008). Rice accounts for nearly 18% of the national GDP (BRRI, 2010). In 1971, the total production of rice in Bangladesh was 10.59 million metric tons (mMt). At that time the population of the country was about 70.88million. During 1970-1975, the share of amount of rice was below 455g per head per day. During 2014-2015, the share of rice per head per day increased more than 500 g although the rice land per capita per year decreased remarkably. This scenario indicates that the country produces enough rice to feed its huge population. This becomes possible because of the cultivation of modern rice varieties in 66% rice land and total rice production increased to 34.495 mMt (BBS, 2014). At present Bangladesh ranks 4th in total production and 6th in the production of per hectare yield of rice in the world. However, the total rice area in 1970-2014 remained almost similar to 10.5 million hectares. It is estimated that the population will gradually increases to 161 million in 2020 although the population growth rate will be much lower than that in 1991. The increase rate of population is 1.36% (BBS, 2014) and the decreasing rate of agricultural land is 1% per annum. So rice yield per unit area should be increased to meet the ever increasing demand of food in the country. Rice plays absolutely dominant role in Bangladesh agriculture as it covers 68.35% of total cropped area (AIS, 2014).

There are three kinds of Rice in Bangladesh named as *Aus, Aman and Boro,* which are cultivated during April to July, August to December and January to May respectively. About two-thirds of the cultivated land area of Bangladesh is occupied by rice. *Aman* is second main rice growing season in Bangladesh. The conventional varieties of rice in Bangladesh are comparatively lower-yield and it seems impossible to change this yield with reachable resources under the prevailing situation. Higher yield can be achieved by two processes, firstly through the cultivation of hybrid varieties and secondly by following improved management practices (IRRI, 1993). In Bangladesh, development of high yield potential variety is one of the ways to satisfy the future demand. Irrigated modern rice contributes 41% of the total rice production in Bangladesh (Anon, 2000) Hybrid rice has about a 30% yield advantages over the conventional pure line varieties (Yuan, 1998).

The average yield of rice is 4.3 t ha^{-1} (BBS, 2014); which is quite lower compared to that of many other rice growing countries like China, Japan, Korea and USA where yields are 6.23, 6.79, 6.59 and 7.04 t ha^{-1}, respectively (FAO, 2014). The total yield of rice in *Aus*, *Aman* and *Boro* season was 2.33, 13.19 and 19.01 million metric tons, respectively (BBS, 2014). In Bangladesh hybrid rice has a good prospect but very little research work has been done for the development of hybrid. Hybrid rice is one of the options for increasing the yield ceiling in rice over the best modern varieties. Hybrid rice offers to break the yield ceiling of conventional semi-dwarf rice varieties. Hybrid rice technology has been introduced through IRRI, BRRI and some commercial seed companies. In *Aman* season, however available information regarding the yield and yield contribution character, morpho-physiological characteristics of hybrid rice varieties are meager in Bangladesh.

In the year 2014, among the *Aman* rice varieties high yielding modern varieties covered 72.35 % and yield was 2.66 t $ha^{-1}$and local varieties covered 22.03 % and yield was 1.64t ha^{-1} (BBS, 2014). Farmers are gradually replacing the local indigenous low yielding rice varieties by high yielding ones and modern varieties of rice.

The hybrid varieties mostly cultivated in Bangladesh are imported from China by private seed companies. Four hybrid variety named BRRI hybrid 1, BRRI hybrid 2, BRRI hybrid 3, BRRI hybrid 4 have been released for commercial cultivation by Bangladesh Rice Research Institute (BRRI). Few seed companies have imported hybrid seeds of different varieties, which are also cultivated in farmer's field. However, the farmers are confusing about the growth characteristics and genetically yield potential of these hybrids in comparison with high yielding varieties locally cultivated in Bangladesh. Since emergence in 1972, the BRRI has earned international standard of agricultural research and heritage status developing over 74 numbers of modern high yielding varieties of rice. Hussain *et al*. (2002) reported that two rice hybrids Sonarbangla 1 (CNSGC6) and Alok 6201 released in Bangladesh during 1998-1999 are not well accepted by the producer, due to high rate of unfilled grains, grain shedding, crop lodging, though their yield advantage were 23% and 5% higher than that of HYVs, respectively. Greater emphasis is being given for increasing yield of hybrid rice during development or imported from other countries. The population of Bangladesh is increasing day by day and that is why horizontal expansion of rice area is not possible due to high population pressure on land. To ensure the food security for her increasing population and reduce the extreme poverty and hunger which is one of the MDG_s goals given by the United Nation Organization, it is an urgent need of the time to increase rice production through increasing yield. Proper practices are the most effective means for increasing yield of rice at farmer level using inbred and hybrid varieties (Alauddin, 2004). However, some of the newly introduced hybrid rice varieties are Shuborna 3, Moyna, Gold, BRRI hybriddhan 4. 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.

Keeping the foregoing problems in view, this study was undertaken with the following objectives-

1. To compare the morpho-physiological characters of hybrid and inbred rice varieties in *Aman* season.

2. To evaluate the yield contributing characters of hybrid rice varieties in *Aman* season.

3. To observe the yield variation among the hybrid and inbred rice varieties in *Aman* season.

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Rice is widely adaptable crop in different environmental condition. Yield is the product of yield components i.e. panicle number, grain number, and grain weight in rice (Yoshida, 1981). Yield potentiality also depends on physiological parameters like leaf area index, dry matter accumulation, translocation of assimilate. The available literatures under the heads of the objectives of the study were also reviewed in the following paragraphs.

2.1 Morpho-Physiological parameters

2.1.1 Plant height

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

Sarkar (2014) observed that height varies variety to variety. He found that Tia (78.46 cm) was the tallest plant and shortest was recorded in Aloron (63.88 cm).

Yuan (2010) suggested the plant height for rice is about 100cm; with culm length of 70 cm.

Samsuzz*aman* (2007) also reported that plant height of the hybrids ranged from 82.46 cm in Richer to 100.31 cm in BRRIdhan 28 with a mean of 89.58 cm.

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

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

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

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

Ganesan, (2001) reported that plant height, days to flowering, number of tillers $^{-1}$ plant, and productive tillers plant^{-1} had both positive and negative indirect effects on yield.

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

Wang (2000) reported that plant height was 88-89 cm directly related to yields. Plant height may not have significant role in the expression of hybrid vigor.

2.1.2 Tillering dynamics

Sarkar (2014) showed that number of total tiller hill^{-1} increased with the advancement of vegetative growth stages and he found highest tiller hill^{-1} in Tia (16.23, 21.34, 21.45 at 50, 70, 90 DAT respectively). He also observed that hybrid produced a significantly higher number of tillers hill^{-1}.

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

Laza *et al*. (2001) concluded that the early vigor of hybrid rice (*Oryza sativa* L.) developed in temperate region has been mainly attributed to its higher tiller rate. However, the tiller rate of hybrids was significantly lower than or equal to that of conventional varieties.

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

Nuruzz*aman et al.* (2000) conducted an experiment to figure out the relationship between the tillering ability and morphological characters among 14 rice varieties. They observed that tillers number varied widely among the varieties and the number of tillers plant^{-1}at the maximum tillering stage ranged between 14.3 and 39.5 in 1995 and 12.2 and 34.6 in 1996. Among all the varieties, IR36 produced the highest number of tillers plant^{-1} followed by Suweon 258 while Dawn produced the lowest number of tillers plant$^{-1.}$

Hossain and Alam (1991) observed that total no. of tillers hill^{-1} and no. of grains panicle^{-1} differed significantly among the rice varieties tillering ability than JND13.

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

2.1.3 Days to maturity

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

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

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

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

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

2.1.4 Leaves hill^{-1}

Sarkar (2014) observed a significant difference on total number of leaves per hill from vegetative to reproductive stage. He found highest no of leaves in Tia (78.67) and lowest in BRRI hybriddhan 2 (64.34).

Hassan (2001) presented that photo synthetically active leaves hill^{-1} of all varieties increased with the growth period up to booting stage except in Binasail. He also observed that maximum number of leaves were produced at the tillering stage and then declined. The rate of declination was sharp in local varieties than that of hybrid varieties.

2.1.5 Leaf area hill^{-1}

Sarkar (2014) showed that hybrid rice variety produce the higher leaf area than the check variety and the variation in leaf area might occur due to the variation in number of leaves.

Islam (2006) observed that the increment of leaf area hill^{-1} varied significantly due to genotype at all growth stages.

Mahdavi (2004) also indicated that improved genotypes were with greater leaf area than traditional genotypes. He found that flag leaf area had positive correlation with grain yield.

Song *et al*. (2004) showed that flag leaf area was greatest in Minghui-63, Hybrid was intermediate, and *O. rufipogon* had the smallest area.

Sharma and Haloi (2001) showed a remarkable variation of leaf area in an experiment on scented rice.

Paranhos *et al.* (1997) found that all the cultivars produced maximum leaf area during panicle initiation.

2.1.6 Leaf area index (LAI)

Haque *et al.* (2014) observed that Leaf area index (LAI) increased gradually in all the tested varieties in all the planting dates up to heading and in most of the cases the differences are insignificant. Thereafter, the reduction of LAI is greater in inbred than that of hybrids. As an outcome, the hybrid varieties sustained higher LAI after heading to maturity over inbred BRRI dhan45 regardless of planting dates. Days to heading decreased gradually with delayed planting and the magnitude of reduction was almost similar in the hybrid and inbred varieties. However, the maximum LAI was recorded from Heera 2 (6.36) at heading stage followed by BRRI hybriddhan 2 (5.94) while it was significantly lower in BRRIdhan 45 (5.10) at 20 December planting of 2008-09. The maximum value of LAI gradually decreased in hybrid and inbred varieties with delayed transplanting due to reduction of vegetative phase. The leaf area development of studied varieties at different planting dates in 2009-10 was more or less similar to the previous year. This result revealed that hybrid rice varieties maintained significantly greater LAI from heading to maturity stage compared to the inbred.

Chandra and Das (2007) observed that LAI was significantly and positively correlated with grain yield.

Mahdevi *et al.* (2004) recorded that all genotypes reached maximum LAI at pre-flowering but Dash and Taron reached LAI at flowering. Neda had greatest LAI (5.70) compared to the other genotypes. Neda was a late maturity genotype and had a greatest LAI due to the longer vegetative phase. Maximum LAI was correlated positively and strongly with grain yield.

Wada *et al*. (2002) observed that higher crop growth rate after anthesis due to the higher mean LAI during ripening period.

Yuan (2001) stated that LAI of top three leaves is about 6 and Miah *et al*. (1996) showed that LAI with 7.3 is the maximum that is necessary to give high grain yield.

Lu *et al.* (2000) found that higher yield of rice was due to the better distribution of LAI after heading.

Reddy *et al*. (1995) experimented and observed that genotypes deferred markedly in LAI, SLW and assimilated rate.

2.1.7 Total dry matter weight hill^{-1}

Sarkar (2014) observed that hybrid rice produced higher TDM than the inbred varieties and he found that Tia showed the highest TDM hill^{-1} (84 g) and the inbred, BRRIdhan 29 showed the lowest TDM hill^{-1} (70.10 g) at 90 DAT. He also found that dry matter accumulation increased with the age of rice plant.

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

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

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

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

2.1.8 Crop growth rate

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

Horie (2006) showed that the most critical growth attribute for rice yield under intensive management is CGR during the latter half of the reproductive period (15 to 20 day before heading).

Maximum CGR occurred at flowering stage for all genotypes than old genotypes. Generally modern genotypes showed greater CGR than old genotypes (Mandavi *et al.*, 2004).

Miah *et al.* (1996) observed that crop growth rate 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 with greatest and lowest dry matter had highest and lowest CGR respectively in leaves cause parallel decrease in NAR and eventually low growth rate.

2.1.9 Flag leaf chlorophyll content

Haque *et al* (2014) told that the hybrid varieties synthesized significantly higher amounts of chlorophyll and maintained higher chlorophyll a: b ratio in their flag leaf over inbred BRRIdhan 45. Flag leaf chlorophyll content and chlorophyll a:b ratio gradually decreased in the hybrid and inbred varieties with advanced maturity. Reduction of chlorophyll content at 23 days after flowering compared to 2 days after flowering was 33 and 36% in hybrids and inbred, respectively. Planting dates had little influence on flag leaf chlorophyll content. Chlorophyll a:b ratio of the flag leaf was higher in both the hybrids. However, environmental influence on total chlorophyll content of flag leaf was relatively small.

Salem *et al.* (2011) stated that crop growth rate during three different growth periods and chlorophyll content were significantly increased for the 20 days seedling and 40 days seedling gave the lowest value for chlorophyll content.

