A COMPARATIVE STUDY ON MORPHO-PHYSIOLOGICAL CHARACTERISTICS AND YIELD OF SOME MODERN RICE VARIETIES IN AMAN SEASON

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CERTIFICATE

This is to certify that the thesis entitled "**A COMPARATIVE STUDY ON MORPHO-PHYSIOLOGICAL CHARACTERISTICS AND YIELD OF SOME MODERN RICE VARIETIES IN AMAN SEASON**" submitted to the ***Department of Agricultural Botany***, 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 **FARJANA AKTER** , Registration. No. 11-04529, 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:
Dhaka, Bangladesh

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Professor
Supervisor
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DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted in the Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to observe the morpho-physiological characteristics and yield of six *Aman*ricevarieties named BRRI dhan33, BRRI dhan56, BRRI dhan57, BRRI dhan62, Hira-2 and BRRI hybrid dhan4. The experiment was laid out in Randomized Complete Block Design with three replications. The hybrid rice variety, BRRI hybrid dhan4 showed superiority in respect of growth parameters like plant height, number of tillers hill^{-1}, number of leaves hill^{-1}, leaf area hill^{-1}, LAI,TDM hill^{-1} over the other varieties. Again, BRRI hybrid dhan4 also showed the highest yield contributing characters like effective tillers hill^{-1} (15.04), panicle length (15.24 cm), filled grain panicle^{-1} (141.17), 1000-grain weight (25.16 g) grain yield (6.21 t ha^{-1}) followed by Hira-2 (6.03 t ha^{-1}), straw yield (7.18 t ha^{-1}), biological yield (13.39 t ha^{-1}) and harvest index (46.39 %) over the other inbred varieties. The lowest grain yield produced by BRRI dhan33 (3.82 t ha^{-1}). In case of grain yield BRRI dhan56 (4.36 t ha^{-1}) and BRRI dhan62 (4.29 t ha^{-1}) showed statistically similar result. The yield was higher in BRRI hybrid dhan4 including another hybrid Hira-2 might be due to the production of higher number of effective tiller hill^{-1}, leaf number, TDM, LAI, panicle hill^{-1}, filled grain panicle^{-1} and 1000-grain weight.

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AEZ	Agro- Ecological Zone
Anon.	Anonymous
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BRAC	Bangladesh Rural Advancement Committee
BRRI	Bangladesh Rice Research Institute
CAT	Catalase
cm	Centi-meter
CV	Co-efficient of Variance
cv.	Cultivar (s)
DAT	Days After Transplanting
DAF	Days After Transplanting
^{0}C	Degree Centigrade
et al.	And others
FAO	Food and Agriculture Organization
G	Gram (s)
HI	Harvest Index
K_2O	Potassium Oxide
Kg	Kilogram (s)
LSD	Least Significant Difference
LAI	Leaf Area Index
M	Meter
m^2	Meter squares
mm	Millimeter
MoP	Muriate of Potash

N	Nitrogen
No.	Number
%	Percentage
P_2O_5	Phosphorus Penta Oxide
S	Sulphur
SAU	Sher-e- Bangla Agricultural University
TDM	Total Dry Mater
t ha^{-1}	Ton per hectare
TSP	Triple Super Phosphate
var.	Variety
Wt.	Weight
Zn	Zinc

CHAPTER I

INTRODUCTION

Rice, *Oryza sativa* (2n = 24) belongs to the family *Gramineae*and subfamily *Ryzoidae*. Rice is the most important human food crop, providing the staple food for nearly half of the global population, especially in Asia, Africa, and Latin America (FAO, 2004). Rice (*Oryza sativa*) is a semi-aquatic annual grass plant and is the most important cereal crop in the developing world. Ninety percent of all rice is grown and consumed in Asia (WRS, 1995). Bangladesh is an agro-based country with population of about 157.9 millions (Bangladesh Economic Review, 2015) living in 14.84 million hectares of land. According to the estimate of World Bank, the population will have possibly increased to 230 million by the year 2030 with almost half of the people living in cities and towns (BBS, 2010). Rice is the staple dietary item for the people and per capita rice consumption is about 166 kg/year (BBS, 2010). Rice alone provides 76% of the calorie intake and 66% of total protein requirement (Bhuiyan*et al.*, 2002). It employs about 43.6% of total labor forces (BBS, 2010, HIES, 2009). Rice covers about 81% of the total cropped area (BBS, 2010). Rice alone shares about 96% of the total cereal food supply. Furthermore, rice alone contributes about 9.5 % of the total agricultural GDP in the country. Among all crops, rice is the driving force of Bangladesh agriculture.

According to Bangladesh Rice Research Institute (BRRI), about 75% of the total cropped area and over 80% of the total irrigated area is planted to rice. Thus, rice plays a vital role in the livelihood of the people of Bangladesh.Total rice production in Bangladesh was about 10.59 million tons in the year 1971 when the country's population was only about 70.88 millions. However, the country is now producing about 25.0 million tons to feed her 135 million people. This indicates that the growth of rice production was much faster than the growth of population. This increased rice production has been possible largely due to the adoption of modern rice varieties on around 66% of the rice land which contributes to about 73% of the country's total rice production.

Aus, *Aman and Boro* are the three rice growing seasons in the Bangladesh which are cultivated during April to July, August to December and January to May respectively. *Boro* is the major rice growing season in Bangladesh which is totally depends on irrigation. *Aman*is second main rice growing season in Bangladesh generally cultivated as a rain fed crops.*Boro*rice is the major rice growing season which uses up a lot of water per hectare (ha) in the production
process. According to one estimate of Biswas and Mandal (1993) it is 11,500m3 ha^{-1}. Demand for both surface and groundwater for irrigation is on the rise in the dry season which is 58.6 percent of the total demand for water (Chowdhury, 2010). Fresh water, however, is becoming increasingly scarce. So government has given more importance on *Aman* season.The hybrid varieties mostly cultivated in Bangladesh are imported from China by private seed companies. Two hybrid varieties named BRRI hybrid dhan4 and BRRI hybrid dhan6 have been released for commercial cultivation for *Aman* season by BRRI along with some other inbred variety. Seed companies haveimported rice seed varieties from different countries. On the other hand farmers are confusing about the growth characteristics andyield potential of these rice varieties.

In *Aman*season, however, available information regarding the yield and yield contribution characters, both morpho-physiological characteristics of hybrid rice verities are meager in Bangladesh. That’s why, it is prime need to conduct more research work to find out and develop sustainable technologies regarding

*Aman*rice cultivation under the prevailing local conditions in the *Aman*season. Farmers are gradually replaced the local indigenous low yielding rice varieties by high yielding and modern varieties of rice. Modern varieties of rice produced 20 to 30% more yield unit land area. In Bangladesh as well as in the world rice research is predominantly being conducted to develop modern high yielding and hybrid varieties.

The population of Bangladesh is increasing day byday and that is why horizontal expansion of rice area is not possible due to highpopulation pressure on land. To ensure the food security for her increasingpopulation and reduce the extreme poverty and hunger which is one of the MDGsgoals given by the United Nation Organization, it is an urgent need of the time toincrease rice production through increasing yield. Proper practices are the mosteffective means for increasing yield of rice at farmer level (Alauddin, 2004).

So it is prime need to evaluate their performance in *Aman*season. Under these circumstances, the study was undertaken to compare the performance of morpho-physiological characteristics and yield of some modern rice varieties in *Aman*season.Keeping the foregoing problems in view, this study was undertaken with the following objectives-

- To compare the morpho-physiological characters of hybrid and inbred rice varieties in *Aman*season.
- To evaluate the yield contributing characters of hybrid rice varieties in *Aman*season.
- To observe the yield variation among the hybrid and inbred rice varieties in*Aman*season.

CHAPTER II

REVIEW OF LITERATURE

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

2.1 Morpho-Physiological parameters

2.1.1 Plant height

Awal*et al.* (2007) observed that tested varieties differed statistically with each other in respect of plant height. Itwas noticed that a conventional variety BRRI dhan32 produced the tallest plants (119cm) and theother treatments were statistically shorter than this. However, the hybrid Sonarbangla-3 had anotable height (113.7 cm)significantly better than BR11 (107.3 cm), BRRI dhan33 (103.7cm) aswell as Sonarbangla-2 (102.3 cm).

Haque and Biswas (2014) found significant variation in plant height among the varieties. They found plant height ranged from 80 cm to 132 cm among the varieties in where average plant height was 89.58 cm.

Siddique *et al.*(2002) statedthat positive and significant correlations were observed between yield per plotand plant height, length of panicle, days to maturity, 1000-grain weight, lengthof grain and L/B ratio.

Samsuzzaman (2007) observed that experimented variety significantly varied in plant height. He found among the 8 genotypes, BRRI dhan28 showed maximum plant height.

Chowhan*et al*. (2017)observed thehighest plant height in Binadhan-13 (131.0 cm) and BRRI dhan71 (128.9 cm).Binadhan-16 and ChakkaPanja produced statistically similar height. Binadhan-17 (109.9cm) and Binadhan-7 (112.2 cm) had the lowest plant height compared to the other varieties and cultivars. Difference in plant height of the varieties was due to varietal variation.

Sarkar (2014) conducted an experiment with six different varieties. He observed that plant height varied variety to variety. He found that Tia (78.46 cm) was the tallest plant and the shortest was Aloron (63.88 cm).

Kabir*et al*. (2004) revealed that Bigunbitchi showed the tallest plant height (66.52cm) at 35 days after transplanting and 50 days after transplanting (83.52cm), whereas chinigura showed the tallest plant height at harvest (148.20 cm).

2.1.2 Tillering Dynamics

Awal*et al.* (2007) revealed that BRRI dhan32 produced thehigh range of effective tillers hill^{-1} (7.67-9.00) which was statistically similar with Sonarbangla-2 and BR11 whereas BRRI dhan33 possessed the lowest number. Regarding non-effect tillers hill^{-1} BRRI dhan33 showed the highest number whereas the minimum number per hill was hybrid Sonarbangla-2.

Nuruzzaman*et al.* (2000) observed that number of tiller varied significantly among the varieties. The number of tillers plant^{-1} at the maximum tiller number stage ranged from 14.3 to 39.5. IR36 produced the highest tiller number followed by Suweon among all the varieties in where Down produced the lowest tiller number.

Song *et al*. (2009) shown that hybrid produced the significantly superior number of tillers than their parental species. Minahui-63 had the least number of tillers hill^{-1}.

Sarkar (2014) showed that number of total tiller hill^{-1} increased with theadvancement 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}.

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 ofconventional varieties.

Hossain and Alam (1991) observed that total number of tillers hill^{-1} and numbers of grainspanicle^{-1} differed significantly among the rice varieties.

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

Haque and Biswas (2014) observed that among all the experimented genotypes Hira showed the highest number of effective tillers (17.7) and Sonarbangla-1 showed the lowest number of effective tillers (13.3) with a grand mean of 15.87. In this study they revealed hybrids have moderate number of effective tillers per plant.

2.1.3 Number of leaves hill^{-1}

Sarkar (2014) observed a significant difference on total number of leaves hill^{-1} from vegetative to reproductive stage. He found highest number of leaves in Tia (78.67) and lowest in BRRI hybrid dhan2 (64.34).