2.1.10 Panicle length

Sarkar (2014) reported that panicle length was longer in hybrid rice than the inbred due to genetic makeup. He observed the longest panicle in Tia (26.34).

Hosain *et al*. (2014) found a significant variation in panicle length. He recorded the longest panicle length in Hera 2 (24.70 cm) which was statistically identical with Aloron 24.52.

Samsuzz*aman* (2007) observed that among the hybrids, the length of main panicle ranged from 27.3 cm in Jagoron to 28.6 cm in Aloron, with a mean of 27.70 cm. In case of checks the panicle length ranged from 26.0 (BRRIdhan 28) to 27.5 (BRRI dhan 29), with a mean of 26.73 cm.

Awal *et al*. (2007) observed the longest panicle in Sonarbangla 3 (31.33 cm) closely followed by Sonarbangla 2 (29.67 cm). The former hybrid retained significant superiority to the conventional varieties (24.67-28.33 cm). However, Sonarbangla-2, BRRIdhan 32 and-33 were statistically similar.

Chakma (2006) found that BINAdhan 5 produced the longest panicle (22.86 cm) followed by BRRIdhan 29 (22.78 cm) and BINA dhan 6 (22.28 cm).

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

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

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

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

2.2 Yield parameters

2.2.1 Days to maturity

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

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

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

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

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

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

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

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

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

2.2.2 Effective tillers hill^{-1}

Awal *et al*. (2007) observed no significant variation among the treatments regarding no. of panicle hill^{-1}. Sonarbanla-3 obtained the highest filled up grains (176 grains panicle^{-1}) but did not differ significantly with BRRIdhan 32 (149 grains panicle^{-1}). Sonarbangla-3 had clear statistical edge over Sonarbangla-2, BRRIdhan 33 and BR11 in this respect.

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

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

Ganesan (2001) reported that plant height, days to flowering, number of tillers/plant, and productive tillers plant^{-1} had both positive and negative indirect effects on yield.

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

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

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

Ganapathy *et al*. (1994) studied that the number of productive tillers per hill, panicle length and grains panicle^{-1} had a significant and positive association with grain yield.

2.2.3 Filled grains per panicle

Hosain *et al*. (2014) observed the highest number of filled spikelet panicle $^{-1}$ (79.53) was recorded BRRIdhan 48. This was may be due to lower sensitiveness of BRRIdhan 48 to high temperature and low sunshine hour at grain filling stage compared to test hybrid varieties. The highest spikelet filling percent was recorded from BRRIdhan 48 (74.43 %) due to favorable environmental condition at grain filling stage.

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

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

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

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

Mrityunjay (2001) conducted an experiment to study the performance of 4 rice hybrids and 4 high yielding rice cultivars. Hybrids, in general; gave higher values for number of filled grains panicle^{-1}, plant height at harvest and panicle length compared with the others.

Ganesan (2001) conducted that an experiment of 48 rice hybrids. Filled grains panicle^{-1} (0.895) had the highest significant positive direct effect on yield plant^{-1}

followed by number of tillers plant^{-1} (0.688, panicle length (0.167) and plant height (0.149).

Oka and Saito (1999) experimented that among F1 hybrids from crosses of rice *cv*. Sasanishiki with other cultivars there were relationships with parental values for grain number panicle^{-1}, panicle length, and panicle emergence date.

R*aman*a *et al.* (1998) observed that hybrids produced more panicles m-2 and filled grains per panicle than conventional cultivars

2.2.4 Unfilled grainspanicle^{-1}

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

2.2.5 Thousand -grain weight

Sarkar (2014) observed that Aloron has the highest 1000-grain weight (29.95g) due to heavier grain followed by Suborna 8 (28.65). On the other hand, BRRI dhan 29 showed the lowest 1000 grain weight (22.56 g).

Awal *et al*. (2007) noted that the grains of the hybrids were clearly heavier, compared to those of the conventional varieties. The highest grain weight (31g) was exhibited by Sonarbangla-2 followed by significantly different Sonarbangla-3 (28.33g). The conventional varieties had a medium range (22-25g) of grain weight and were statistically lighter with respect to the hybrids.

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

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

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

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

Padmavathi *et al*. (1996) concluded that number of tillers plant^{-1}, number of panicles plant^{-1}, panicle length and 1000-grain weight was positively associated with grain yield.

Kumar *et al*. (1994) stated that grain weight was highly correlated to grain size, which is product of grain length and width that are inherited independently and this independent inheritance lead to variation in F1 grain weights.

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

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

2.2.6 Grain yield

Hosain *et al*. (2014) observed that BRRIdhan 48 gave significantly higher grain yield 3.51 t ha $^{-}$1 over the tested hybrid varieties Heera 2 (3.03 t ha $^{-1}$) and Aloron (2.77 t ha $^{-1}$). The higher grain yield of BRRI dhan48 was associated with higher number of panicles hill $^{-1}$ and higher spikelet filling percent.

Sarkar (2014) showed that Tia produced the highest grain yield (8.32t ha^{-1}) followed by Shakti 2 (8.15t ha^{-1}). On the other hand, BRRI dhan 29 produced the lowest grain yield (4.36 t ha^{-1}).

Awal *et al*. (2007) observed that Sonarbangla-3 obtained the highest grain yield (6.20 t ha^{-1}) which significantly varied with the rest of the treatments. However, yield of BRRI dhan-32 (5.70tha^{-1}) was statistically higher than those of Sonarbangla2 (5.15 tha^{-1}) as well as other conventional varieties (4.17- 4.96 t ha^{-1}).

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

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).

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

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

Ganesan (2001) concluded that grains plant^{-1} had the least significant positive direct effect on number of tillers plant^{-1} (0.688), panicle exertions (0.172), panicle length (0.167) and plant height (0.149).

BRRI (1999–2000) conducted a study on newly introduced BRRI varieties and one hybrid rice variety. They found that irrespective of different land types, the highest yield (7.02 t ha^{-1}) was obtained from BRRI Dhan29 followed by hybrid variety, BRRIDhan 28 and BRRI Dhan36 which gave an average yield of 6.03 t ha^{-1}, 5.53 t ha^{-1} and 4.69 t ha^{-1}, respectively.

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

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

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

Ganapathy *et al.* (1994) concluded that the number of productive tillers per hill, panicle length and grains panicle^{-1} had a significant and positive association with grain yield.

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

2.2.7 Straw yield

Awal *et al.* (2007) Observed that BRRI dhan 32 produced the top most straw yield (8.6 t ha^{-1}) which differed statistically with the rest of the treatment. Sonarbangla-3 produced a good amount of straw (6.5t ha^{-1}) which was significantly higher than Sonarbangla-2 (5 t ha^{-1}), BR 11(5 t ha^{-1}) and BRRI dhan-33 (4.2 t ha^{-1}).

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

2.2.8 Biological yield

Sarkar (2014) observed that the highest biological yield ha^{-1} was recorded in Shakti 2 (17.07 t ha^{-1}) followed by Tia (16.67 t ha^{-1}). On the other hand, the lowest biological yield was recorded in BRRIdhan 29 (10.10 t ha^{-1}).

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

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

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

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

2.2.9 Harvest index

Hosain *et al*. (2014) found a remarkable variation in harvest index (HI) among the studied varieties. The highest HI was obtained from BRRIdhan 48 while it was lowest in Aloron.

Sarkar (2014) observed that Tia recorded significantly the highest harvest index (49.91%) and BRRI dhan 29recordedthe highest harvest index (43.17%).

Jian Chang *et al.* (2006) found that super high yielding rice had more harvest index (51%) than the high yielding rice.

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.

Shrirame and Mulley (2003) conducted an experiment on variability and correlation studies of different biometric and morphological plant characters of rice with grain yield. It was carried out with rice hybrids TNRH10, TNRH13 and

TNRH18 and cultivar Jaya. They found that grain yield exhibited a very strong positive correlation with harvest index. Grain yield was also significantly correlated with dry matter weight hill^{-1}, effective tillers hill^{-1} and number of filled grains panicle^{-1}.

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

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

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

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

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

2.2.10 Yield potential of hybrid

Parvez *et al.* (2003) conducted a comparative study to evaluate four imported hybrid rice cultivars with a high yielding variety (BRRIdhan 29). The Chinese cultivar Sonarbangla-1 gave the best performance in terms of all the parameters under consideration. The other three Indian cultivars (Amarsiri-1, Aalok and Loknath) had lower performance than the control. Sonarbangla-1 produced 20%

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

Ma *et al.* (2001) studied comparative performance of 8 rice hybrids and the control cultivars PS02 and PTT1. The hybrids possessed more leaves (12–15.9) than the local cultivars (15.1–15.3) as well as higher yield. NN49 produced the highest yield (7.142 t ha^{-1}) which was 58.78% and 26.52% higher than those of PS02 and PTT1. They also experimented with ADTRH1 which was a rice hybrid. In different trials, ADTRH1 showed 26.9% and 24.5% higher yield over CORH1 and ASD18 respectively; with an average yield of 6.6 t ha^{-1}. The hybrid recorded the highest grain yield (11.4 t ha^{-1}). The highest yield of the control in these trials was 9.6 t ha^{-1}.

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

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

Ramana *et al.* (1998) observed the mean grain yield of the best performing rice hybrids was 37.7% higher than the conventional cv. IR-64 during 1993; while in 1995, the maximum yield of rice hybrid MTUHR 2037 was 10.3%, 17.4% and 31.1% higher than that of comparing cultivars Chaitanya, BPT 5204 and Tellahamsa, respectively. The mean grain yields of rice hybrids during 1996 were 23.7% and 26% higher than BPT 5204 and Tellahamsa, respectively.

Chapter III

Materials & Methods

CHAPTER III

MATERIALS AND METHODS

Material and methods adopted for this study are presented in this chapter. This chapter deals with a brief description on experimental site, climate, soil, land preparation, planting materials, layout of the experimental design, land preparation, fertilizer application, irrigation and drainage, intercultural operation, data recording and their analysis. Experimental procedure or technique, method of data collection on relevant parameters like number of effective tillers plant^{-1}, days to maturity, panicle length, number of filled grains panicle^{-1}, number of unfilled grains panicle^{-1}, total number of filled grains panicle^{-1}, 1000-grain weight, biological yield plant^{-1}, grain yield ha^{-1}, harvest index etc are also clearly described in this chapter.

3.1 Description of the experimental site

3.1.1 Location

The field experiment was conducted at the central research farm of Sher-e- Bangla Agricultural University, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28 during the period from July 2014 to December 2014.The experimental site was located at 8.45m elevation above sea level with latitude of $23^{0}74^{/}$N and longitude of $90^{0}33^{/}$E (Anon.1989). For better understanding about the experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.1.2 Soil

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

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 III.

3.2 Planting materials

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

Varieties are:

1. Gold
2. BRRIdhan 56
3. BRRIdhan 57
4. BRRIdhan 62
5. Shuborna 3
6. BRRIhybri dhan 4
7. Moyna

Source of the genotypes

Varieties	Developed by	Imported by
Gold	China	Lal Teer Seed Company Ltd.
BRRIdhan 56	BRRI	
BRRIdhan 57	BRRI	
BRRIdhan 62	BRRI	
Suborna 3	China	Supreme Seed Company Ltd.
BRRI hybriddhan 4	BRRI	
Moyna	China	Lal Teer Seed Company Ltd.

3.3 Details of the Experiment

3.3.1 Experimental treatments

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

3.3.2 Layout of the experimental design

The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications, where the experimental area was divided into three blocks representing the replications to reduce soil heterogenetic effects. The total no. of unit plots was 21. The size of unit plot is 3m x 3m. The distances between plot to plot and block to block were 0.5m and 1m respectively.

3.3.3 Seed Sprouting

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

3.3.4 Raising of seedling

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

3.3.5 Land preparation

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

3.3.6 Fertilizer Management

Cow-dung at the rate of 10 t ha^{-1} was applied at the time of first ploughing. The experimental land was fertilized with 125, 55, 80, and 60kg of Urea, TSP, MP and Gypsum per hectare respectively. The whole amount of fertilizer for unit plot were calculated, measured and applied separately. One third Urea and all other fertilizer were applied and incorporated into the soil at the time of final land preparation and the rest amount of Urea was top dressed in two equal splits, one at 25 DAT (Days after transplanting) and other at 50DAT.

3.3.7 Uprooting of seedling

The seedbed was 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.

3.3.8 Transplantation

25 days old seedlings were transplanted in 3m x 3m plot with spacing of 25 cm x 15 cm between rows and plants, respectively with single seedling per hill.

3.4 Intercultural operation

3.4.1 Irrigation and Drainage

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

3.4.2 Gap filling

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

3.4.3 Weeding

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

3.4.4 Application of irrigation water

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

3.4.5 Plant protection measures

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

3.5 Growth parameters

3.5.1 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 sample plant were washed carefully. Then the plants were taken to the laboratory for data collection. Same procedure was followed at 70 DAT and 90 DAT (reproductive stage) too.

3.5.2 Data collection

Data were recorded on the following physical characters

3.5.2.1 Plant height

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

3.5.2.2 Tiller hill^{-1}

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

3.5.2.3 Leaves hill^{-1}

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

3.5.2.4 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. Subsampling was done when the sample volume was excess and difficult to handle. Finally leaf area was calculated hill^{-1}.

3.5.2.5 Leaf area index

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

$$LAI = \frac{\text{Total leaf area}}{\text{Ground area}} \times 100$$

3.5.2.6 Root dry matter hill^{-1}

Root dry matter hill^{-1} was recorded at 50, 70, 90 DAT and at harvest respectively from 10 randomly collected root hill^{-1} of each plot from inner rows leaving the border 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 per hill.

3.5.2.7 Stem dry matter hill^{-1}

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

3.5.2.8 Leaf dry matter hill^{-1}

10 hills of each plot were collected randomly and their leaves were separated from the stem. 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 per hill. Thus leaf dry matter hill^{-1} was obtained at 50, 70, 90 DAT and at harvest respectively.

3.5.2.9 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 leaf dry matter hill^{-1}.

3.5.2.10 Crop growth rate

It means increase of plant material per unit of time per unit of land area.

$$CGR=\frac{1}{A}\times\frac{W2-W1}{T1-T2}\text{g m}^{-2}\text{d}^{-1}$$

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)

3.5.2.11 Flag leaf chlorophyll content

Flag leaves were sampled from main tillers at 3, 9, 15 and 21 days after flowering and a segment of 20 mg from middle portion of leaf was used for chlorophyll analysis. Chlorophyll content was measured on fresh weight basis extracting with 80 % acetone and used doubled beam spectrophotometer (Model: U-2001, Hitachi, Japan) according to Witham *et al.* (1986). Amount of chlorophyll was calculated using following formulae.

$$\text{Chlorophyll a (mg g}^{-1}) = [12.7\ (OD_{663})-2.69\ (OD_{645})]\ X\ \frac{V}{1000\ W}$$

$$\text{Chlorophyll b (mg g}^{-1}) = [12.9\ (OD_{663})-4.68\ (OD_{645})]\ X\ \frac{V}{1000\ W}$$

Where,

OD = Optical density of the chlorophyll extract at the specific wave length.

V = Final volume of the 80% acetone chlorophyll extract (ml)

W = Fresh weight in gram of the tissues extracted.

The total chlorophyll content was estimated by adding chlorophyll a and chlorophyll b.

3.5.2.12 Panicle length

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

3.6 Yield parameters

3.6.1 Harvest and processing

Maturity of crop was determined when 90% of the grains become golden yellow in color. Sample plant was separately harvested and bundled properly tagged and then brought to the threshing floor for recording grain and straw yield. Grain yield was determined by harvesting one square meter which was prefixed at the corner of each plot. The grains were cleaned and sun dried to moisture content of 14%. Straw was also sun dried properly. Finally grain and straw yield per plot were recorded and converted to t ha^{-1}.

3.6.2 Data collection

Data were collected on the following yield parameters:

3.6.2.1 Days to maturity

It was recorded by counting the number of days required to harvest in each plot.

3.6.2.2 Panicle hill^{-1}

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

3.6.2.3 Non-effective tiller hill^{-1}

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

3.6.2.4 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 were counted from 10 selected hills and average value was recorded.

3.6.2.5 Filled grains panicle^{-1}

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

3.6.2.6 Unfilled grains panicle^{-1}

The total number 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 number of unfilled grains panicle^{-1}was recorded.

3.6.2.7 Total grains panicle^{-1}

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

3.6.2.8 Weight of 1000 grains

One thousand clean oven dried (72 ± 2^0C 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.

3.6.2.9 Grain yield

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

3.6.2.10 Straw yield

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

Straw yield (dry weight basis) = Fresh weight of straw at harvest X Conversion factor (CF)

Where, $CF = \frac{\text{Dry weight of straw sample}}{\text{Fresh weight of straw sample}}$

3.6.2.11 Biological yield

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

Biological yield (BY) = Grain yield+ straw yield

3.6.2.12 Harvest index

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

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

3.7 Statistical Analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques to obtain the level of significance by using Statistical computer software Statistix-10. The means were separated by Least Significant Difference (LSD) test at 5% level of significant.

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

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

4.1 Growth parameters

4.1.1 Plant height

Significant effect on plant height was found in hybrid and inbred rice varieties in *Aman* season (Fig. 1). The increasing pattern of plant height was almost similar in all varieties. The tallest plant was recorded in Shuborna 3 (81.13 cm) followed by BRRI hybriddhan 4 (80.38 cm) at vegetative phase (50 days after transplanting). On the other hand, the shortest plant was recorded in BRRIdhan 62 (70.76 cm) followed by BRRIdhan 56 (77.99 cm). Again at reproductive stages (70 and 90 DAT) the highest plant height was found in BRRI hybriddhan 4 (106.87cm and 111.43 cm respectively) and the lowest plant height was observed in BRRIdhan 62 (88.5 cm and 95.27 cm respectively).

At harvest BRRI hybriddhan 4 was found as the highest plant (112.97cm) followed by BRRIdhan 57 (112.5cm) and the shortest plant was BRRIdhan 62 (99.57 cm) followed by Gold (101.87cm) with same statistical rank. Rest of the varieties showed intermediate status. BRRI (1995), DRR (1996), Om *et al*. (1998) and Kabir *et al*. (2004) also found a variation in plant height due to varietal differences. From the study it has been found that the highest and the lowest plant height was in BRRI hybriddhan 4 and BRRIdhan 62 respectively.

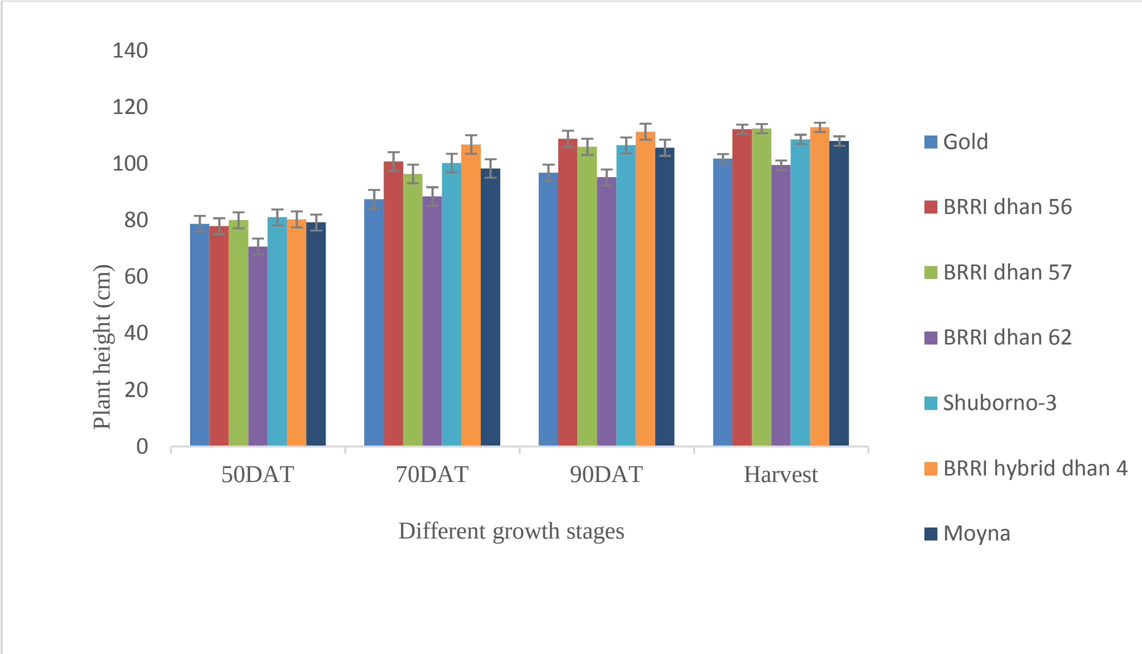

Figure 1. Plant height at different days after transplanting (DAT) in the test hybrid and inbred rice varieties. Vertical, capped lines represent LSD values.

4.1.2 Tillers hill^{-1}

A significant variation in the total number of tillers hill^{-1} was found among the hybrid and inbred rice varieties at all growth stages (Fig 2). From the experiment result it has been observed that the number of total tillers hill^{-1} increased with the advancement of vegetative growth stages. But the number of total tillers hill^{-1} decreased at reproductive stage. The maximum number of tillers hill^{-1} was found in BRRI hybriddhan 4 (12.85) at vegetative stages (50 DAT) and the lowest number of tillers hill^{-1} was observed in BRRIdhan 62 (8.5). At reproductive stages (70 and 90 DAT) maximum number of tillers hill^{-1} was produced by BRRI hybrid dhan 4 (19.59 and 19.66 respectively). On the other hand, the lowest number of tiller hill^{-1} was recorded in BRRIdhan 62 (12 and 10.5 respectively).

Again at the time of final harvest the maximum number of tiller hill^{-1} was observed in BRRI hybriddhan 4(16.62) and the lowest was in BRRIdhan 62 (9.15) with same statistical rank. Hoque (2004) observed that with the decrease of tiller hill^{-1} yield also decreases. The present study also shows the same result. Mondal *et al*. (2005) showed significant difference in number of tiller hill^{-1} in 17 rice varieties. Kabir *et al*. (2004) observed significant variation among the cultivars. In this experiment it has been found that hybrid produce higher number of tiller than the inbred. Same result was shown by Song *et al*. (2009). He showed that hybrid produced a significantly higher number of tillers than their parental species.

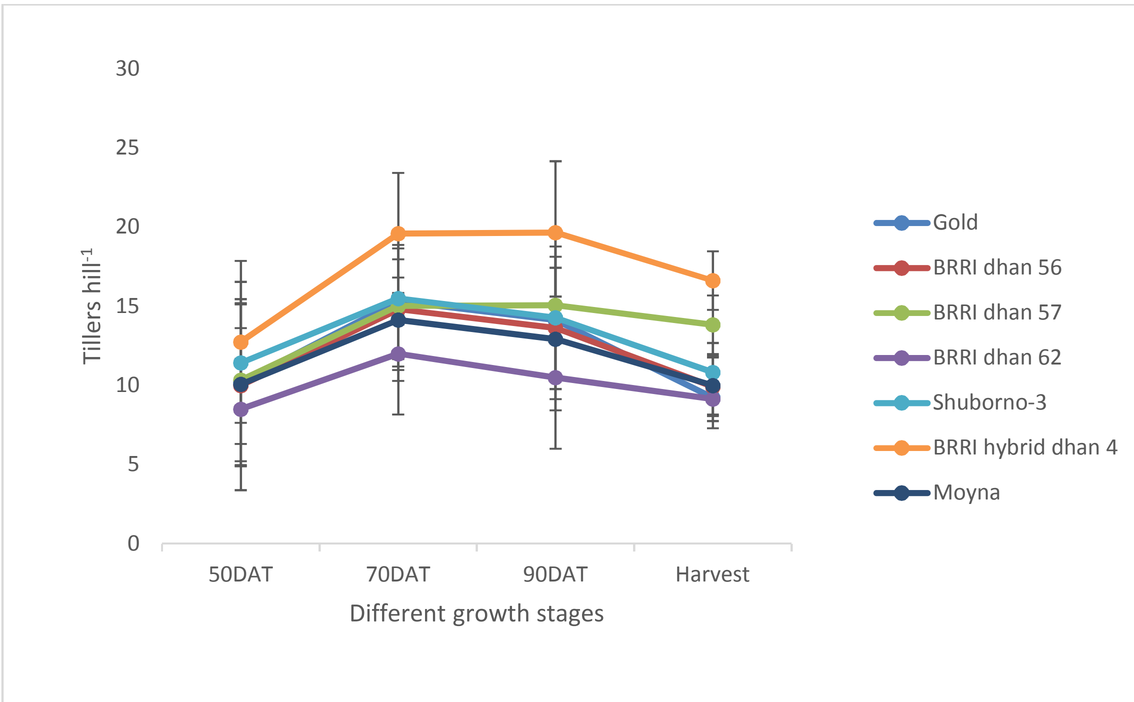

Figure 2. Tillers hill^{-1} at different days after transplanting (DAT) in the hybrid and inbred rice varieties. Vertical, capped lines represent LSD values.