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

Hosen (2015) observed the significance difference on total number of leaves hill^{-1} among the ricevarieties. The total number of leaves continued to increase up to 70 DAT and then declined. From this study he found the highest number of leaves in BRRI hybrid dhan4 (70.15) at vegetative phase (50 DAT) followed by Shuborno 3 (60.97). At 70 DAT, the highest number of leaves in BRRI hybrid dhan4 (79.77) followed by Shuborna 3 (72.7) and they werestatistically same at 5% level of probability. On the other hand, at 50 DAT and 70 DAT, BRRI dhan62 produced the lowest number of leaves (50.38 and 61.57respectively) followed by BRRI dhan57 (56.22 and 68.17 respectively). Again atreproductive stage (90 DAT) BRRI hybrid dhan4 produced the highest number of leaves (75.8) and BRRI dhan62 produced the lowest (56.87). Rest of the varieties showed intermediate values. This result indicated that BRRI hybrid dhan4produced the highest number of leaves and BRRI dhan62 produced the lowest number of leaves.

2.1.4 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) showed that the increment of leaf area hill^{-1} significantly different due to genotype at all growth stages.

Mandavi*et al.* (2004) observed that improved genotypes were with greater leafarea than traditional genotypes. He concluded that flag leaf area had positivecorrelation with grain yield.

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

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

Paranhos*et al.* (1997) observed that all the cultivars produced maximum leaf areaduring panicle initiation.

2.1.5 Leaf Area Index (LAI)

Reddy *et al.*(1995) concluded that LAI,SLW and assimilation rate markedly differed among the genotypes. The highest assimilation rate was observed with LAI of 4-5. Assimilation rates decrease with the increases of LAI due to mutual shading.

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

Chandra and Das (2007) stated that LAI has significant and positive effect to increase grain yield.

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

Mandevi*et al*. (2004) stated that all genotypes reached maximum LAI at pre-lowering except Dash and Tarom. At pre-flowering Neda (highyieldinggenotype) had greatest LAI comparing to other genotypes (LA1= 5.70).

Ghosh and Hossain (1998) observed a significant and positive correlation of LAI with grain yield. They also concluded that LAI at flowering stage showed 79% yield variation and 15 days delay in planting drastically affected in LAI of rice.

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 stagefollowed by BRRI hybrid dhan2 (5.94) while it was significantly lower inBRRI dhan45 (5.10).The maximum value of LAI gradually decreased in hybrid and inbred varieties with delayed transplanting due to reduction of vegetative phase. This result revealed that hybrid rice varieties maintainedsignificantly greater LAI from heading to maturity stage compared to the inbred.

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

Evans and Fischer (1999) concluded that greater yield depends on total crop biomass.

Sharma and Haloi (2001) revealed that check variety KunkuniJoha consistently maintained high rate of dry matter production through the growth stages and high dry matter accumulation at the panicle in initiation stage.

JianChang*et al*. (2006) found the highest total dry matter weight at maturity (>22 t ha^{-1}).

Mahdavi*et al*. (2004) observed that the photosynthetic potentials of improved genotypes were higher as reflected by their TDM production. TDM have significant correlation with grain yield.

Chandra and Das (2007) reported that dry matter production of culms and leaves were significantly associated with grain yield and leaf area index.

Sarker (2014) observed significant difference on leaf area index (LAI) in the studied rice varieties. He also stated 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 BRRIdhan33 showed the lowest TDM hill^{-1} (70.10 g) at 90 DAT. He alsofound that dry matter accumulation increased with the age of rice plant.

2.1.7 Flag leaf chlorophyll content

Haque*et al* (2014) told that hybrid varieties synthesized significantly higheramounts of chlorophyll and maintained higher chlorophyll a: b ratio in their flagleaf over inbred BRRI dhan45. Flag leaf chlorophyll content and chlorophyll a:bratio gradually decreased in the hybrid and inbred varieties with advancedmaturity. 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:bratio of the flag leaf was higher in both the hybrids. However, environmentalinfluence on total chlorophyll content of flag leaf was relatively small.

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

2.2 Yield parameters

2.2.1 Days to maturity

G.H *et al.* (2001) studied a comparativeperformance of 8 rice hybrids. All hybrids showed shorter growth duration (97-107 days) than the controls (110-116 days).

Parvez, *et al*. (2003) observed that shorter field duration was observed inSonarbangla-1 than the control.

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

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

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.

Rao and Patnaik (2006) observed that most of the long duration hybrids possessed long panicles with high grain number panicle^{-1}. The flowering duration was observed to be longest in CR 874- 23 (153 days) followed by CR 758-16 (151 days). The earliest varieties were found to be Swarna (110 days).

Patnaik and Mohanty (2006) observed that there was significant variation in the maturity duration of varieties.

Haque and Biswas (2014) concluded that the days to maturity among hybrids ranged from 118.0 days for Sonarbangla-1 to 148.7 days for BRRI hybrid dhan1 with a mean of 130.77 days. In case of checks BRRI dhan28 mature earlier (123.0) than both the checks, with a mean of 135.90 days. The ranged for days to maturity among all the genotypes varied from 118.0 days (Sonarbangla-1) to 148.7 days (BRRI hybridDhan-1). The grand mean for days to maturity of all the genotypes was 131.95 days.

2.2.2 Panicle length

Ghosh (2001) reported that hybrids variety in general gave higher values of panicle length compared to inbred varieties.

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

Patnaik and Mohanty (2006) observed the longestpanicle length in the genotype CR 874-59 (28.8 cm) followed by CR 2008-129 (26.9 cm).

Chakma (2006) stated that BINA dhan-5 produced the highest panicle length (22.86 cm) followed by BRRI dhan29 (22.78 cm) and BINA dhan-6 (22.28 cm) whereas Chandra and Das (2007) concluded that panicle m^{-2} was significantly and negatively correlated with panicle weight and sterility percentage, while the association of panicle length with panicle weight and 1000-grain weight was found positive and highly significant.

Kabir*et al*. (2004) observed that the cultivar chingura produced the longest panicle length (26.86 cm) followed by Begunbitchi and Kalijira varieties.

Myungkyu*et al*. (2005) conducted experiment with four rice varietiesand found different panicle characters.

Dixit *et al*. (2004) studied with three lines i.e. IR-58025 A, IR- 58025 B and BR-827-1-1 R (A,B and R lines respectively) and concluded that A line produced the highest of panicles hill^{-1} (8.9) which was significantly superior to the R and B lines, while the lowest (7.7) was obtained in the R line.

Hossain *et al*. (2002) conducted experiment with Sonar Bangla-1, BRRI dhan39 and Nijarshail and He reported that the cultivars were not significantlydifferent in 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. Incase of checks the panicle length ranged from 26.0 (BRRI dhan28) to 27.5 (BRRI dhan29), 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 retainedsignificant superiority to the conventional varieties (24.67-28.33 cm).

However,

Sonarbangla-2, BRRI dhan32 and BRRI dhan33 were statistically similar.

2.2.3 Effective tillers hill^{-1}

Malini*et al*.(2006) reported thathybrids varietiesproduced more effective tillers plants^{-1}.

Asraf*et al*. (1999) reported that transplanting of two and three seedlings of 35 days old nursery gave more promising results in terms of number of effective tillers per unit of area. Number of effective tillers plant^{-1} is associated with the higher productivity.

Awal*et al*. (2007) observed no significant variation among the treatments regarding number of panicle hill^{-1}. Sonarbanla-3 obtained the highest filled up grains(176 grains panicle^{-1}) but did not differ significantly with BRRI dhan32 (149grains panicle^{-1}). Sonarbangla-3 had clear statistical edge over Sonarbangla-2, BRRI dhan33 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 positive association with yieldand yield components.

Ma *et al.* (2001) experimented with hybrid variety ADTRH1. It produced profuse number of tiller (12-15 productive tillers per hill) under 20 x 10 cm spacing, with each panicle27.5-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^{-1} and productive tillers plant^{-1} had both positive and negative indirecteffects on yield.

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

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

Haque and Bishwash (2014) reported that Hira showed the highest number of effective tillers (17.7) and Sonarbangla-1 showed the lowest number of effective tillers (13.3) with a grand mean of 15.87. The group of genotypes that showed higher number of effective tillers per plant was constituted by Aloron (16.3) and Hira (17.7). The group of genotypes which showed least number of effective tillers per plant was constituted by Sonarbangla-1 (13.3) and Jagoron (15.3).

2.2.4 Non- effective tillers hill^{-1}

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

2.2.5 Filled grains panicle^{-1}

Hosain(2014) observed the highest number of filled spikelet panicle $^{-1}$(79.53) was recorded from BRRI dhan48. This was may be due to lower sensitivenessof BRRI dhan48 to high temperature and low sunshine hour at grain filling stagecompared to test hybrid varieties. The highest spikelet filling percent was recorded from BRRI dhan48 (74.43%) due to favorable environmental condition at grainfilling stage.

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

Parvez*et al*. (2003) reported that the yield advantage of the hybrid rice due to the relative proportion of higher filled grains per panicle which leads to heavier grain weight.

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

Liu and Yuan (2002) studied the relationships between yielding traits and yield. Filled grains per panicle was positively correlated withbiomass, harvest index and grain weight per plant.

Mrityunjay (2001) conducted an experiment to study the performance of 4 ricehybrids 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 with 48 rice hybrids. Filled grainspanicle^{-1}had the significant positive effect on yield plant^{-1}.

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

2.2.6 Unfilled grains panicle^{-1}

Chowdhury *et al.* (1995) reported that the cultivar BR23 showed superiorperformance 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 tallerplant, higher number of total spikelets panicle^{-1}, grains panicle^{-1} and unfilled spikelets panicle^{-1}.

2.2.7 1000-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 dhan29 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-2followed 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) reported 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 the highest 1000 kernel weight recordedfrom PR113.

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

Ma *et al.* (2001) reported that 1000-grain weight of hybrid variety ADTRH1is23.8 g. In different trials, ADTRH1 showed 26.9 and 24.5% higher yield overCORH1 and ASD18.

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

Kumar *et al*. (1994) stated that grain weight was highly correlated to grain size.

Marekar and Siddiqui (1996) reported that positive and significant correlationsbetween yield per plot and plant height, panicle length, 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.

2.2.8 Grain yield

Hosain (2014) observed that BRRI dhan48 gave significantly higher grainyield 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}) and BRRI dhan29 produced thelowest grain yield (4.36 t ha^{-1}) among the tested verities.

Awal*et al*. (2007) observed that Sonarbangla-3 produced the highest grain yield(6.20 t ha^{-1}) which significantly varied with the rest of the treatments. However, yield of BRRI dhan32 (5.70tha^{-1}) was statistically higher than Sonarbangla-2 (5.15 ha^{-1}) as well as other conventional varieties (4.17- 4.96 t ha^{-1}).Twenty-one advanced cultivars were evaluated in transplanted condition during2005 wet season in a replicated trial along with three checks (Swarna, Pooja andGayatri) for yield and yield contributing characters like plant height, days toflowering and number of ear bearing tillers. Variety Swarna (4.864 t ha^{-1}) and CR874-59 (4.675 t ha^{-1}) gave higher grain yield compared to others. (Patnaik andMohanty, 2006).

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

Shrirame and Mulley (2003) observed that grain yield exhibited a very strongpositive correlation with harvest index. Grain yield was also significantlycorrelated with dry matter weight hill^{-1}, effective tillers hill^{-1}and number of filled grains panicle^{-1}.

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

2.2.9 Straw yield

Awal*et al*. (2007) Observed that BRRI dhan32 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 thanSonarbangla-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 atmultiple sites in 1999 - 2000 seasons and found variability in straw quantity andquality which can have critical impacts on biomass industries. The length of thepre-heading period was the strongest indicator for straw yield. Harvested strawyield is also strongly affected by cutting height with a non-linear distributionresulting in nearly half of the straw biomass occurring in the lower third of theplant.

2.2.10 Biological yield

Sarkar (2014) observed that the highest biological yield ha^{-1} was recorded inShakti 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 BRRI dhan29 (10.10 t ha^{-1}).