4.1.3 Leaves hill^{-1}

There is significance difference on total number of leaves hill^{-1} among the rice varieties and it has been observed from vegetative (50 DAT) to reproductive (90 DAT) stages (Fig.3). The total number of leaves continued to increase up to 70 DAT and then declined. From this study the highest number of leaves was observed in BRRI hybriddhan 4 (70.15) at vegetative phase (50 DAT) followed by Shuborno 3 (60.97). At 70 DAT, the highest number of leaves was observed in

BRRI hybriddhan 4 (79.77) followed by Shuborna 3 (72.7) and they were statistically same at 5% level of probability. On the other hand, at 50 DAT and 70 DAT, BRRIdhan 62 produced the lowest number of leaves (50.38 and 61.57 respectively) followed by BRRIdhan 57 (56.22 and 68.17 respectively). Again at reproductive stage (90 DAT) BRRI hybriddhan 4 produced the highest number of leaves (75.8) and BRRIdhan 62 produced the lowest (56.87). Rest of the varieties showed intermediate values. This result indicated that BRRI hybriddhan 4 produced the highest number of leaves and BRRIdhan 62 produced the lowest number of leaves. The study also indicate that number of leaves increase up to certain growth stage till the end of the vegetative stage and then declined. Same result was supported by Hasan (2001). He found that maximum number of leaves were produced at the tillering stage and then decline in later stages.

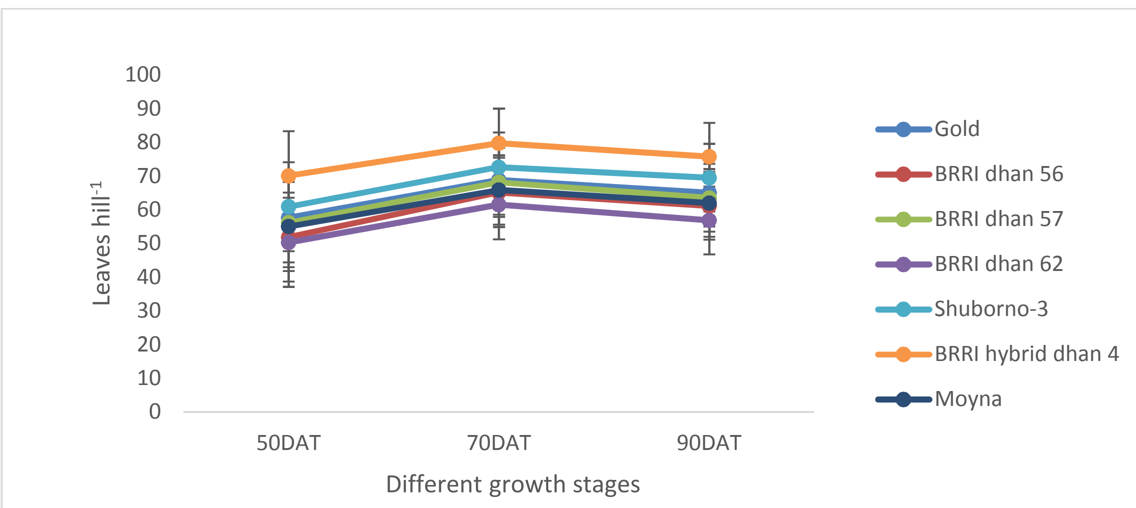

Figure 3. Leaves hill^{-1} at different days after transplanting (DAT) in the test hybrid and inbred rice varieties. Vertical, capped lines represent LSD values.

4.1.4 Leaf area hill^{-1}

Leaf area of tested rice varieties was significantly varied during the vegetative and reproductive growth phase (Fig 4). From the study it has been revealed that LA increases with age till the end of the vegetative stage and thereafter decline. The highest leaf area hill^{-1} at vegetative phase (50 and 70 DAT) was produced by BRRI hybriddhan 4 (1393.3 cm^2 and 1921.3 cm^2 respectively) and followed by Gold (1204.7 cm^2 and 1828.3 cm^2). They are statistically different at 5% level of probability. On the other hand, BRRIdhan 62 showed the lowest leaf area hill^{-1} (886 cm^2 and 1476.7 cm^2 respectively) and it was followed by BRRIdhan 57 (1049.3 cm^2 and 1629.3 cm^2 respectively). At reproductive stage (90 DAT), the highest and the lowest leaf area hill^{-1} were observed in BRRI hybriddhan 4 (1830 cm^2) and BRRIdhan 62 (1416.7 cm^2) respectively. Other rice varieties showed the intermediate status. The result from the study is consistent with the result of Sharma and Haloi (2001). They studied on scented rice and explained that the variation in Leaf area (LA) could be attributed to the changes in number of leaves. This result is also consistent with the result of Chandra and Das (2007) in rice. From above discussion it can easily be said that hybrid rice varieties produced the higher leaf area than the inbred and the variation in leaf area might occur with the variation of number of leaves.

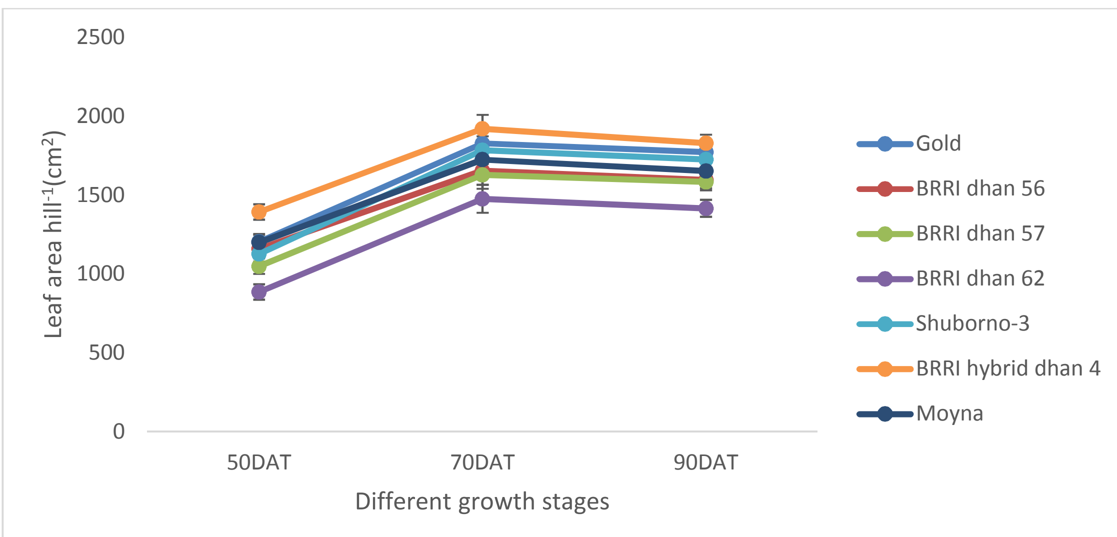

Figure 4. Leaf area hill^{-1} at different days after transplanting (DAT) in the tested hybrid and inbred rice varieties. Vertical, capped lines represent LSD values.

4.1.5 Leaf area index

Leaf area index may be defined as the ratio of leaf area to the ground area occupied by the crop. There is significant difference of leaf area index (LAI) among the studied rice varieties from vegetative (50 DAT) to reproductive (90 DAT) stages (Fig. 5). The LAI continued to increase throughout the vegetative stage and with the start of reproductive stage it started to decline. At vegetative phase (50 DAT) BRRI hybriddhan 4 showed the maximum LAI (3.46) and it is followed by Moyna (3.38) and Gold (3.36) respectively. Again at 70 DAT the maximum LAI was found in BRRI hybriddhan 4 (4.82) followed by Moyna (4.77). In contrast, at 50 and 70 DAT, BRRIdhan 62 showed the lowest LAI (2.43 and 3.81 respectively) over their growth period. Rest of the varieties showed intermediate values. At reproductive phase (90DAT) the highest LAI was found in BRRI hybriddhan 4 (4.64) followed by Moyna (4.61). On the other hand, BRRIdhan 62 showed the lowest LAI (3.64) at 90 DAT. These results are consistent with the result of Mondal *et al.* (2007) who stated that the variation in LAI could be attributed due to the changes in number of leaves and the rate of leaf expansion and abscission. According to Ready *et al*. (1995), the high yielding varieties possessed higher LAI which led to the higher biomass production and yield. This result indicated that hybrid rice varieties showed higher LAI than the inbred and the increase in LAI with time could be attributed to increase in number of tillers consequently higher number of leaves hill^{-1}(Fig.2 and 3).

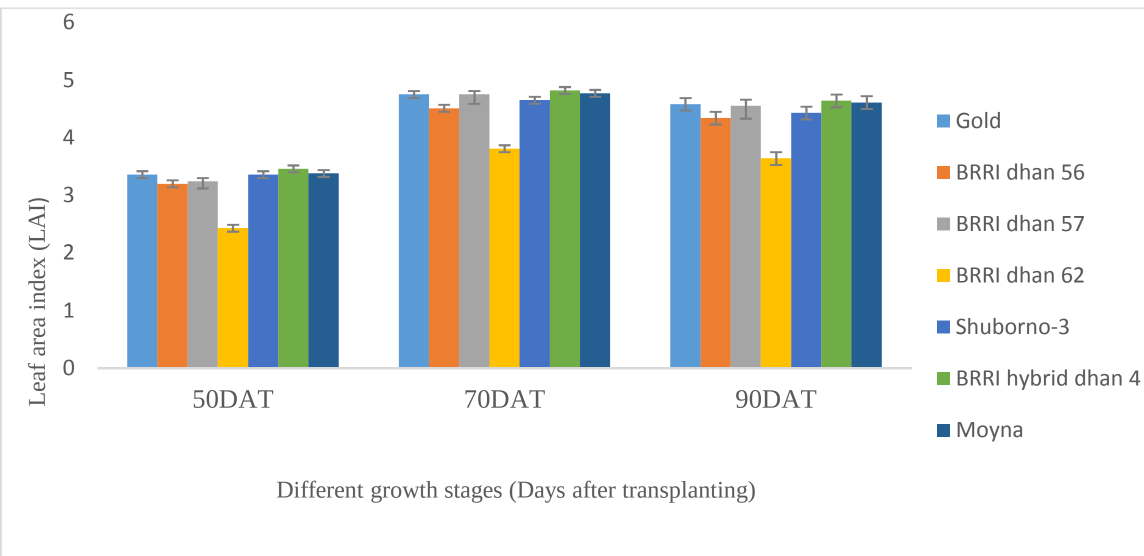

Figure 5. Leaf area index (LAI) at different days after transplanting (DAT) in the test hybrid and inbred rice varieties. Vertical, capped lines represent LSD values.

4.1.6 Root dry matter hill^{-1}

There has been found a significant variation observed in root dry matter production among the rice varieties at different growth stages (Table 1). Maximum root dry matter was observed in BRRI hybriddhan 4 (6.2 g) followed by Moyna (6.13) at vegetative phase (50 DAT) and the lowest was found in BRRIdhan 62 (4.23 g). At reproductive stage (70 and 90 DAT) BRRI hybriddhan 4 showed the highest root dry matter hill^{-1} (8.33 g and 14.33 g respectively). On the other hand, inbred rice variety BRRIdhan 62 showed the lowest value (6.30 g and 10.76 g respectively). This result revealed that root dry matter was gradually increased with time.

4.1.7 Stem dry matter hill^{-1}

Another important factor for plant growth and development is stem dry matter. From the test rice varieties, it has been found a significant difference in stem dry matter at different growth stages (Table 1). At 50 DAT (vegetative stage) the highest stem dry matter was found in Shuborna 3 (15.23 g) followed by BRRI hybriddhan 4 (14.90 g) and they are statistically same at 5% level of probability. On the other hand, the lowest was found in BRRIdhan 56 (10.65 g) followed by BRRIdhan 62 (11.17 g) and they also statistically same. Again at reproductive stage (70 and 90 DAT) BRRI hybriddhan 4 showed the highest stem dry matter hill^{-1} (35.10 g and 54.80 g respectively) and BRRIdhan 62 showed the lowest values (25.33g and 42.47 g respectively). 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 tested rice varieties at different growth stages (Table 1). At 50 DAT (vegetative stage) the highest leaf dry matter was observed in BRRI hybriddhan 4 (6.73 g) followed by Moyna (6.53 g). On the other hand, the lowest value was found in BRRIdhan 57 (4.90 g) followed by BRRIdhan 56 (4.93 g) and BRRIdhan 62 (5.06 g) but they all are statistically same. This result revealed that leaf dry matter was gradually increased with time.