Peng *et al.* (2000) concluded that the increasing trend in yield of cultivars due tothe improvement in harvest index (HI), while an increase in total biomass wasassociated with yield trends for cultivars-lines.

Ramesha*et al*. (1998) reported that the superior yielding ability of the hybridsover the controls resulted from increased total biomass and increased panicleweight, with almost the same level of harvest index.

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

2.2.11 Harvest index

Hosain (2014) found a remarkable variation in harvest index (HI) among the studied varieties. The highest HI was obtained from BRRI dhan48 while it was lowest in Aloron.

Sarkar (2014) observed that Tia recorded significantly the highest harvest index (49.91%) and BRRI dhan29recordedthe highest harvest index (43.17%).

Jiang*et al.*(2000) found that super high yielding rice had more harvestindex (51%) than the high yielding rice.

Liao-Yaoping *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 andcorrelation studies of different biometric and morphological plant characters ofrice 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 strongpositive correlation with harvest index. Grain yield was also significantlycorrelated with dry matter weight hill^{-1}, effective tillers hill^{-1} and number of filledgrains panicle^{-1}.

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

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

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

Ramesha*et al.* (1998) conducted that hybrids showed heterosis for dry matteraccumulation 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**.**

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, 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 2016 to December 2016. The experimental site was located at 8.45m elevation above sea level with latitude of 23074/N and longitude of 90033/E (Anon.1988). 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. 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 (2002). Soil series: Tejgaon, General soil: Non calcarious dark grey.

3.1.3 Climate

The area had sub tropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the Rabi season (October-March). Weather information regarding temperature, relative humidity, rainfall and sunshine hours prevailed at the experimental site during the study period was presented in.

3.2 Planting materials

Two hybrid rice variety and four inbred variety were used for this experiment. Varieties are:

(i) BRRI dhan33
(ii) BRRI dhan56
(iii) BRRI dhan57
(iv) BRRI dhan62
(v) Hira-2
(vi) BRRI hybrid dhan4

Varieties	Developed by	Imported by
BRRI dhan33	BRRI	
BRRI dhan56	BRRI	
BRRI dhan57	BRRI	
BRRI dhan62	BRRI	
Hira-2		Supreme Seed Company Ltd
BRRI hybrid dhan4	BRRI	

3.3 Details of the Experiment

3.3.1 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 number of unit plots was 18. The size of unit plot is 3m x 3m. The distances between plot to plot and block to block were 1m and 1m respectively.

3.3.2 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.

3.3.3 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.

3.3.4 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.

3.3.5 Fertilizer management

The experimental area was fertilized with 120, 80, 80, 20 and 5 kg ha^{-1} of N, P2O5, K2O, S and Zn applied in the form of urea, triple super phosphate (TSP), muriate of potash (MoP), gypsum and zinc sulphate, respectively. The entire amounts of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied as basal dose at final land preparation. Urea was top dressed in three equal installments i.e., after seedling recovery, during the vegetation stage and at 7 days before panicle initiation.

3.3.6 Uprooting of seedlings

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

3.3.7 Transplanting of seedlings

36 days old seedlings were then transplanted with 25 cm × 15 cm spacing on the well-puddled plots.

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 Thinning and gap filling

After one week of each transplantation, a minor gap filling was done as and where necessary using the seedling from the previous source as per treatment. No thinning was done for any treatment.

3.4.3 Weeding

The crop was infested with some weeds during the early stage of crop establishment. Two hand weedings were done for each treatment; first weeding was done at 20 days after transplanting followed by second weeding at 15 days after first weeding.

3.4.4 Plant protection measures

Plants were infested with rice stem borer (*Scirphophagaincertolus*) and leaf hopper (*Nephotettixnigropictus*) to some extent which were successfully controlled by applying Diazinon @ 10 ml/10 liter of water for 5 decimal lands and by Ripcord @ 10 ml/10 liter of water for 5 decimal lands as and 21 when needed. Crop was protected from birds during the grain filling period. For controlling the birds watching was done properly, especially during morning and afternoon.

3.4.5 General observation of the experimental field

The field was investigated time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest could be minimized. The field looked nice with normal green color plants. Incidence of stem borer, green leaf hopper, leaf roller and rice hispa was observed during tillering stage that controlled properly. No bacterial and fungal disease was observed in the field.

3.4.6 Harvesting and post harvest operation

Maturity of crop was determined when 90% of the grain yellow in color. Five pre-selected hills plot^{-1} were selected from which different crop growth data were collected and 4 m^2 areas from middle portion of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done using by pedal thresher. The grains were cleaned and sun dried to moisture content of about 12%. Straw was also sun dried properly. Finally grain and straw yields plot^{-1} were recorded and converted to t ha^{-1}.

3.5 Growth parameters

i. Plant height

Plant height was measured at 50, 70, 90 DAT and at harvest. The height of the randomly pre-selected 5 hills plot^{-1} was determined by measuring the distance from the soil surface to the tip of the leaf height before heading, and to the tip of panicle after heading. The collected data were finally averaged.

ii. Number of tillers hill^{-1}

Number of tillers hiil^{-1} were counted at 50, 70, 90 DAT and at harvest from five randomly pre-selected hills and averaged as their number hill^{-1}. Only those tillers having three or more leaves were considered for counting.

iii. Number of leaves hill^{-1}

Number of leaves hiil-1 were counted at 50, 70, 90 DAT and at harvest from five randomly pre-selected hills and finally averaged as their number hill^{-1} basis.

iv. Leaf area hill^{-1} (cm^2)

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

v. Leaf Area Index (LAI)

Leaf area index were estimated measuring the length and width of leaf and multiplying by a factor of 0.75 followed by Yoshida (1981). Leaf area index (LAI) was measured manually at the time of 50, 70 and 90 DAT Data were recorded as the average of five plants selected at random the inner rows of each plots.

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

vi. Root dry matter hill^{-1} Root dry matter hill^{-1} was recorded at 50, 70 and 90 DAT respectively from 5 randomly collected root hill^{-1} of each plot from inner rows leaving the border row. Collected roots were oven dried at 70^{0}C 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.

vii. Stem dry matter hill^{-1}

Stem dry matter hill^{-1} was measured at 50, 70 and 90 DAT. Stem was collected randomly from 5 hills of each plot from inner rows leaving the border row. Then the collected stems were oven dried at 70^{0}C 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.

viii. Leaf dry matter hill^{-1}

5 hills of each plot were collected randomly and their leaves were separated from the stem. Collected leaves were oven dried at 70^{0}C 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 and 90 DAT respectively.

ix. 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}.

x. 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.

$$\text{Chlorophyll a (mg g}^{-1}\text{)} = [12.7\ (OD663)-2.69\ (OD645)] \times \frac{V}{1000\,W}$$

$$\text{Chlorophyll b (mg g}^{-1}\text{)} = [12.9\ (OD663)-4.68\ (OD645)] \times \frac{V}{1000\,W}$$

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.

3.6 Yield parameters

i. Panicle length

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of randomly 10 panicles.

ii. Days to maturity

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

iii. Number of 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.

iv. Number of non-effective tiller hill^{-1}

The total number of non-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.

v. Number of effective tiller 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.

vi. Number of filled grains panicle^{-1}

Grain was considered to be filled if any kernel was present there in. The number of total filled grains present on ten panicles were recorded and finally averaged.

vii. Number of unfilled grains panicle^{-1}

Unfilled grains means the absence of any kernel inside in and such grains present on each of ten panicles were counted and finally averaged.

viii. Weight of 1000-grains

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

ix. Grain yield

Grain yield was determined from the central 4 m^2 area of each plot and expressed as t ha^{-1} on about 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

x. Straw yield

Straw yield was determined from the central 4 m^2 area of each plot. After separating of grains, the sub-samples were oven dried to a constant weight and finally converted to t ha^{-1}.

xi. Biological yield

Grain yield and straw yield were all together regarded as biological yield. Biological yield was calculated with the following formula: Biological yield (t ha^{-1}) = Grain yield (t ha^{-1}) + Straw yield (t ha^{-1}).

xii. Harvest Index (%)

It denotes the ratio of economic yield to biological yield and was calculated with following formula (Donald, 1963; Gardner *et al*., 1985).

Harvest index (%) = $\frac{\text{Grain yie; d}}{\text{Biological yield}} \times 100$

xiii. Statistical Analyses

All the data collected on different parameters were statistically analyzed following the analysis of variance (ANOVA) technique using STATISTIX 10 computer package program and the mean differences were adjudged by least significant difference (LSD) test at 5 % level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises of the presentation and discussion of the results obtainedfrom the present study. The results have been presented, discussed and possibleinterpretations were given in tabular and graphical forms. The results obtainedfrom the experiment have been presented under separate headings and subheadings as follows:

4.1 Growth parameters

4.1.1 Plant height (cm)

Plant height was significantly varied among the modern varieties at 50, 70, 90 days after transplanting (DAT) and at harvest (Fig. 1). At vegetative stage (50 DAT) BRRI hybrid dhan4 (81.04) produced the tallest plant which was statistically similar with BRRI dhan56 (78.49) and BRRI dhan57 (78.46). The lowest plant height was found from Hira-2 (55.75). At reproductive stage (70 and 90 DAT) the highest plant height was recorded from BRRI hybrid dhan4 (106.69 and 110.51 respectively) and the shortest from Hira-2 (76.70) and BRRI dhan62 (96.54) respectively.

At harvest the longest plant height found in BRRI hybrid dhan4 (115.29) and the shortest from BRRI dhan33 (99.15). Plant height increased progressively with the advancement of time and growth stages. Hosen (2015) also found the highest plant height from BRRI hybrid dhan4 at reproductive stage and at harvest over the inbred varieties. Sarker (2014), Om *et al*. (1998) and Kabir*et al.* (2004), Awal*et al.* (2007), Haque and Biswas (2014) also observed variation in plant height due to varietal differences.These varietal differences between the tested varieties might be due to their genetic characteristics.

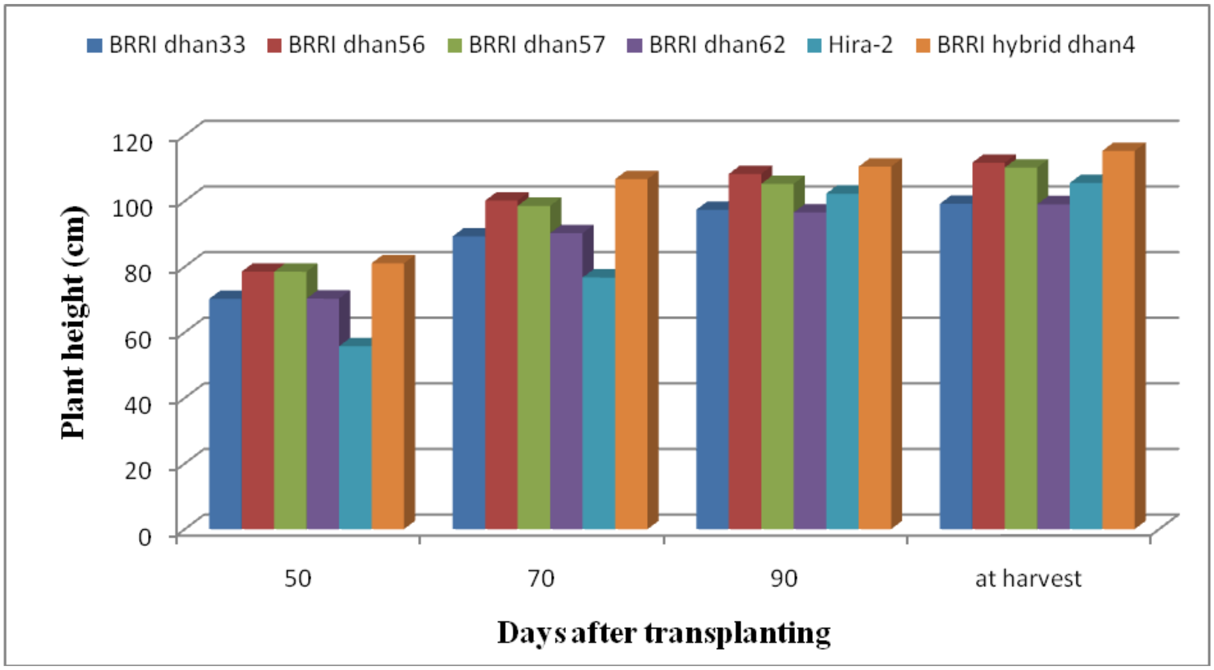

Figure 1: Plant height at different days after transplanting (DAT) of some modern rice varieties of *Aman* season($LSD_{(0.05)}$ value = 7.43, 1.67, 4.34, 4.97 at 50, 70, 90 DAT and at harvest respectively)

4.1.2 Number of tillers hill^{-1}

There was a significant variation in the number of tillers hill^{-1} among the some modern varieties of *Aman* season (Fig. 2). Result showed that number of tillers hill^{-1} increased upto at 70 DAT. But at 90 DAT and at harvest number of tiller hill^{-1} was decreased gradually. At vegetative (50 DAT) stage, the maximum number of tillers At vegetative (50 DAT) stage, the maximum number of tillers hill^{-1} was recorded in BRRI hybrid dhan4 (17.11) that was statistically similar with Hira-2 (15.45) and BRRI dhan62 (14.27). The lowest number of tillers hill^{-1} at vegetative stages (50 DAT) was observed in BRRI dhan33 (10.52). At reproductive (70 and 90 DAT) stages and at harvest the maximum number of tillers hill^{-1} was obtained from BRRI hybrid dhan4 (22.41, 21.72 and 17.98 respectively). At reproductive stages (70 and 90 DAT) and at harvest Hira-2

(21.64, 20.09 and 15.80) was statistically similar with BRRI hybrid dhan4. The minimum number of tiller hill^{-1} was recorded from BRRI dhan33 at 70 DAT (14.11), 90 DAT (13.07) and at harvest (9.8). Song *et. al*. (2009) shown that hybrid produced a significantly superior number of tillers than their parental species. Sarkar (2014) also observed that number of total tiller hill^{-1} increased with the advancement of vegetative growth stages. Haque and Biswas (2014) revealed hybrids have moderate number of effective tillers per plant. Kabir*etal.* (2004) also observed significant variation among the cultivars. In this experiment it has been found that hybrid produce higher number of tiller than the inbred.

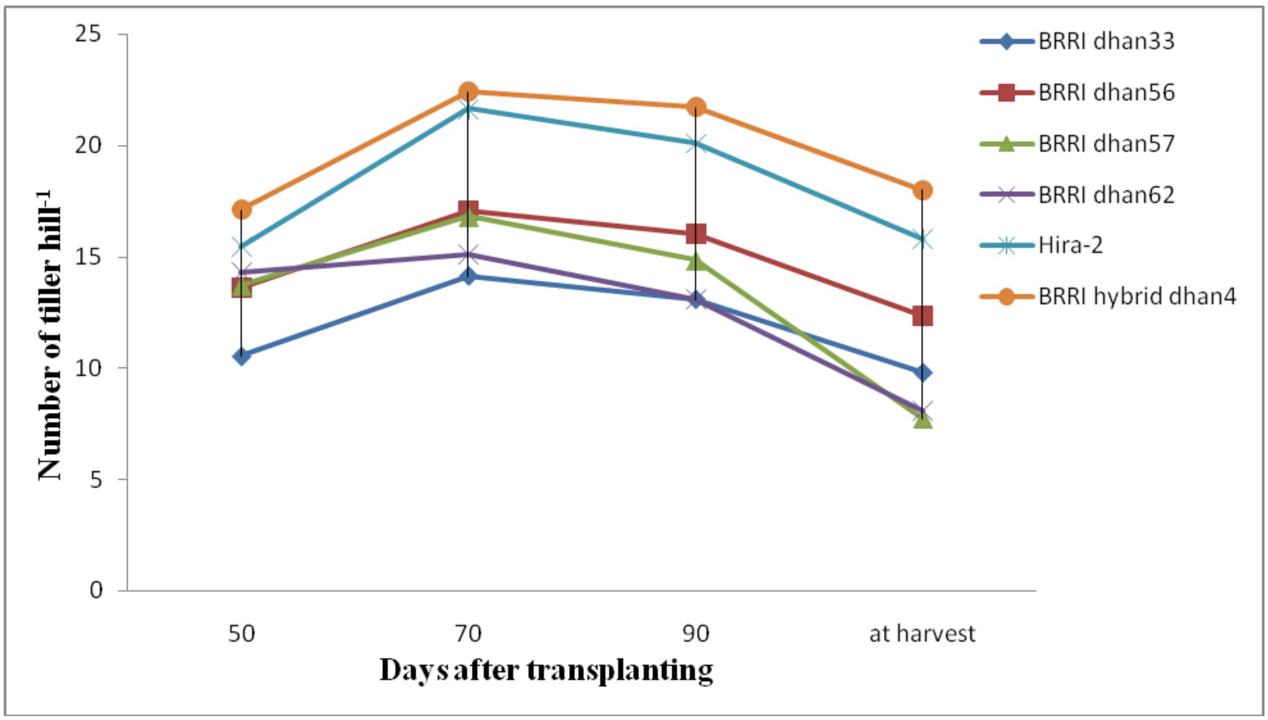

Figure 2: Number of tiller hill^{-1} at different days after transplanting (DAT) of some modern rice varieties of *Aman* season($LSD_{(0.05)}$ value = 2.94, 4.07, 4.64, 2.98 at 50, 70, 90 DAT and at harvest respectively)

4.1.3 Numbers of leaves hill^{-1}

Total number of leaves hill^{-1} in the rice varieties was significantly influenced from vegetative (50 DAT) to reproductive (90 DAT) stage (Fig. 3). The total number of leaves was continued to increase up to 70 DAT and thereafter declined. The maximum number of leaves was observed in BRRI hybrid dhan4 (69.46) at vegetative stage (50 DAT) followed by BRRI dhan56 (58.84) and they were statistically different. At 70 DAT, the maximum number of leaves was recorded from BRRI hybrid dhan4 (77.52) followed by Hira-2 (70.20) but they were statistically different at 5% level of probability. At reproduced stage (90 DAT), the highest number of leaves was also obtained from BRRI hybrid dhan4 (69.97).

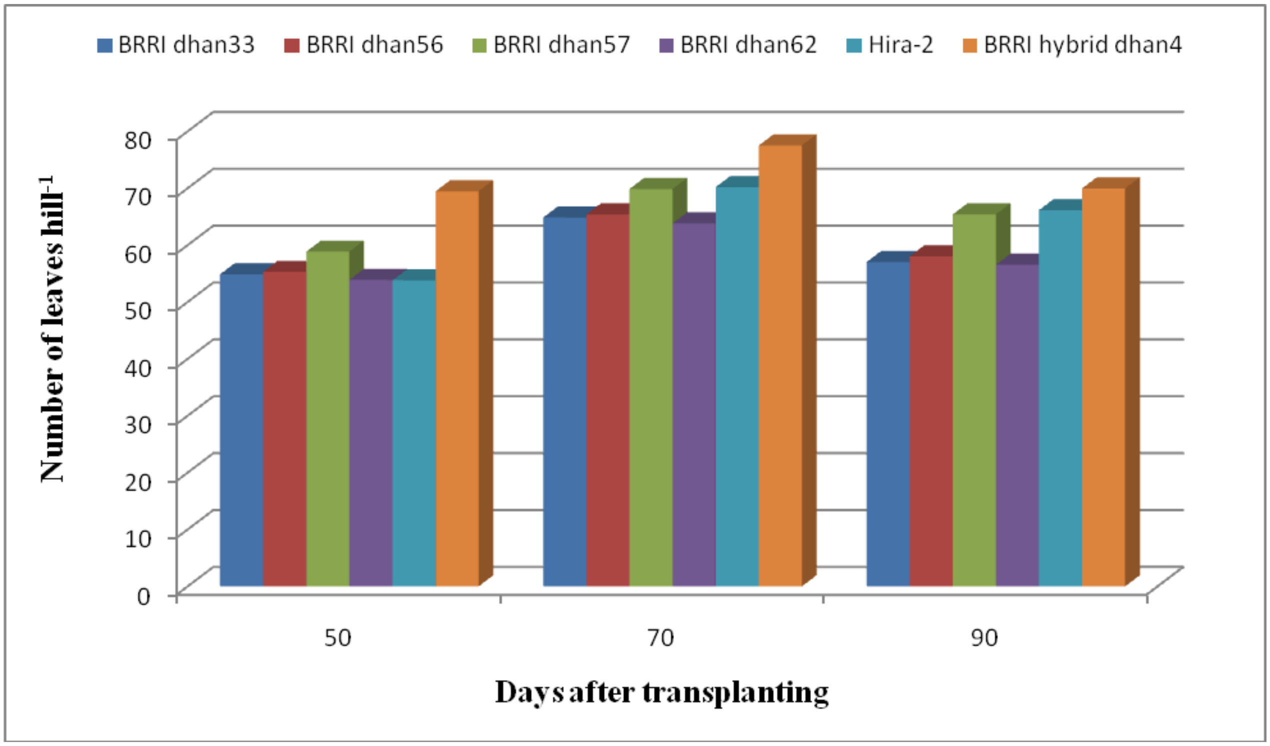

Figure 3: Number of leaves hill^{-1} at different days after transplanting (DAT) of some modern rice varieties of *Aman* season(LSD$_{(0.05)}$ value = 4.56, 5.02, 3.43 at 50, 70 and 90 DAT respectively)

At vegetative stage (50 DAT) Hira-2 (53.82) showed the lowest numbers of leaves hill^{-1}. At 70 DAT BRRI dhan33 (64.86) produced the minimum number of leaves. At 90 DAT BRRI dhan62 (56.55) showed the lowest number of leaves hill^{-1} which was statistically similar with BRRI dhan33 (57.02) and BRRI dhan57 (58.02).Sarkar (2014) observed a significant difference on total number of leaves per hill from vegetative to reproductive stage. Hassan (2001) showed that photo synthetically active leaves hill^{-1} of all varieties increased with the growth period up to booting stage except in Binasail. He also showed that maximum number of leaves were found at the tillering stage and then decreased. The rate of declination was prominent in local varieties than that of hybrid varieties.

4.1.4 Leaf area hill^{-1} (cm^2)

The increasement of leaf area (LA) with the passes of time in test rice varieties was significantly varied during the vegetative and reproductive growth phases (Fig. 4). Results revealed that LA increased with the age till 70 DAT and thereafter declined. The increment of leaf area hill^{-1} varied significantly among the rice varieties. At vegetative stage (50 DAT) and at reproductive stage (70 DAT and 90 DAT) the highest leaf area hill^{-1} was produced by BRRI hybrid dhan4 (1395.3 cm^2, 1985 cm^2 and 1885.7 cm^2 respectively). At vegetative stage (50 DAT) the lowest that was leaf area hill^{-1} was obtained from BRRI dhan57 (1074.6 cm^2) and at reproductive stage (70 DAT and 90 DAT) the lowest leaf area hill^{-1} was produced by BRRI dhan33 (1471.4 cm^2 and 1395.3 cm^2 respectively).