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
Gold	5.00 b	6.20 c	11.56 c	11.70 b	25.83 d	46.93 c	5.10 c	11.70 cd	12.73 c
BRRIdhan 56	4.96 b	6.30 c	11.3 cd	10.67 b	25.77 d	45.26 cd	4.93 c	11.76 cd	12.57 c
BRRIdhan 57	5.20 b	6.43 bc	11.4 c	14.20 a	32.7 b	53.50 ab	4.90 c	11.63 cd	12.37 c
BRRIdhan 62	4.23 c	6.30 c	10.76 d	11.17 b	25.33 d	42.47 d	5.06 c	10.93 d	12.50 c
Shuborno 3	6.07a	6.77 b	13.4 b	15.23 a	33.97 ab	52.87 ab	5.93 b	12.40 bc	13.86 b
BRRI hybriddhan 4	6.20 a	8.30 a	14.33 a	14.90 a	35.10 a	54.80 a	6.73 a	14.20 a	15.34 a
Moyna	6.13 a	8.20 a	13.23 b	14.37 a	30.03 c	50.30 b	6.53 a	12.90 b	14.00 b
LSD (.05)	0.53	0.36	0.58	1.57	1.97	3.22	0.48	0.97	0.98
CV (%)	5.48	2.81	2.65	6.72	3.72	3.67	4.87	4.45	4.14

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

4.1.9 Total dry matter hill^{-1}

There is a significant variation of total dry matter production among hybrid and inbred rice varieties (Fig. 6). At vegetative phase (50 DAT) BRRI hybriddhan 4 produced the highest TDM (27.63 g) followed by Moyna (27.23) and Shuborna 3 (27.23) and they are statistically same. On the other hand, the lowest value was found in BRRIdhan 62 (20.50 g). At reproductive stage (70 and 90 DAT) the highest TDM was also produced by BRRI hybriddhan 4 (57.6 g and 84.47 g respectively) and the lowest TDM produced by BRRIdhan 62 (42.57g and 65.73 g respectively) preceded by BRRIdhan 56 (43.73g and 69.13g respectively). The rest of the varieties showed intermediate status (Fig 6). This result revealed that dry matter production increased with age of plant and the dry matter accumulation in plant was low at vegetative stage and thereafter increased rapidly. It was also consistent with the result of Hoque (2004) who stated that TDM increased with the increase of plant age up to physiological maturity and high yielding rice varieties always maintain higher TDM hill^{-1}. It is clear that the hybrid rice varieties produce higher TDM than the inbred varieties. Increased dry matter in hybrid rice was possibly due to greater leaf area hill^{-1} (Fig 4).

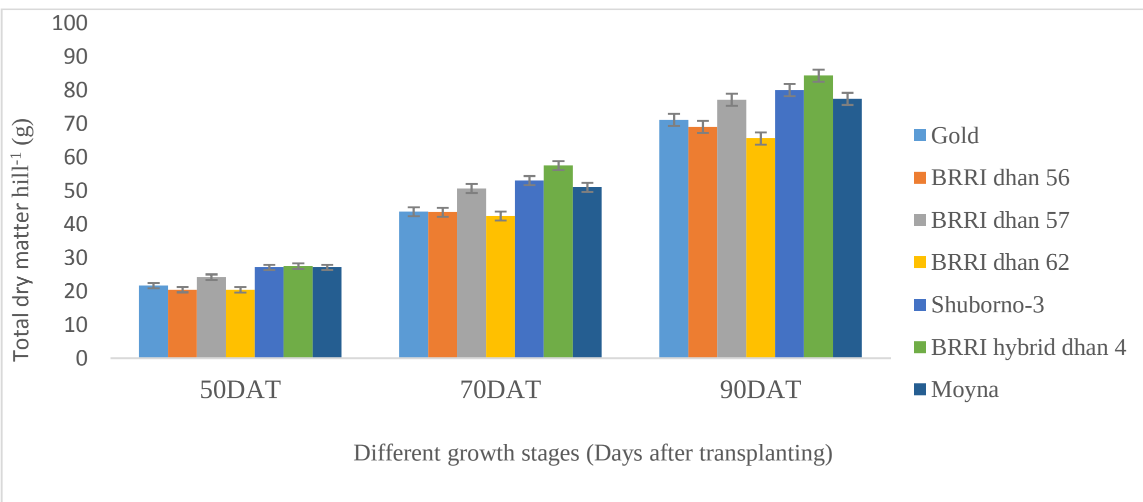

Figure 6. Total dry matter hill^{-1} (TDM) at different days after transplanting (DAT) in the test hybrid and inbred rice varieties. Vertical, capped lines represent LSD values.

4.1.10. Crop growth rate

The influence of the rice varieties on CGR was observed during the vegetative (50-70 DAT) and reproductive (70-90 DAT) growth phase (Fig.7). BRRI hybriddhan 4 showed the highest CGR value (40.83 g m^{-2} d^{-1}) at vegetative phase (50-70 DAT) followed by Gold (36.67 g m^{-2} d^{-1}) and there is no significant difference between them. On the other hands the lowest CGR was observed in BRRIdhan 62 (30.89 g m^{-2} d^{-1}) preceded by BRRIdhan 56 (33.73 g m^{-2} d^{-1}). Again at reproductive stage (70-90 DAT) the highest CGR value was found in BRRI hybrid dhan 4 (39.9 g m^{-2} d^{-1}) followed by BRRIdhan 57 (35.29 g m^{-2} d^{-1}) and the lowest CGR was observed in BRRIdhan 62 (29.29 g m^{-2} d^{-1}) preceded by Gold (29.42 g m^{-2} d^{-1}). It is seen that CGR decline at reproductive stage. The reason for declination was might be attributed to the decrease in LAI at reproductive stage (Table 2). That means the CGR increased along with increases in LAI and this was supported by the finding of Yang *et al*. (2010). At vegetative phase (50-70 DAT), the CGR was found to be maximum and it indicated that plants expanded assimilate for growth of leaf area. This result was supported by the result of Mia *et al*. (1996) and Mandavi *et al*. (2004) who observed that varietal differences of CGR were significant at different growth stages. From the study it can be said that the hybrid varieties give the highest CGR values than the inbred.

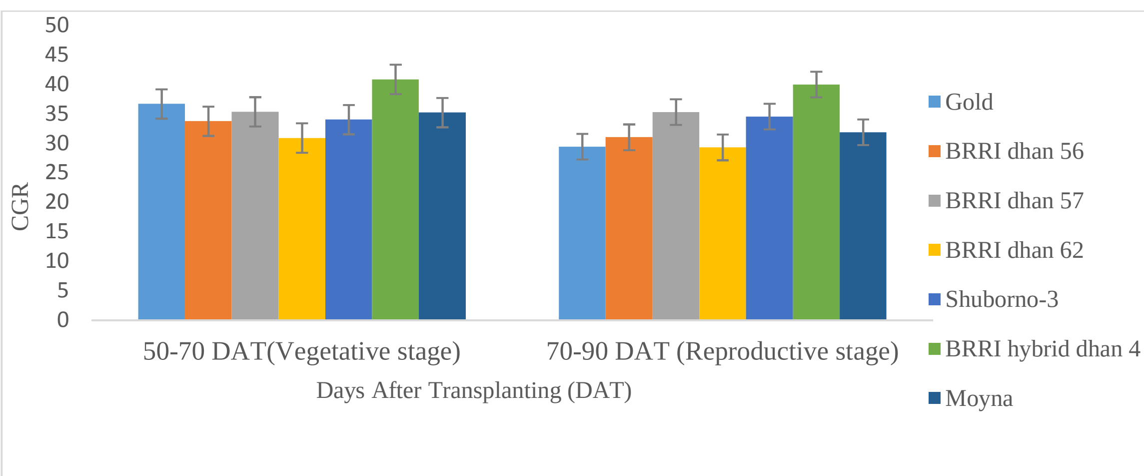

Figure 7. Crop growth rate (CGR) at different days after transplanting (DAT) in the test hybrid and inbred rice varieties. Vertical, capped lines represent LSD values.

4.1.11. Flag leaf chlorophyll content

The hybrid and inbred varieties showed significant variation in chlorophyll content of flag leaf (Table 2). At 2 days after flowering BRRI hybriddhan 4 (2.40 mg g^{-1} fresh weight) synthesized higher amount of chlorophyll followed by Moyna (2.35 mg g^{-1} fresh weight), Shuborna 3 (2.32 mg g^{-1} fresh weight) and Gold (2.22 mg g^{-1} fresh weight) respectively. On the other hand, the inbred varieties BRRIdhan 62 (2.03 mg g^{-1} fresh weight) synthesized the lowest chlorophyll among the seven varieties and it was preceded by BRRIdhan 57 (2.14 mg g^{-1} fresh weight) and BRRIdhan 56 (2.13 mg g^{-1} fresh weight) respectively. That means BRRIdhan 62 showed 15.4 % lower chlorophyll content than the BRRI hybriddhan 4. From the table it can be seen that chlorophyll content decreases with time. The total flag leaf chlorophyll content was decreased by 33.7%, 30.9%, 31.7%, 29%, 33.1%, 19.5% and 28.9% in Gold, BRRI dhan56, BRRIdhan 57, BRRIdhan 62, Shuborno 3, BRRI hybriddhan 4 and Moyna respectively at 21 DAF compared to the 3 DAF.

Table 2. Flag leaf chlorophyll content of hybrid and inbred rice varieties at different days after flowering (DAF) in *Aman* Season.

Treatments	Total chlorophyll content at different days after flowering (mg g^{-1} fresh weight)			
	3 DAF	9 DAF	15 DAF	21 DAF
Gold	2.22 c	2.14 c	2.09 c	1.60 ab
BRRIdhan 56	2.13 d	2.05 d	1.76 e	1.47 b
BRRIdhan 57	2.14 d	2.06 d	1.77 e	1.46 b
BRRIdhan 62	2.03 e	1.88 e	1.81 d	1.44 b
Shuborno 3	2.32 b	2.21 b	2.11 bc	1.55 ab
BRRIhybriddhan 4	2.40 a	2.33 a	2.20 a	1.93 a
Moyna	2.35 b	2.23 b	2.14 b	1.67 ab
LSD (.05)	0.045	0.024	0.04	0.39
CV (%)	1.14	0.65	1.04	14.21

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

From the result it is clear that generally hybrid synthesized higher chlorophyll than the inbred and it was supported by Haque *et al*. (2012). He found significant difference among the inbred and hybrid rice varieties in synthesis of chlorophyll.

4.1.12 Days to maturity

There is significant variation among the tested rice varieties in case of days to maturity (Fig 8). The maximum days to maturity was observed in Gold (135) followed by Moyna (132.33) and Shuborna 3 (131.33) respectively. They are statistically similar at 5% level of probability. On the other hands the minimum days to maturity was observed in BRRIdhan 62 (106.33) preceded by BRRIdhan 57 (108.33) and they are also statistically similar but differ from BRRI hybriddhan 4. Similar result was also reported by Hosain *et al.* (2014) and Chowdhury *et al*. (1995) from their earlier experiment.

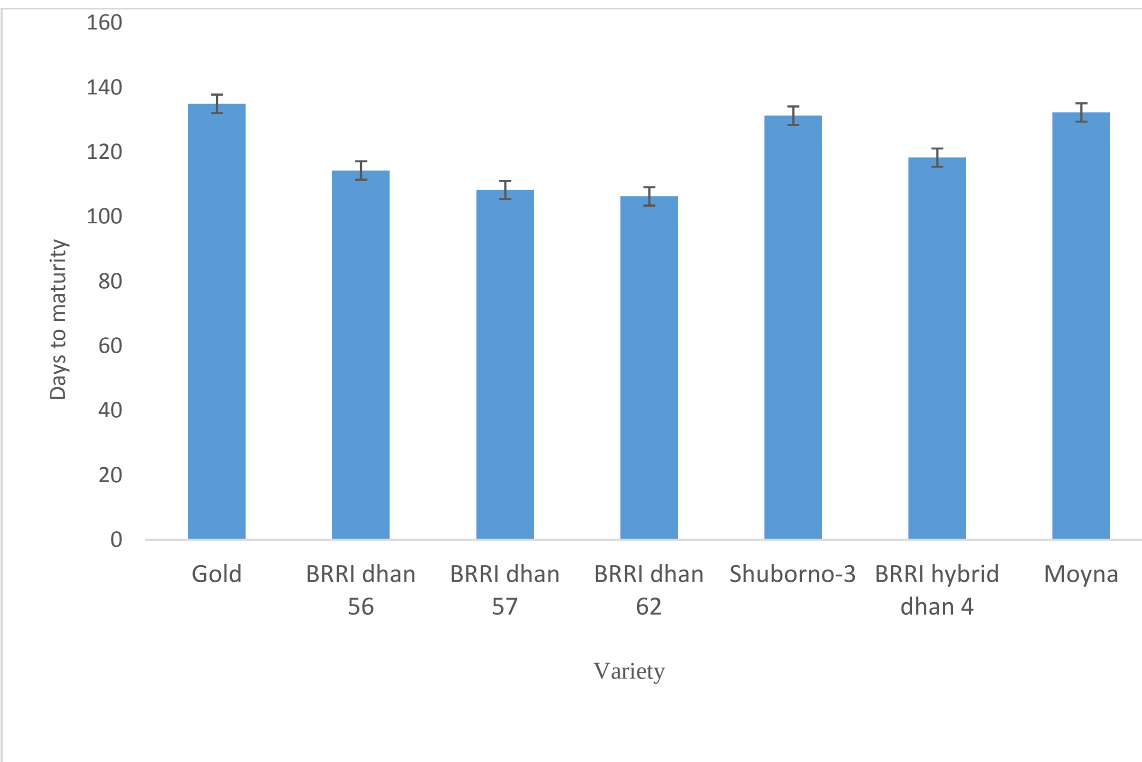

Figure 8. Days to maturity of some selected hybrid and inbred rice varieties**.** Vertical capped lines represent LSD values.