The result obtained from the present study is consistent with the result of Sharma and Haloi (2001) in scented rice, who stated that variation in Leaf area (LA) could be attributed to the changes in number of leaves. Sarker (2014) also found leaf area of tested rice varieties was significantly varied during the vegetative and reproductive growth phase and LA increases with age till the end of the vegetative stage and thereafter decline. The result is also supported by the result of Chandra and Das (2007) in rice. The result indicated that hybrid rice varieties produced the higher leaf area than the check variety and the variation in leaf area might occur due to the variation in number of leaves.

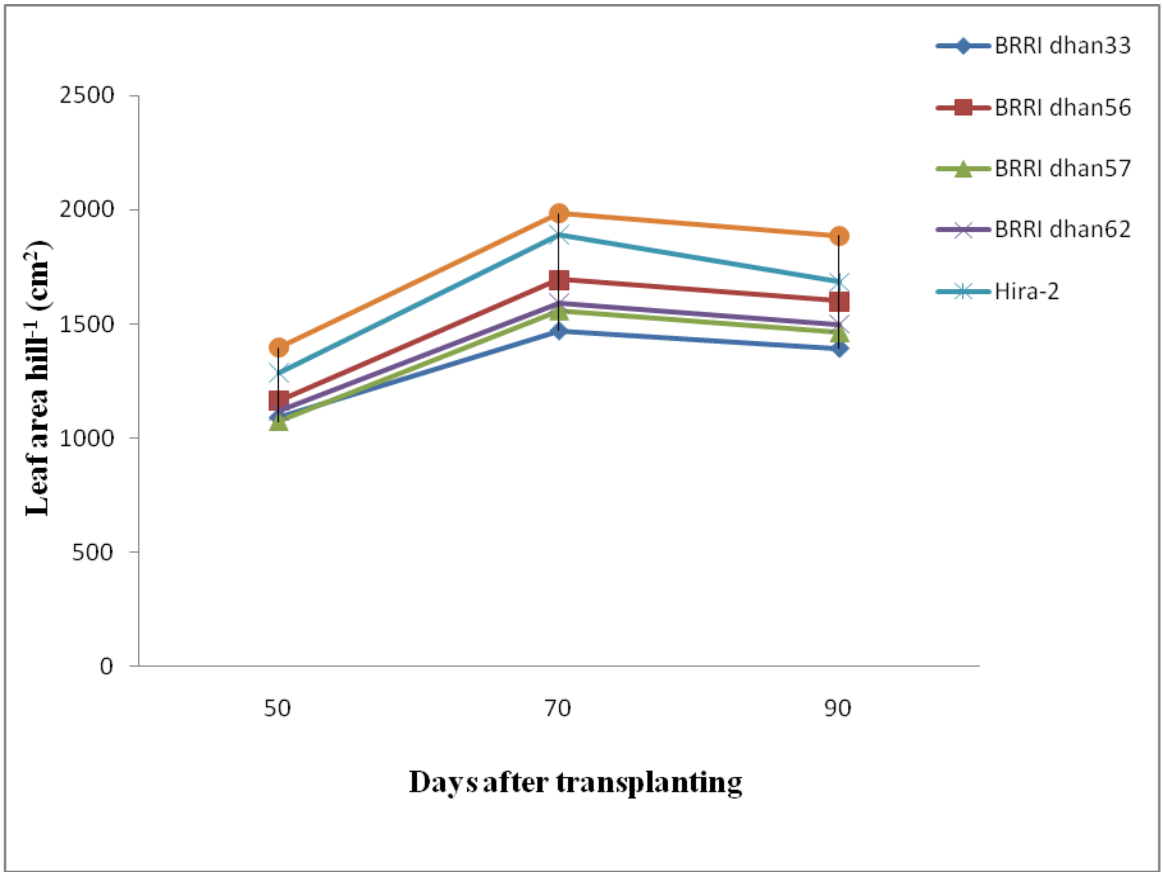

Figure 4: Number of leaf area hill^{-1} at different days after transplanting (DAT) of some modern rice varieties of *Aman* season($LSD_{(0.05)}$ value = 79.36, 31.57, 46.2 at 50, 70 and 90 DAT respectively)

4.1.5 Leaf area index

Leaf area index was significantly varied among the *Aman* varieties (Fig. 5). Result revealed that leaf area index was increased from 50 DAT to 70 DAT and thereafter decreased. At 50 DAT the maximum leaf area index was obtained from BRRI hybrid dhan4 (3.54) and BRRI dhan57 (3.54) which was statistically similar with Hira-2 (3.41) and BRRI dhan56 (3.30). At 70 and 90 DAT BRRI hybrid dhan4 (4.91 and 4.79 respectively) produced the highest leaf area index.But at 70 DAT BRRI hybrid dhan4 (4.91) was statistically similar with Hira-2 (4.80) and BRRI dhan56 (4.76). At 90 DAT BRRI hybrid dhan4 (4.79) was statistically similar with Hira-2 (4.66) and BRRI dhan56 (4.68). Throughout the growth stage BRRI dhan62 produced the lowest leaf area index which was 2.51, 4.01 and 3.81 at 50, 70 and 90 DAT respectively.

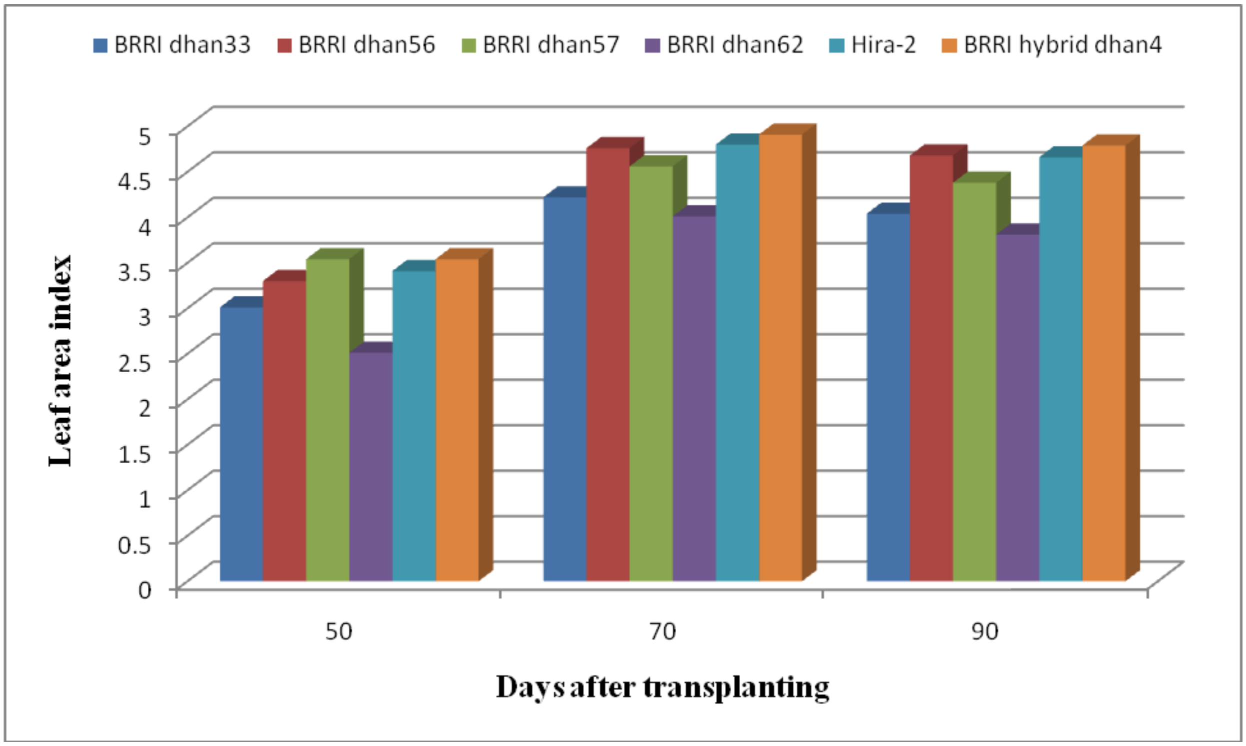

Figure 5: Number of leaf area index at different days after transplanting (DAT) of some modern rice varieties of *Aman* season($LSD_{(0.05)}$ value = 0.29, 0.17, 0.2 at 50, 70 and 90 DAT respectively)

These results are consistent with the result of Mondal*et al.* (2007) who stated that the variation in LAI might be due to the variation 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 $hill^{-1}$. Hosen (2015) and Sarker (2014) also stated that LAI was higher in hybrid rice varieties over inbred variety. They also stated that LAI gradually increases from tillering stage to early reproductive stage and thereafter decreases.

4.1.6 Root dry matter hill^{-1} (g)

There was a significant variation observed in root dry matter production among the rice varieties at different growth stages (Table 1). At 50 DAT maximum root dry weight was produced by BRRI dhan56 (6.36 g) which was statistically similar with Hira-2 (6.28 g), BRRI hybrid dhan4 (6.25 g) and BRRI dhan57 (6.25 g). At 50 DAT minimum root dry weight was produced by BRRI dhn62 (4.30 g). BRRI hybrid dhan4 (9.36 g) produced the highest root dry weight at 70 DAT and the lowest by BRRI dhan57 (6.22 g) which statistically similar with BRRI dhan62 (6.41 g). At 90 DAT maximum root dry weight was obtained from Hira-2 (14.39 g) and BRRI hybrid dhan4 (14.39 g) and the lowest from BRRI dhan33 (10.29 g).

Table 1: Root dry matter hill^{-1} (g) at different days after transplanting (DAT)

Variety	**Root dry matter hill^{-1} (g) at different days after transplanting (DAT)**		
	50	**70**	**90**
BRRI dhan33	4.77 b	7.39 c	10.29 e
BRRI dhan56	6.36 a	7.25 c	13.12 b
BRRI dhan57	6.25 a	6.22 d	12.47 c
BRRI dhan62	4.30 c	6.41d	10.43 d
Hira-2	6.28 a	8.74 b	14.39 a
BRRI hybrid dhan4	6.25 a	9.36 a	14.39 a
LSD $_{(0.05)}$	0.23	0.21	0.32
CV (%)	2.20	1.51	1.49

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

4.1.7 Stem dry matter hill^{-1} (g)

There was a significant variation observed in stem dry matter production among the rice varieties at different growth stages (Table 2). At 50 DAT maximum stem dry weight was produced by Hira-2 (14.89 g) which was statistically similar with BRRI hybrid dhan4 (14.86 g). BRRI hybrid dhan4 (35.22 g) produced the highest stem dry weight at 70 DAT which statistically similar with Hira-2 (35.15 g) and the lowest from BRRI dhan62 (25.42 g). At 90 DAT maximum stem dry weight was obtained from Hira-2 (55.19 g) and BRRI hybrid dhan4 (55.03 g) and the minimum from BRRI dhan57 (40.55 g).

Table 2: Stem dry matter hill^{-1} (g) at different days after transplanting (DAT)

Variety	Stem dry matter hill^{-1} (g) at different days after transplanting (DAT)		
	50	**70**	**90**
BRRI dhan33	10.47 c	25.12 e	44.91 b
BRRI dhan56	10.78 c	25.70 c	42.62 c
BRRI dhan57	10.47 c	26.40 b	40.55 d
BRRI dhan62	11.82 b	25.42 d	42.72 c
Hira-2	14.89 a	35.15 a	55.19 a
BRRI hybrid dhan4	14.86 a	35.22 a	55.03 a
LSD $_{(0.05)}$	0.37	0.25	0.38
CV (%)	1.65	0.47	0.44

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

4.1.8 Leaf dry matter hill^{-1} (g)

There was a significant variation observed in leaf dry matter production among the rice varieties at different growth stages (Table 3). At 50 DAT maximum leafdry weight was produced by BRRI hybrid dhan4 (6.78 g) which was statistically similar with Hira-2 (6.58 g). BRRI hybrid dhan4 (13.86 g and 15.41 g respectively) produced the highest leaf dry weight at 70 DAT and 90 DAT. At 70 DAT, BRRI dhan62 (11.72 g) and BRRI dhan33 (11.72 g) produced the lowest leaf dry weight. At 90 DAT, BRRI dhan33 (13.43 g) produced the lowest leaf dry weight which statistically similar with BRRI dhan62 (13.48 g).

Table 3: Leaf dry matter hill^{-1} (g) at different days after transplanting (DAT)

Variety	Leaf dry matter hill^{-1} (g) at different days after transplanting (DAT)		
	50	**70**	**90**
BRRI dhan33	5.52 b	11.72 d	13.43 d
BRRI dhan56	5.02 c	12.73 bc	13.79 c
BRRI dhan57	5.11 c	12.29 c	14.17 b
BRRI dhan62	5.24 c	11.72 d	13.48 cd
Hira-2	6.58 a	12.81 b	14.17 b
BRRI hybrid dhan4	6.78 a	13.86 a	15.41 a
LSD $_{(0.05)}$	0.25	0.46	0.32
CV (%)	2.40	2.02	1.25

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

4.1.9 Total dry matter hill^{-1} (TDM) (g)

Total dry matter weight was significantly varied among the varieties throughout the growth stages (Fig. 6). Result showed that total dry mater weight was increased with the passes of time. BRRI hybrid dhan4 (27.89 g, 58.44 g and 84.83 g at 50, 70 and 90 DAT respectively) produced the highest dry matter weight throughout the growth stages. At 50 DAT, BRRI hybrid dhan4 (27.89 g) was statistically significant with Hira-2 (27.75 g). At 50 DAT, minimum total dry weight was recorded from BRRI dhan33 (23.45 g) and at 70 the lowest total dry weight obtained from BRRI dhan62 (43.55 g) which was statistically similar with BRRI dhan33 (44.23 g). BRRI dhan33 (64.73 g)) produced the lowest dry matter weight.

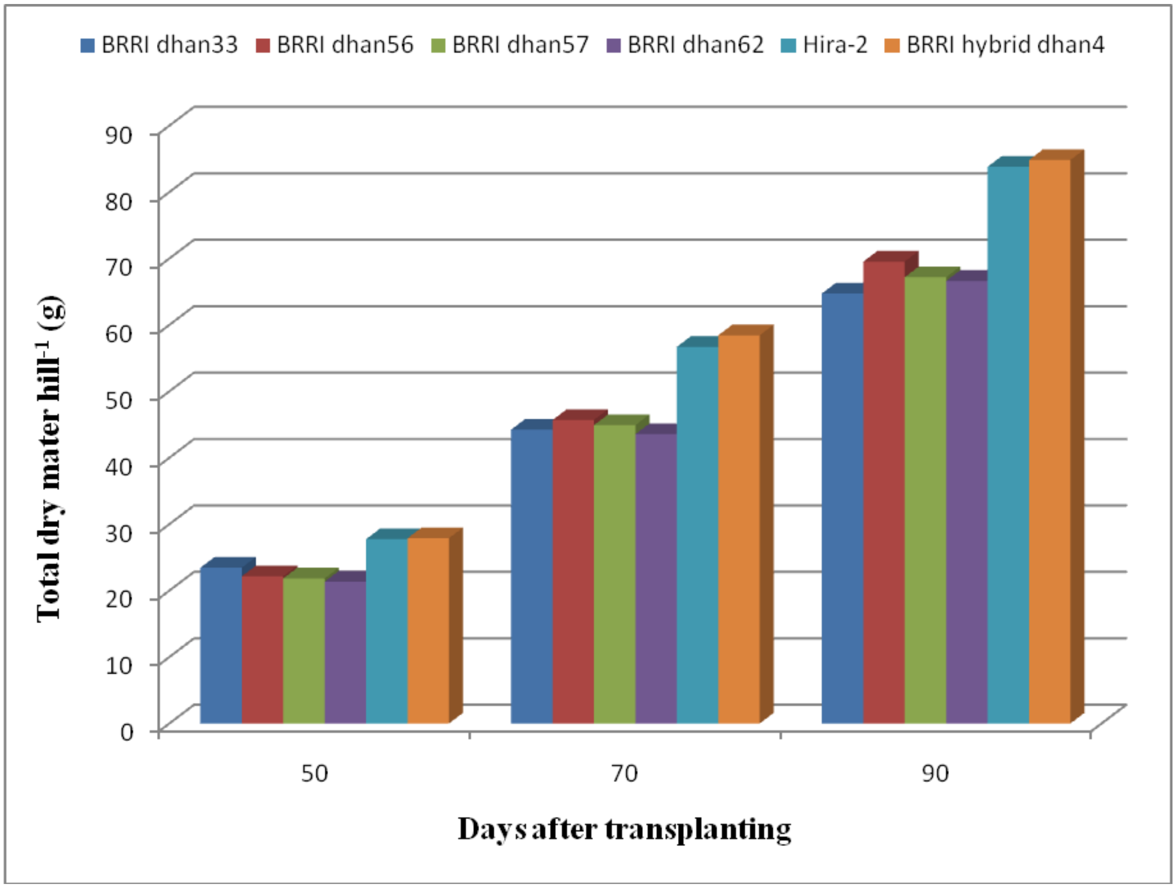

Figure 6: Total dry mater at different days after transplanting (DAT) of some modern rice varieties of *Aman* season($LSD_{(0.05)}$ value = 1.24, 0.75 and 0.59 at 50, 70 and 90 DAT respectively)

TDM was dependent on the leaf area production as reported by Chandra and Das (2010). This result was also supported by the result of Hoque (2004) who reported that TDM increased with increasing plant age up to physiological maturity and high yielding rice always maintained higher TDM hill^{-1}. The results indicated that hybrid rice produced higher TDM than the inbred variety.

Increased dry matter in hybrid rice was possibly due to greater leaf area $hill^{-1}$. Sarker (2014) revealed that dry matter production increased with age of rice plant and dry matter accumulation in plant was low at 50 DAT and thereafter increased rapidly. Hosen (2015) also found hybrid variety produced maximum dry weight.

4.1.10. Flag leaf chlorophyll content (mg g^{-1})

The varieties showed significant variation in chlorophyll content of flag leaf (Table 4). BRRI hybrid dhan4 (2.45 mg g^{-1}, 2.38 mg g^{-1}, 2.25 mg g^{-1} and 1.96 mg g^{-1} fresh weight) synthesized higher amount of chlorophyll at 3 DAF, 9 DAF, 15 DAF and 21 DAF respectively. BRRI dhan33 (2.07 mg g^{-1}, 1.88 mg g^{-1}, 1.88 mg g^{-1} and 1.46 mg g^{-1} fresh weight) synthesized lower amount of chlorophyll at 3 DAF, 9 DAF, 15 DAF and 21 DAF respectively. But at 15 DAF BRRI dhan57 (1.88 mg g^{-1}) and BRRI dhan62 (1.88 mg g^{-1}) were statistically similar with BRRI dhan33 (1.88 mg g^{-1}).

The total flag leaf chlorophyll content was decreased by 28.99%, 31.88%, 32.30%, 32.14%, 24.01% and 20% in BRRI dhan33, BRRI dhan56, BRRI dhan57, BRRI dhan62, Hira-2 and BRRI hybrid dhan4 respectively at 21 DAF compared to the 3 DAF.

Table 4: Flag leaf chlorophyll content of modern *Aman* rice varieties atdifferent days after flowering (DAF)

Variety	Total chlorophyll content at different days after flowering (DAF) (mg g^{-1} fresh weight)			
	3	**9**	**15**	**21**
BRRI dhan33	2.07 d	1.88 e	1.84 d	1.47 e
BRRI dhan56	2.29 b	2.18 c	1.88 c	1.56 c
BRRI dhan57	2.26 bc	2.15 d	1.84 d	1.53 d
BRRI dhan62	2.24 c	2.14 d	1.84 d	1.52 d
Hira-2	2.29 b	2.29 b	2.19 b	1.74 b
BRRI hybrid dhan4	2.45 a	2.38 a	2.25 a	1.96 a
$LSD_{(0.05)}$	0.03	0.03	0.02	0.02
CV (%)	0.74	0.78	0.67	0.89

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

4.2 Yield parameters

4.2.1 Days to maturity

Days to maturity of rice showed statistically significant variation among the varieties (Fig.7). The maximum days to maturity was observed in BRRI hybrid dhan4 (117.60) which was statistically similar with BRRI dhan33 (116.54). while the minimum days to maturity was found in BRRI dhan62 (99.33).

Similar results also reported by Masum*et al*. (2008); and Chowdhury *et al*. (1993) from their earlier experiment. Patnaik and Mohanty (2006) observed that there was significant variation in the maturity duration of varieties. They stated that most of the long duration hybrids possessed long panicles with high grain number $panicle^{-1}$.

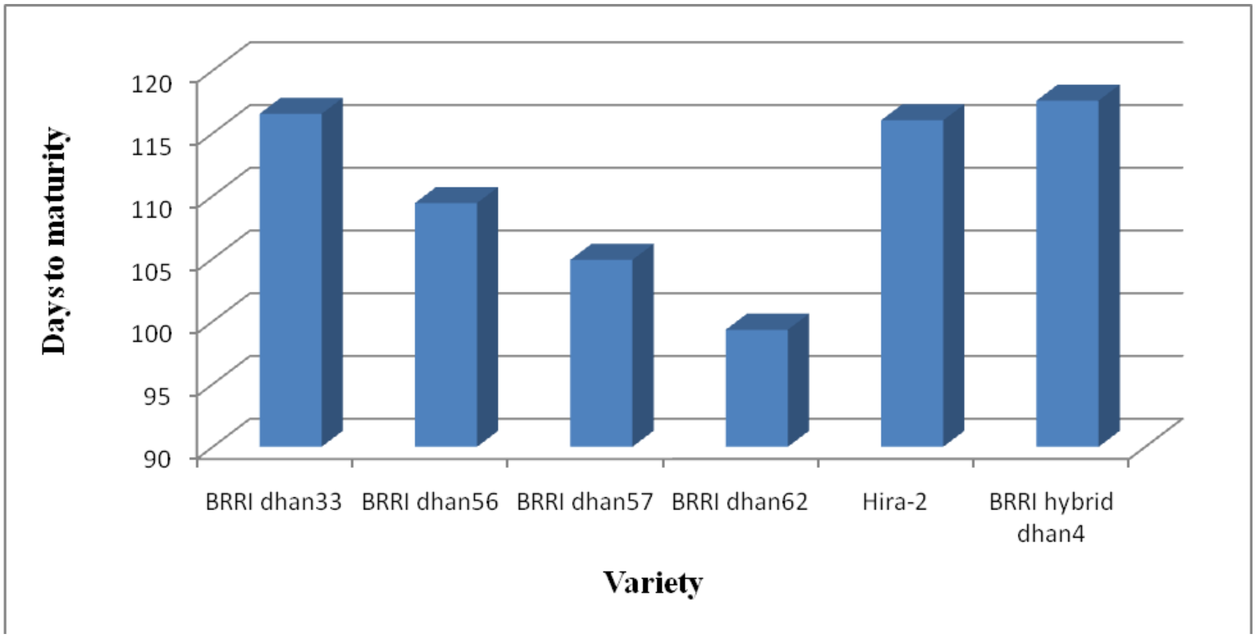

Figure 7: Days to maturity of some modern rice varieties of *Aman* season(LSD $_{(0.05)}$ value = 1.36)

4.2.2 Panicle length (cm)

Panicle length of rice showed statistically significant variation among the varieties (Fig. 8). The maximum panicle length was found in BRRI hybrid dhan4 (26.68 cm) while the minimum panicle length was found in BRRI dhan33 (21.32 cm). Ghosh (2001) reported that hybrids variety in general gave higher values of panicle length compared to inbred varieties. Myungkyu*et al*. (2005), Chakma (2006), Diaz *et al*. (2000) also found variation in panicle length among the varieties. Panicle length was longer in hybrid rice than the inbred due to genetic makeup Sarkar (2014).