4.1.12 Panicle length

A significant variation of panicle length was found among the tested inbred and hybrid rice varieties (Fig 9). The longest panicle was observed in BRRI hybriddhan 4 (27.89 cm) followed by Moyna (25.35 cm) and Shuborna 3 (25.15 cm) but they are statistically similar and differ from rest of the varieties. On the other hand, BRRIdhan 62 showed the shortest panicle (21.12 cm) preceded by BRRIdhan 56 (21.59 cm). From the study, it was found that panicle length was longer in hybrid rice than the inbred and it possibly due to genetic makeup. This result was supported by the result of Chakma (2006) who stated that panicle length was significantly varied in varieties. Panicle length is related to the higher yield in rice (Salam *et al*., 1990).

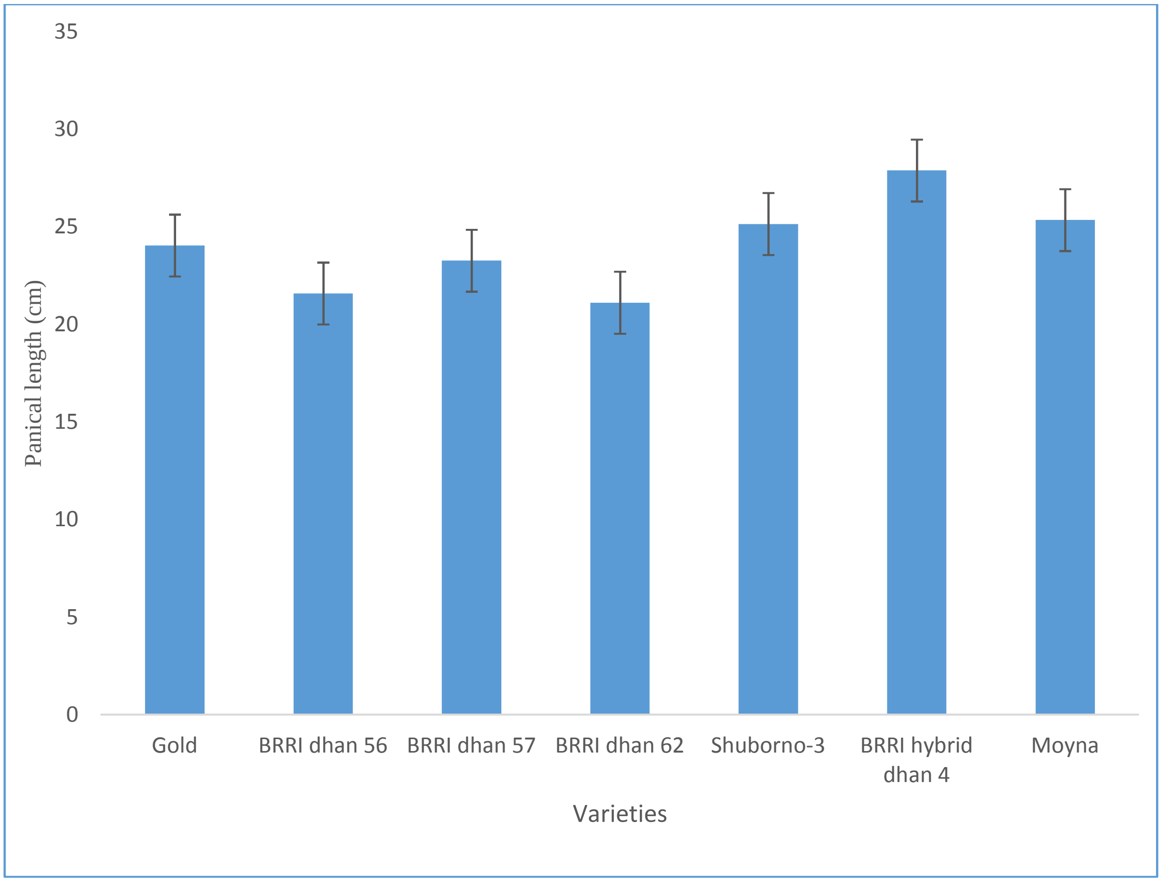

Figure 9. Panicle length of some selected hybrid and inbred rice varieties**.** Vertical, capped lines represent LSD values.

4.2 Yield parameters

4.2.1 Panicles hill^{-1}

Number of effective tillers hill^{-1} was significantly varied among the studied rice varieties (Table 3). Among these varieties BRRI hybriddhan 4 (14.27) showed the highest number of effective tillers hill^{-1} and it is followed by Gold (11.44) and BRRIdhan 57 (11.41) respectively. The first one is statistically dissimilar from the rest two varieties at 5% level of significance. On the other hand, BRRIdhan 56 (8.72) produced the lowest number of effective tillers hill^{-1} preceded by Moyna (8.90). Result further revealed that generally hybrid rice varieties produced greater number of effective tillers hill^{-1} than the inbred rice varieties. That means yield and effective tiller number are positively correlated. This result is also supported by many researchers (Yang *et al*., 2010; Shrirame and Muley, 2003; Munshi, 2005).

4.2.2 Non- effective tillers hill^{-1}

There is significant difference in non-effective tillers hill^{-1} among the studied rice varieties (Table 3). BRRIdhan 62 (2.65) produced the highest number of non-effective tillers hill^{-1} and it is followed by Gold (2.50) and Moyna (2.33) respectively. In contrast BRRI hybriddhan 4 (1.38) produced the lowest number of non-effective tillers hill^{-1} preceded by BRRIdhan 56 (1.90) and Shuborna 3 (1.90). This result proved that hybrid rice produced less non-effective tillers than inbred varieties.

4.2.3 Filled grains panicle^{-1}

Filled grain panicle^{-1} had shown a significant variation among the tested rice varieties (Table 3). From the study, it was noticed that BRRI hybrid dhan 4 (168.43) produced the highest number of filled grain panicle^{-1} followed by Shuborno 3 (157.23) and Gold (145.63) respectively. The first two are statistically similar but the first and the third are statistically dissimilar at 5 % level of significant. On the other hand, the lowest filled grain panicle^{-1} was observed in BRRIdhan 62 (132.58) preceded by BRR dhan 57 (136.65). The result showed that there was no significant difference between BRRI dhan 62 and BRRI dhan 57. It appears that hybrid varieties produced more filled grain panicle^{-1} than the inbred varieties and it is related with the higher yield. This result was supported by Dutta *et al*. (2002) who stated that yield was affected by the filled grain panicle^{-1}.

4.2.4 Unfilled grains panicle^{-1}

From the analyzed data it was found that number of unfilled grains panicle^{-1} varied significantly among the tested rice varieties (Table 3). The highest number of unfilled grains panicle^{-1} was found in BRRIdhan 56 (23.30) followed by BRRI dhan 62 (22.02) and Shuborna 3 (20.73) respectively. On the other hand, BRRI hybriddhan 4 (8.93) showed the lowest number of unfilled grain panicle^{-1} preceded by Moyna (9.13) and both are statistically similar at 5% level of significant. It is clear from the experiment that hybrid rice significantly differed in respect of unfilled grain panicle^{-1}. This result was also supported by Dutta *et al*. (2002) who found a wide range of variability in number of unfilled grain panicle^{-1}. Chowdhary *et al.* (1993) also stated that difference in number of unfilled grains panicle^{-1} was due to varietal character.

4.2.5 Thousand grain weight

There was a significant difference in thousand grain weight among the inbred and hybrid rice varieties (Table 3). Moyna showed the highest 1000-grain weight (32.26 g) followed by BRRI hybriddhan 4 (26.07 g) and both were significantly different from each other. On the other hand, the lowest 1000-grain weight was found in BRRI dhan 62 (19.90 g) preceded by Shuborna 3 (21.79 g) and BRRIdhan 56 (22.00 g) respectively and they are statistically similar shown in table 2. This result was supported by Mondal *et al*. (2005) who studied with 17 modern varieties of *Aman* rice and stated that 1000- grain weight differed significantly among the cultivars studied. Fujia *et al*. (1984) showed that length and thickness of rice grains were positively correlated with 1000-grain weight. The reason behind the variation in 1000- grain weight was possibly due to genetic makeup of particular rice and sink strength.

Table 3. **Yield contributing characters for selected hybrid and inbred rice varieties in *Aman* season.**

Treatments	Panicle $hill^{-1}$	Non-effective tiller $hill^{-1}$	Filled grain $panicle^{-1}$	Unfilled grain $panicle^{-1}$	1000-grain weight (g)
Gold	11.44 b	2.50 a	145.63 bc	11.87 b	25.50 b
BRRIdhan 56	8.72 c	1.9 ab	145.20 bc	13.69 b	22.00 c
BRRIdhan 57	11.41 b	2.17 ab	136.65 c	23.3 a	22.57 c
BRRIdhan 62	9.4 bc	2.65 a	132.58 c	22.07 a	19.90 d
Shuborna 3	10.93 bc	1.90 ab	157.23 ab	20.73 a	21.79 c
BRRI hybriddhan 4	14.27 a	1.38 b	168.43 a	8.93 b	26.07 b
Moyna	8.90 bc	2.33 ab	137.17 c	9.13 b	32.26 a
LSD (0.05)	2.59	1.01	18.21	5.74	1.46
CV (%)	13.57	26.92	7.01	20.60	3.39

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

4.2.6 Grain yield

There has been found a significant difference in respect of grain yield ha^{-1} (Table 4). The highest grain yield was found in BRRI hybriddhan 4 (6.13 t ha^{-1}) followed by Shuborna 3 (5.60 t ha^{-1}) and they were statistically similar at 5% level of probability. On the other hand, BRRIdhan 62 (3.76 t ha^{-1}) showed the lowest grain yield and it was preceded by BRRIdhan 57 (4.25 t ha^{-1}). Both are significantly differed from each other. Here it can be noticed that BRRIdhan 62 showed about 38.6% lower yield than BRRI hybriddhan 4. The higher yield in hybrid must be attributed to the production of higher LAI, CGR, RGR, TDM, higher number of effective tiller $hill^{-1}$ and higher number of filled grain $panicle^{-1}$. This result indicated that the hybrid varieties had remarkable superiority to growth, yield attributes and grain yield over other rice varieties. This result was supported by Mondal *et al*. (2005) and Pruneddu and Spanu (2001) who stated that the hybrid rice produced the higher number of effective tiller $hill^{-1}$ and higher number of filled grains $panicle^{-1}$ and also showed the higher yield ha^{-1}.

4.2.7 Straw yield

The straw yield of different variety was observed to differ significantly (Table 4). From the study it was found that BRRI hybriddhan 4 produced the highest straw yield (7.20 t ha^{-1}) followed by BRRIdhan 57 (6.56 t ha^{-1}) and both are statistically similar to each other. In contrast, BRRIdhan 62 produced lowest straw yield (5.03 t ha^{-1}) preceded by Moyna (5.57 t ha^{-1}) and BRRIdhan 56 (5.60 t ha^{-1}) respectively. Straw yield was possibly related to the plant height and tiller $hill^{-1}$ and it was supported by the result of Panda and Leeuwrik (1971) who stated that straw yield could be assigned to plant height.

4.2.8 Biological yield

Grain yield and straw yield together were regarded as biological yield. Biological yield was found statistically different among the hybrid and inbred varieties (Table4). BRRI hybriddhan 4 was found to give the highest biological yield (13.33 tha^{-1}) followed by BRRIdhan 57 (11.98 t ha^{-1}) both are statistically similar. On the other hand, the lowest biological yield was given by BRRIdhan 62 (9.13 t ha^{-1}) preceded by Gold (10.30 t ha^{-1}) and BRRIdhan 56 (10.32 t ha^{-1}) respectively. That means hybrid varieties produced more biological yield than inbred. Munshi (2005) and Chowdhury *et al*. (1995) observed that grain yield was positively correlated with biological yield in rice.

Table 4. Yield of hybrid and inbred rice varieties in *Aman* season.

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
Gold	5.15 bc	5.66 bc	10.30 bc
BRRIdhan 56	4.63 cd	5.60 bc	10.32 bc
BRRIdhan 57	4.25 de	6.56 ab	11.98 ab
BRRIdhan 62	3.76 e	5.03 c	9.13 c
Shuborna 3	5.60 ab	6.00 bc	11.93 ab
BRRIhybriddhan 4	6.13 a	7.20 a	13.33 a
Moyna	4.86 b-d	5.57 c	10.67 bc
LSD (0.05)	0.83	1.15	1.75
CV (%)	9.53	10.88	8.89

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

4.2.9 Harvest index

There was significant variation in harvest index among hybrid and inbred rice varieties (Fig 10). The highest harvest index was recorded in BRRI hybriddhan 4 (46.92 %) followed by Shuborno 3 (46.06). That means dry matter partitioning to economic yield was superior in BRRI hybrid dhan 4 to the other rice varieties. On the other hand, BRRIdhan 62 showed the lowest harvest index (41.07 %) which means dry matter partitioning to economic yield was inferior in BRRIdhan 62 to the rest of varieties. From this experiment it appears that hybrid varieties generally maintain higher harvest index. This result is consistent with the findings of Chandra and Das (2010), Cui *et al.* (2000) and Ready *et al*. (1994) who observed that hybrid varieties maintained higher harvest index compared to the inbred.

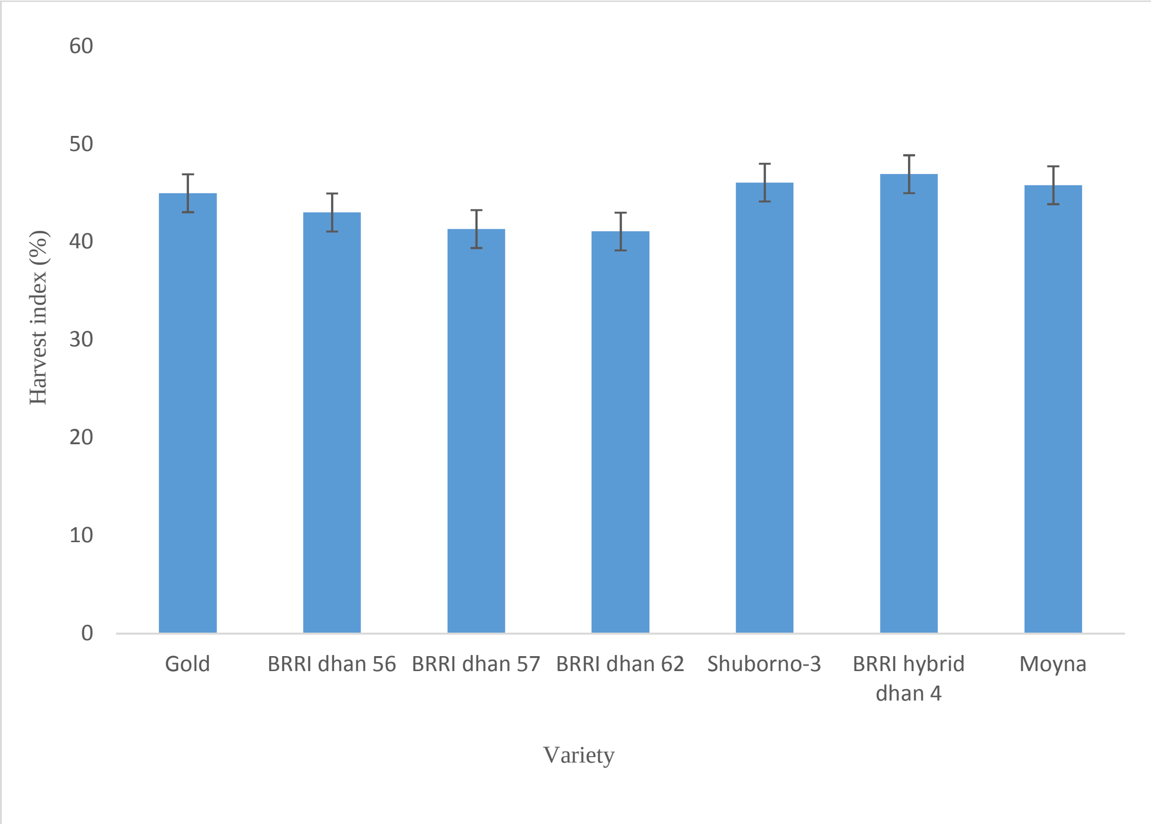

Figure 10. Harvest index (HI) of some selected hybrid and inbred rice varieties**.** Vertical, capped lines represent LSD values.

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Experimental Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from July to December, with a view to finding out the growth and yield performance of selected hybrid and inbred rice varieties in *Aman* season. There were seven treatments which comprised seven rice varieties *viz*. Gold-5, BRRIdhan 56, BRRIdhan 57, BRRIdhan 62, Suborna-3, BRRI hybriddhan 4 and Moyna. The experiment layout was Randomized Completely Block Design (RCBD) with three replications. Seedling of 25 days old was transplanted to the main field maintaining space with 25cm X 15cm. The plot size was 3 X 3 m^2. Intercultural operations including rouging, weeding, topdressing, irrigation, pesticide application etc were done according to necessary. Collected data were analyzed with Statistix 10 software following the standard procedure and method.

There have been observed a significant variation among the selected inbred and hybrid rice varieties in plant height, tillers $hill^{-1}$, leaves $hill^{-1}$, TDM, leaf area, LAI, CGR, panicle length, and yield attributes like days to maturity, panicle $hill^{-1}$, filled and unfilled grains $panicle^{-1}$, 1000- grain weight, biological yield, grain yield and harvest index (HI). The hybrid rice variety, BRRI hybriddhan 4 was found showing superiority over the rest varieties in respect of different growth and physiological parameters like plant height (106.87 cm, 111.43 cm and 112.97 cm at 70 DAT, 90 DAT and harvest respectively), tillers $hill^{-1}$ (12.75, 19.59, 19.66 and 16.62 at different DAT), leaves $hill^{-1}$ (70.15, 79.77 and 75.8 at different DAT), TDM hil^{-1} (27.63 g, 57.6 g and 84.47 g at different DAT), leaf area $hill^{-1}$ (1393.3 cm^2, 1921.3 cm^2 and 1830 cm^2 at different DAT), LAI (3.46, 4.82 and 4.64 at different DAT), CGR (40.83 g m^{-2} d^{-1} and 39.9 g m^{-2} d^{-1} at vegetative and reproductive stages respectively), flag leaf chlorophyll content (2.40, 2.33, 2.20, 1.93 mg g^{-1} at 3, 9, 15, 21 DAF respectively) and panicle length(27.89 cm). From the study it has been seen that number of total tillers $hill^{-1}$ gradually increase with the progress of growth. Leaf number also increased till the end of the vegetative phase and then declined. Leaf area $hill^{-1}$ and LAI increased up to a certain period (till the start of reproductive phase) and thereafter started to decline. Accumulation of dry matter was low at 50 DAT and thereafter increased rapidly. Relative growth rate was found to increase rapidly in the early stage but it declined in the latter growth stage. Again BRRI hybriddhan 4 was also found to show superiority in case of yield parameters like panicle $hill^{-1}$ (14.27), filled grains $panicle^{-1}$ (168.43), 1000- grain weight (26.07 g), biological yield (13.33 t ha^{-1}), grain yield (6.13 t ha^{-1}) and harvest index (46.92 %). On the other hand among seven rice varieties BRRIdhan 62 was found inferior in respect of both growth and yield parameters like plant height(70.76, 88.5, 95.27 and 99.57 cm at different growth stages), tillers $hill^{-1}$ (8.5, 12, 10.5 and 9.15 at different growth stages), TDM $hill^{-1}$ (20.5, 42.57 and 65.73 mg g^{-1} d^{-1}), LAI (2.43,3.81 and 3.64 at different growth stages), CGR (30.89 g m^{-2} d^{-1} and 29.29 g m^{-2} d^{-1} at vegetative and reproductive stages respectively), panicle $hill^{-1}$ (9.4), filled grains $panicle^{-1}$ (132.58), 1000- grain weight (19.9), biological yield (9.13), grain yield (3.76 t ha^{-1}) and harvest index (41.07 %). However, hybrid of the test varieties produced higher grain yield compared to the inbred. Yield components such as effective tillers $hill^{-1}$, Filled grain $panicle^{-1}$ and 1000- grain weight mainly contributed to the higher grain yield of the hybrid varieties over the inbred. In respect of biological yield, hybrid rice varieties such as BRRI hybriddhan 4 (13.33 t ha^{-1}), Moyna (10.67 t ha^{-1}) and Shuborna3 (11.93 t ha^{-1}) performed better than that of inbred varieties like BRRIdhan 62 (9.13 t ha^{-1}) and BRRIdhan 56 (10.32 t ha^{-1}). This result indicates that BRRI hybriddhan 4 and Shuborna 3 produce higher biological yield because of higher total dry matter production (TDM), harvest index (HI), Crop growth rate (CGR) and finally they have more yield advantages over the inbred varieties.

From the above summary of the study, it can be concluded that among the seven hybrid and inbred varieties, BRRI hybriddhan 4 demonstrated the best performance followed by shuborna3. All studied hybrids contained higher amount of chlorophyll in their flag leaf and accumulated more dry matter than the inbred. Among the seven varieties the hybrids converted more dry matter into grain compared to inbred varieties. The main determinants for the higher grain yield of the hybrids over the inbred are panicle hill^{-1} and 1000- grain weight.

Considering the results of the experiment, it could be suggested that-

1. BRRI hybriddhan 4 may be chosen for cultivation in *Aman* season.
2. For wider acceptability, the same experiment should be repeated at different agro-ecological zones of the country.

Chapter VI

References

CHAPTER VI

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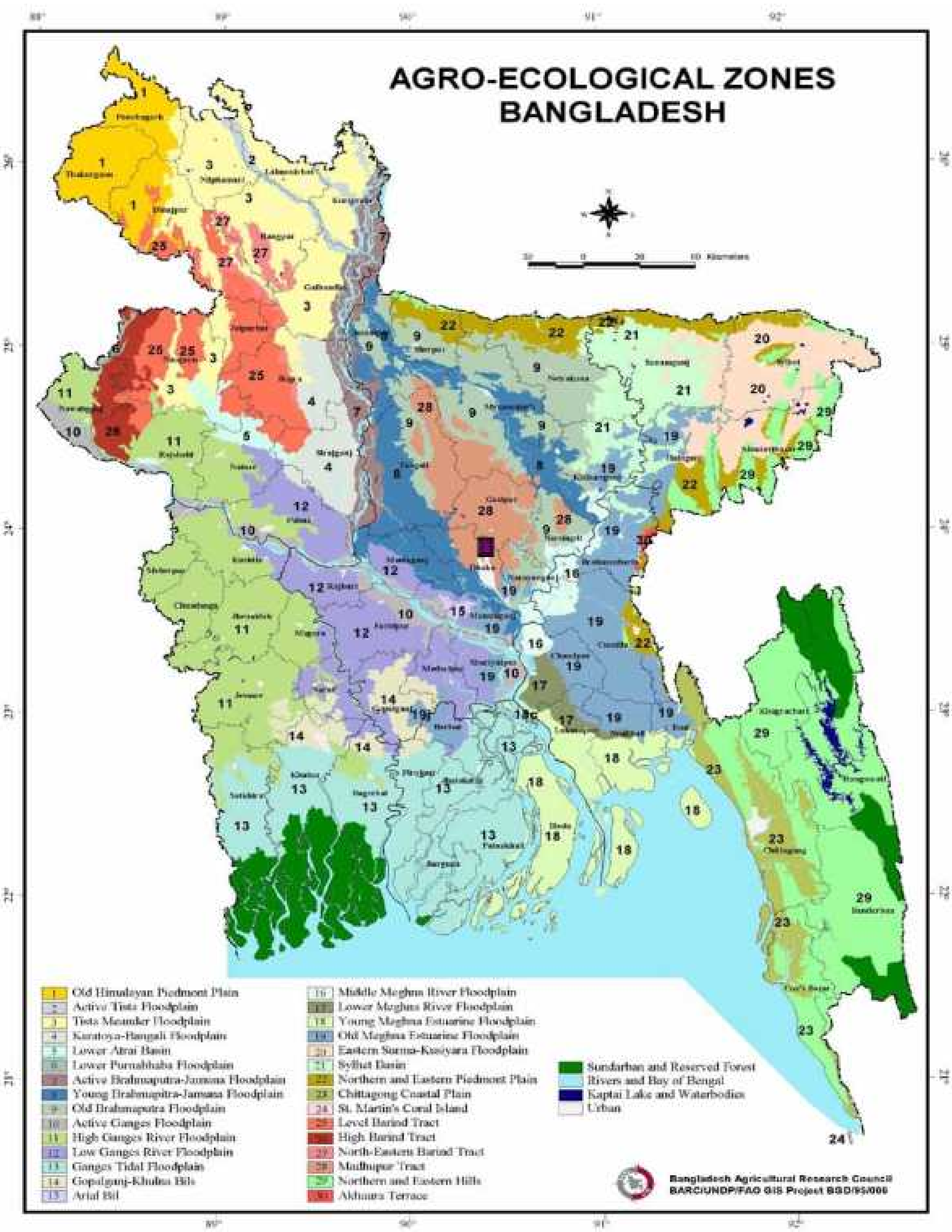
Appendices

APPENDICES

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



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

A. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the initial soil

Characteristics	Value
%Sand	27
%Silt	43
%clay	30
Textural class	Silt-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI, 2014

Appendix III: Monthly average of Temperature, Relative humidity, total Rainfall and sunshine hour of the experiment site during the period from july 2014 to December 2014

Month (2013)	Air temperature (ºC)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
June	35.4	22.5	80	577
July	36	24.6	83	563
August	36	23.6	81	319
September	34.8	24.4	81	279
October	26.5	19.4	81	22

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

Appendix IV: Analysis of variance (mean square) of plant height of selected hybrid and inbred cultivars at different days after transplanting.