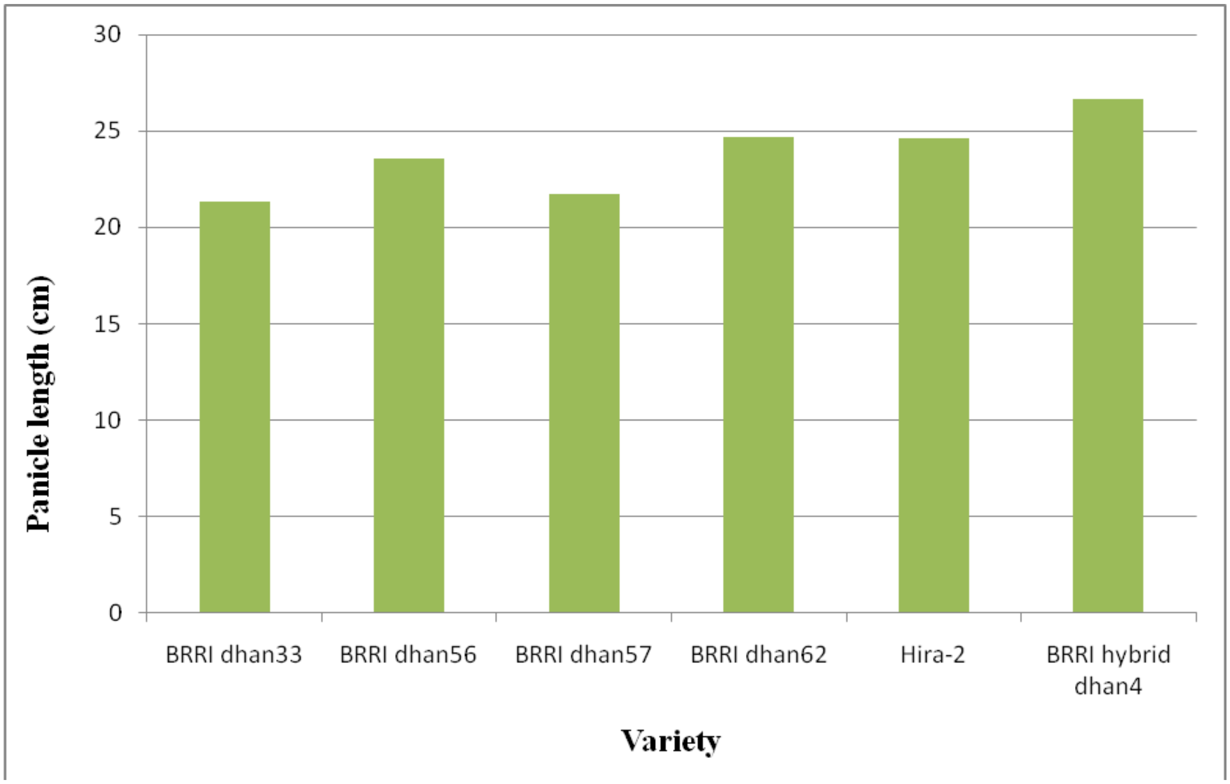

Figure 8: Panicle length of some modern rice varieties of *Aman* season(LSD $_{(0.05)}$ value = 0.44)

4.2.3 Number of panicles hill^{-1}

Number of panicles hill^{-1}was significantly varied among the studied rice varieties (Fig. 9). Among these varieties BRRI hybrid dhan4 (15.24) showed the highest number of panicles hill^{-1} and the lowest number of panicles hill^{-1} produced by BRRI dhan33 (9.11) which was statistically similar with BRRI dhan57 (9.57). Result further revealed that generally hybrid rice varieties produced greater number of effective tillers hill-1 than the inbred rice varieties. This result is also supported by many researchers (Yang *et al*., 2011; Shrirame and Muley, 2003; Munshi, 2005).

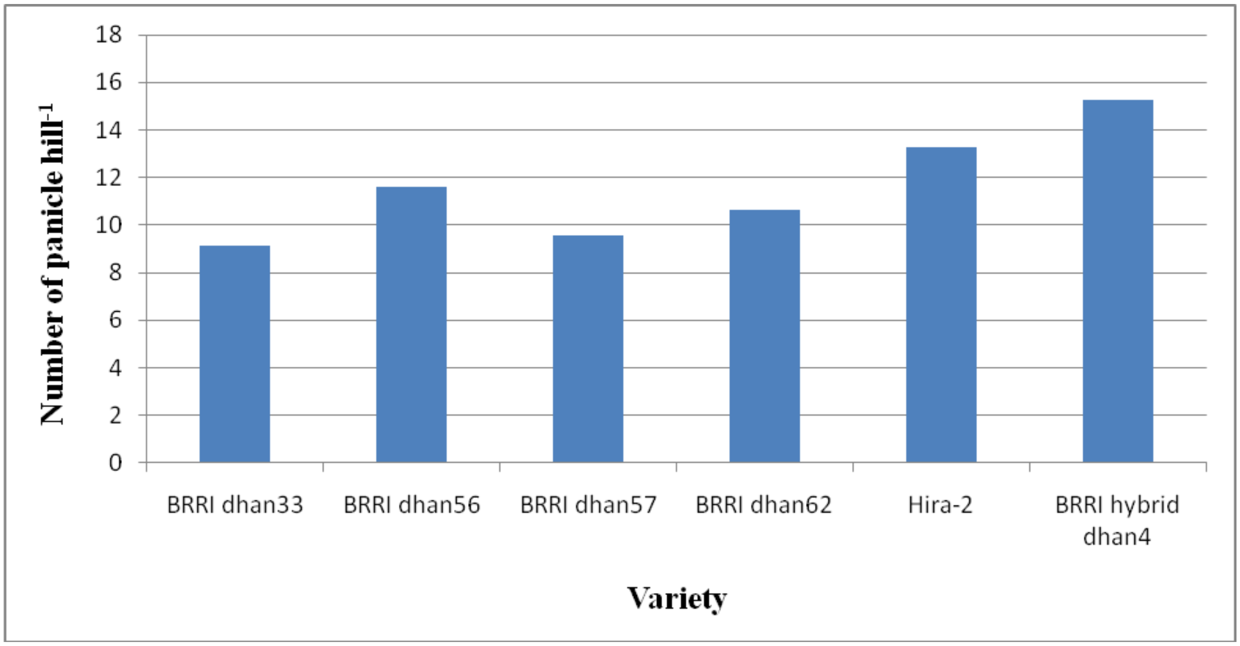

Figure 9: Number panicles hill^{-1} of some modern rice varieties of *Aman* season(LSD $_{(0.05)}$ value = 0.47)

4.2.4 Number effective tillers hill^{-1}

Number effective tillers hill^{-1} was significantly varied among the varieties (Fig. 10). The highest number of effective tiller was produced by BRRI hybrid dhan4 (13.60) and the lowest by BRRI dhan33 (9.02) which was statistically similar with BRRI dhan62 (9.49). Maliniet *et al*. (2006), Awalet *al*. (2007) also found variation in number of effective tiller Number of effective tillers hill^{-1}. Number of effective tiller is associated with the higher productivity Asrafet *al*. (1999), Nehru *et al*. (2000). Somnath and Ghosh (2004) reported that the number of effective tillers had positive association with yield and yield components.

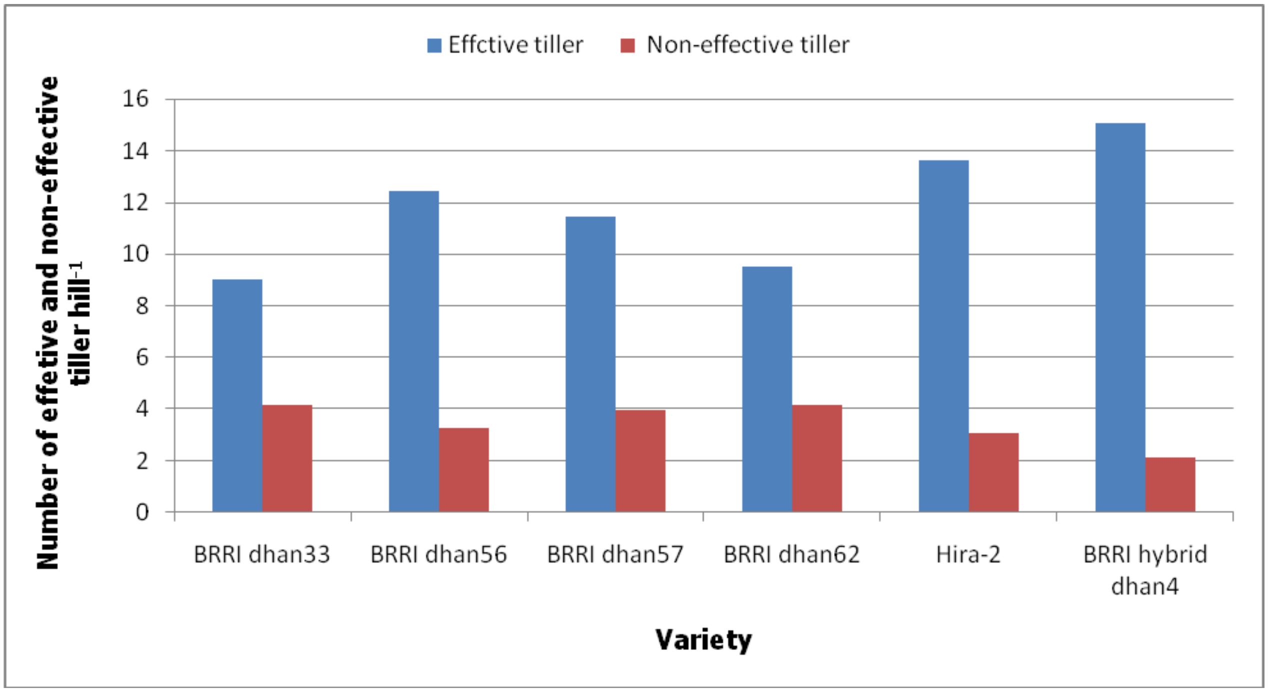

Figure 10: Number effective and non-effective tiller hill^{-1} of some modern rice varieties of *Aman* season(LSD $_{(0.05)}$ value = 0.61 and 0.22 for effective tiller and non-effective tiller respectively)

4.2.5 Number non-effective tillers hill^{-1}

Non- effective tillers hill^{-1} had shown significant difference among the studied varieties (Fig. 10). The highest number of non-effective tillers was recorded from BRRI dhan62 (4.15) which was statistically similar with BRRI dhan33 (4.14) and BRRI dhan57 (3.96). The lowest number was recorded from BRRI hybrid dhan4 (2.11).

4.2.6 Number of filled grains panicle^{-1}

Filled grains panicle^{-1} shown significant variation among the tested rice varieties (Fig 11). From the study, it was noticed that BRRI hybrid dhan4 (141.17) produced the highest number of filled grains panicle^{-1} and the lowest by BRRI dhan33 (115). Shrirame and Mulley (2003), Chaudhary and Motir*aman*i (2003) and Liu and Yuan (2002) stated that grain yield was significantly correlated with number of filled grains panicle^{-1}. Parvez*et al*. (2003) reported that the yield advantage of the hybrid rice due to the relative proportion of higher filled grains per panicle which leads to heavier grain weight. Ganesan (2001), R*amanaet al.* (1998) and Mrityunjay (2001) also stated similar kinds of result.