Sources of variation	Degrees of freedom	Mean Square of plant height at different days after transplanting			
		50 DAT	70 DAT	90 DAT	At harvest
Replication	2	0.236	12.603	3.553	0.897
Treatment	6	36.869 *	144.07 **	109.468 **	86.184 **
Error	12	10.135	13.650	10.195	3.452

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

Appendix V: Plant height of the test varieties at different days after transplanting.

Treatments	Plant height (cm)			
	50 DAT	70 DAT	90 DAT	At the time of harvest
Gold	78.83 a	87.50 c	96.90 c	101.87 c
BRRIdhan 56	77.99 a	100.87 ab	108.93 ab	112.27 a
BRRIdhan 57	80.09 a	96.47 b	106.07 ab	112.50 a
BRRIdhan 62	70.76 b	88.50 c	95.27 c	99.57 c
Shuborna 3	81.13 a	100.33 ab	106.57ab	108.70 b
BRRI hybriddhan 4	80.38 a	106.87 a	111.43 a	112.97 a
Moyna	79.29 a	98.4 b	105.73 b	108.13 b
Lsd (.05)	5.66	6.57	5.68	3.31
CV (%)	4.06	3.81	3.06	1.72

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

Appendix VI: Analysis of variance (mean square) of tiller hill^{-1} of selected hybrid and inbred cultivars at different days after transplanting.

Sources of variation	Degrees of freedom	Mean Square of tiller hill^{-1} at different days after transplanting			
		50 DAT	70 DAT	90 DAT	At harvest
Replication	2	0.432	1.745	9.788	1.913
Treatment	6	7.391	10.563	31.123 **	23.137 **
Error	12	8.296	4.661	6.426	1.081

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

Appendix VII: Tiller hill^{-1} of the test varieties at different days after transplanting.

Treatments	Tiller hill^{-1}			
	50 DAT	70 DAT	90 DAT	At the time of harvest
Gold	10.2 ab	15.33 b	14.13 b	9.23 c
BRRIdhan 56	10.00 ab	14.81 b	13.63 b	9.92 c
BRRIdhan 57	10.33ab	15.03 b	15.07 b	13.83 b
BRRIdhan 62	8.5a b	12 b	10.5 bc	9.15 c
Shuborna 3	11.42 ab	15.50 b	14.27 b	10.83 c
BRRI hybriddhan 4	12.75 a	19.59 a	19.66 a	16.62 a
Moyna	10.08 ab	14.13 b	12.93 bc	10 c
Lsd (.05)	5.12	3.84	4.50	1.85
CV (%)	27.27	13.92	18.03	8.85

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

Appendix VIII: Analysis of variance (mean square) of leaves hill^{-1} of selected hybrid and inbred cultivars at different days after transplanting.

Sources of variation	Degrees of freedom	Mean Square of leaves hill^{-1}at different days after transplanting			
		50 DAT	70 DAT	90 DAT	At harvest
Replication	2	578.14	547.05	510.53	3271.9
Treatment	6	130.87	104.74 *	114.15 *	72480.0 **
Error	12	55.13	33.38	31.909	743.2

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

Appendix IX: Leaves hill^{-1} of the test varieties at different days after transplanting.

Treatments	Leaves hill^{-1}		
	50DAT	70DAT	90DAT
Gold	57.67ab	68.87bc	65.07bc
BRRIdhan 56	51.92b	65.20bc	61.23bc
BRRIdhan 57	56.22b	68.17bc	63.6bc
BRRIdhan 62	50.38b	61.57c	56.87c
Shuborna 3	60.97ab	72.7ab	69.57ab
BRRI hybriddhan 4	70.15a	79.77a	75.8a
Moyna	55.07b	65.9bc	62.07bc
Lsd (.05)	13.21	10.28	10.04
CV (%)	12.92	8.39	8.71

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

Appendix X: Analysis of variance (mean square) of leaf area hill^{-1} of selected hybrid and inbred cultivars at different days after transplanting.

Sources of variation	Degrees of freedom	Mean Square of leaf area hill^{-1}at different days after transplanting		
		50 DAT	70 DAT	90 DAT
Replication	2	3271.9	8356	7224.3
Treatment	6	72480 **	64023.5 **	57533.2 **
Error	12	743.2	2458.5	913.2

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

Appendix XI: Leaf area hill^{-1} of the test varieties at different days after transplanting.

Treatments	Leaf area hill^{-1}		
	50 DAT	70 DAT	90 DAT
Gold	1204.7 b	1828.3 b	1773.3 b
BRRIdhan 56	1160.0 bc	1655.7de	1597.0 d
BRRIdhan 57	1049.3 d	1629.3 e	1583.3 d
BRRIdhan 62	886.0 e	1476.7 f	1416.7 e
Shuborna 3	1128 c	1785b c	1726.7 b
BRRI hybriddhan 4	1393.3 a	1921.3 a	1830.0 a
Moyna	1199.7 b	1725.3 cd	1653.3 c
Lsd (.05)	48.5	88.20	53.76
CV (%)	2.38	2.89	1.83

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

Appendix XII: Analysis of variance (mean square) of leaf area index of selected hybrid and inbred cultivars at different days after transplanting

Sources of variation	Degrees of freedom	Mean Square of leaf area indexat different days after transplanting		
		50 DAT	70 DAT	90 DAT
Replication	2	0.025	0.028	0.064
Treatment	6	0.375 **	0.378 **	0.373 **
Error	12	0.005	0.009	0.015

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

Appendix XIII: Leaf area index of the test varieties at different days after transplanting.

Treatments	Leaf area index		
	50 DAT	70 DAT	90 DAT
Gold	3.36a	4.75 ab	4.58a
BRRIdhan 56	3.20c	4.51 c	4.34b
BRRIdhan 57	3.24bc	4.75 ab	4.55ab
BRRIdhan 62	2.43d	3.81 d	3.64c
Shuborna 3	3.36ab	4.65 bc	4.43ab
BRRI hybriddhan 4	3.46a	4.82 a	4.64a
Moyna	3.38a	4.77 ab	4.61a
Lsd (.05)	0.121	0.167	0.22
CV (%)	2.12	2.06	2.77

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

Appendix XIV: Analysis of variance (mean square) of root dry matter hill^{-1} of selected hybrid and inbred cultivars at different days after transplanting.

Sources of variation	Degrees of freedom	Mean Square of root dry matter hill^{-1} at different days after transplanting		
		50 DAT	70 DAT	90 DAT
Replication	2	0.018	0.040	0.017
Treatment	6	1.69 **	2.545 **	5.456 **
Error	12	0.088	0.038	0.106

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

Appendix XV: Analysis of variance (mean square) of stem dry matter hill^{-1} of selected hybrid and inbred cultivars at different days after transplanting

Sources of variation	Degrees of freedom	Mean Square of stem dry matter hill^{-1} at different days after transplanting		
		50 DAT	70 DAT	90 DAT
Replication	2	1.403	11.25	10.44
Treatment	6	11.091 **	52.93 **	65.01 **
Error	12	0.783	1.23	3.29

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

Appendix XVI: Analysis of variance (mean square) of leaf dry matter hill^{-1} of selected hybrid and inbred cultivars at different days after transplanting

Sources of variation	Degrees of freedom	Mean Square of leaf dry matter hill^{-1} at different days after transplanting		
		50 DAT	70 DAT	90 DAT
Replication	2	0.01	1.523	0.992
Treatment	6	1.867 **	3.445 **	3.659 **
Error	12	0.074	0.296	0.305

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

Appendix XVII: Analysis of variance (mean square) of total dry matter hill^{-1} of selected hybrid and inbred cultivars at different days after transplanting.

Sources of variation	Degrees of freedom	Mean Square of total dry matter hill^{-1} at different days after transplanting		
		50 DAT	70 DAT	90 DAT
Replication	2	1.98	22.14	8.767
Treatment	6	31.50 **	97.26 **	131.01 **
Error	12	0.826	2.33	4.17

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

Appendix XVIII: Total dry matter hill^{-1} of the test varieties at different days after transplanting.

Treatments	Total dry matter hill^{-1}		
	50 DAT	70 DAT	90 DAT
Gold	21.77c	43.83c	71.23c
BRRIdhan 56	20.57c	43.73c	69.13cd
BRRIdhan 57	24.30b	50.76b	77.27b
BRRIdhan 62	20.50c	42.57c	65.73d
Shuborna 3	27.23a	53.13b	80.13b
BRRI hybriddhan 4	27.63a	57.6a	84.47a
Moyna	27.23a	51.13b	77.53b
Lsd (.05)	1.62	2.71	3.63
CV (%)	3.76	3.72	2.72

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

Appendix XIX: Analysis of variance (mean square) of crop growth rate of selected hybrid and inbred cultivars at different days after transplanting.

Sources of variation	Degrees of freedom	Mean Square of crop growth rate at different days after transplanting	
		50-70 DAT (vegetative stage)	70-90 DAT (reproductive stage)
Replication	2	5.50	19.35
Treatment	6	11.43	43.86 **
Error	12	7.83	6.02

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

Appendix XX: Analysis of variance (mean square) of flag leaf chlorophyll content of selected hybrid and inbred cultivars at different days after flowering.

Sources of variation	Degrees of freedom	Mean Square of flag leaf chlorophyll content at different days after flowering			
		3 DAF	9 DAF	15 DAF	21 DAF
Replication	2	0.00002	0.00002	0.00061	0.045
Treatment	6	0.054 **	0.065 **	0.113 **	0.095
Error	12	0.0007	0.0002	0.00043	0.05

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

Appendix XXI: Analysis of variance (mean square) of days to maturity and panicle length of selected hybrid and inbred cultivars.

Sources of variation	Degrees of freedom	Mean Square of days to maturity	Mean Square of Panicle length (cm)
Replication	2	3.00	0.207
Treatment	6	429.09 **	16.44 **
Error	12	10.16	3.17

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

Appendix XXII: Days to maturity of the test varieties at different days after transplanting.

Treatments	Days to maturity	Panicle length (cm)
Gold	135 a	24.05bc
BRRIdhan 56	114.33 b	21.59c
BRRIdhan 57	108.33 c	23.27bc
BRRIdhan 62	106.33 c	21.12c
Shuborna 3	131.33 a	25.15ab
BRRI hybriddhan 4	118.33 b	27.89a
Moyna	132.33 a	25.35ab
Lsd (.05)	5.67	3.17
CV (%)	2.64	7.40

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

Appendix XXIII: Analysis of variance (mean square) of yield components of selected hybrid and inbred cultivars

Sources of variation	Degrees of freedom	Mean Square of yield components				
		Non-effective tiller hill^{-1}	Panicle hill^{-1} (No.)	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	1000-grain weight (g)
Replication	2	0.045	5.04	57.13	21.72	0.98
Treatment	6	0.556	11.35 **	487.70 *	115.64 **	50.97 **
Error	12	0.325	2.11	104.80	10.482	0.677

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

Appendix XXIV: Analysis of variance (mean square) of yield and harvest index of selected hybrid and inbred cultivars.

Sources of variation	Degrees of freedom	Mean square of yields and harvest index			
		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest index (%)
Replication	2	0.157	2.94	0.535	20.70
Treatment	6	1.93 **	1.56 *	5.895 **	16.77*
Error	12	0.219	0.418	0.972	4.74

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