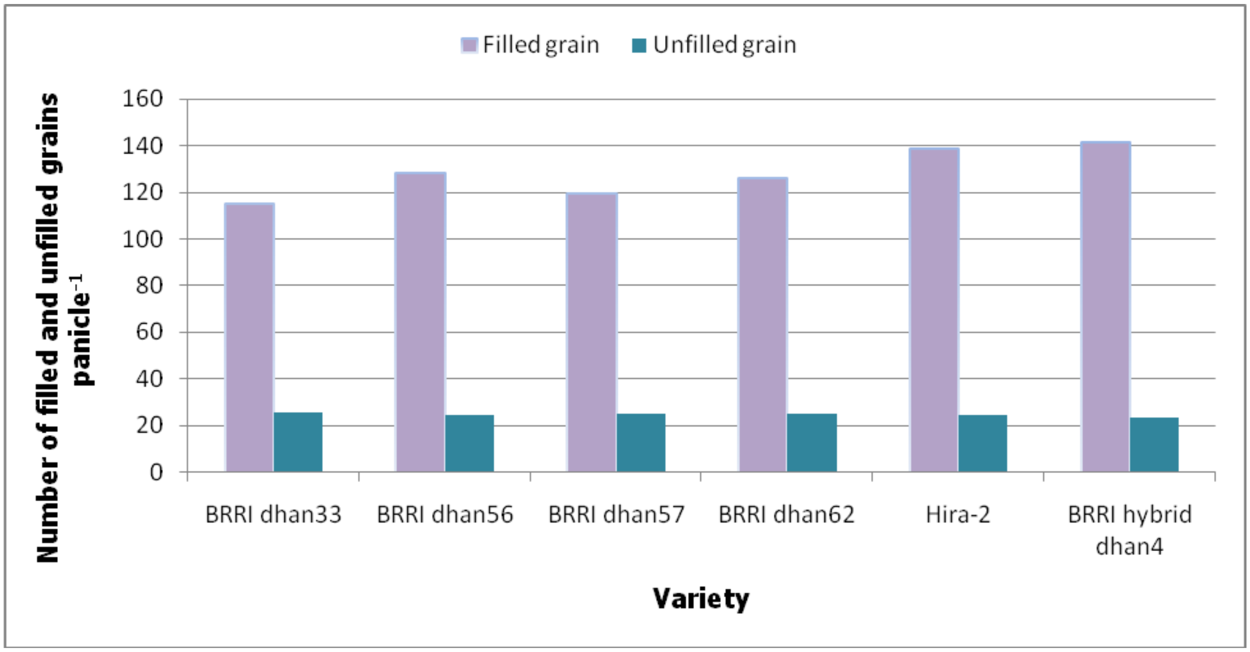

Figure 11: Number of filled and unfilled grains panicle^{-1} of some modern rice varieties of *Aman* season(LSD $_{(0.05)}$ value = 2.27 and 0.8 for filled grains and unfilled grains respectively)

4.2.7 Number of 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 (Fig 11). The highest number of unfilled grains panicle^{-1} was found in BRRI dhan33 (25.78) which was statistically similar with BRRI dhan62 (25.07) and BRRI dhan56 (25). The lowest number of unfilled grains panicle^{-1} was recorded from BRRI hybrid dhan4 (23.74). Chowdhary*et al.* (1999) stated that variation in number of unfilled grains panicle^{-1} due to varietal characteristics. Hosen (2015) also found the highest number unfilled grain from BRRI dhan56.

4.2.8 1000-grain weight (g)

1000-grain weight was significantly different among the test varieties (Table 5). The maximum 1000-grain weight was found in BRRI hybrid dhan4 (25.16 g) which was statistically similar with Hira-2 (25.09 g) and the minimum from BRRI dhan33 (19.98 g).

Sarkar (2014) stated that hybrid variety showed the highest 1000-grain weight due to heavier grain. 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.

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

There was a remarkable difference in respect of grain yield (Table 6). BRRI hybrid dhan4 (6.21 t ha^{-1}) produced the highest grain yield followed by Hira-2 (6.03 t ha^{-1}). The lowest grain yield was produced by BRRI dhan33 (3.82 t ha^{-1}).The yield was higher in BRRI hybrid dhan4 including another hybrid Hira-2 might be due to the production of higher number of effective tiller, leaf number, TDM, LAI, panicle hill^{-1}, filled grain panicle^{-1} and 1000-grain weight.

Hosain (2014), Sarkar (2014), Awal*et al*. (2007) and Chaudhary and Motiramani (2003) stated that higher grain yield associated with dry matter weight hill^{-1}, higher number of panicles hill^{-1} and higher spikelet filling percent.

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

Result showed that straw yield was significantly different among the varieties (Table 7). The highest straw yield was recorded from BRRI hybrid dhan4 (7.18 t ha^{-1}) which was statistically similar with Hira-2 (7.06 t ha^{-1}) and the lowest strawyield obtained from BRRI dhan33 (5.04 t ha^{-1}).

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

There was a remarkable difference shown in respect of biological yield among the tested varieties (Table 8). BRRI hybrid dhan4 (13.39 t ha^{-1}) produced the highest biological yield which was statistically similar with Hira-2 (13.09 t ha^{-1}). The lowest biological yield obtained from BRRI dhan33 (8.86 t ha^{-1}). Result revealed that hybrid rice produced more biological yield than inbred varieties. Munshi (2005) and Chowdhury *et al.* (1999) reported that grain yield was positively correlated with biological yield in rice.

Table 5: 1000-grain weight, grain yield, straw yield and biological yieldof some modern rice varieties

Variety	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
BRRI dhan33	19.98 c	3.82 e	5.04 c	8.86 c
BRRI dhan56	22.11 b	4.36 c	5.89 b	10.25 b
BRRI dhan57	22.04 b	4.08 d	5.97 b	10.05 b
BRRI dhan62	21.81b	4.29 c	5.87 b	10.17 b
Hira-2	25.09 a	6.03 b	7.06 a	13.09 a
BRRI hybrid dhan4	25.16 a	6.21 a	7.18 a	13.39 a
LSD (0.05)	0.34	0.13	0.32	0.32
CV (%)	0.84	1.53	2.89	1.61

4.2.12 Harvest index

Harvest index was significantly influenced by Varieties (Fig. 12). The highest harvest index was found in BRRI hybrid dhan4 (46.39 %) which was statistically similar with Hira-2 (46.08 %).

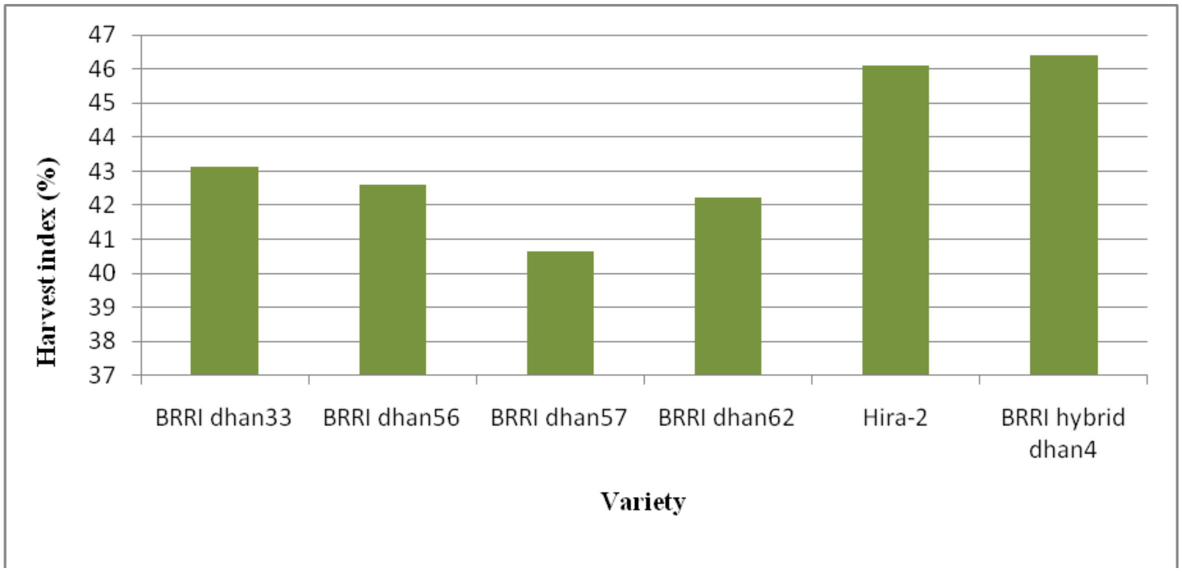

Figure 12: Harvest indexof some modern rice varieties of *Aman*season(LSD $_{(0.05)}$ value = 1.57)

The lowest harvest index was found in BRRI dhan57 (40.63 %). 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) and Cui *et al.* (2000) who observed that hybrid varieties maintained higher harvest index compared to the inbred.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the at the central research farm of Sher-e-Bangla Agricultural University, Dhaka during the period from July to December, 2016 with a view to finding morpho-physiologic characteristics and yield of some modern rice varieties in *Aman* season. The experimental treatments included six *Aman* rice varieties *viz.* BRRI dhan33, BRRI dhan56, BRRI dhan57, BRRI dhan62, Hira-2, and BRRI hybrid dhan4 The experiment was laid out in a randomized Complete Block Design (RCBD) with three replications. Two seedlings of thirty-six days old was transplanted in each hill maintaining pacing 25 cm X 15 cm. The unit plot size was 3 x 3 m^2. All the necessary intercultural operation including weeding, top dressing, irrigation and pesticide applications etc. were done according to the necessity. Collected data were analyzed following the standard procedure and method.

Plant height, tillers $hill^{-1}$, leaves $hill^{-1}$, TDM, leaf area, LAI and yield attributes like days to maturity, panicle $length^{-1}$, effective and non-effective tillers $hill^{-1}$, filled and unfilled grains $panicle^{-1}$, 1000-grain weight, grain yield, straw yield biological yield, and Harvest Index (HI) were significantly varied among the studied hybrid and inbred varieties. The hybrid rice variety, BRRI hybrid dhan4 showed superiority in respect of growth parameters like plant height (81.05 cm, 106.69 cm, 110.51 cm and 115.29 cm at 50, 70, 90 DAT and at harvest respectively), number of tillers $hill^{-1}$ (17.11, 22.41 21.72 and 17.98 at 50, 70, 90 DAT and at harvest respectively), number of leaves $hill^{-1}$ (69.46, 77.52 and 69.97 at 50, 70 and 90 DAT), leaf area $hill^{-1}$ (1395.3 cm^2, 1985 cm^2 94.35 and 1885.7 cm^2 at 50, 70 and 90 DAT), LAI (3.54, 4.91 and 4.79 at 50, 70 and 90 DAT) TDM $hill^{-1}$ (27.89 g, 58.44 g and 84.83 g at 50, 70 and 90 DAT).Again, BRRI hybrid dhan4 also showed the highest yield contributing characters like effective tillers hill^{-1} (15.04), panicle length (15.24 cm), filled grain panicle^{-1} (141.17), 1000-grain weight (25.16 g) grain yield (6.21 t ha^{-1}), straw yield (7.18 t ha^{-1}), biological yield (13.39 t ha^{-1}) and harvest index (46.39 %) over the other inbred varieties.

Therefore, it is concluded that BRRI hybrid dhan4 was superior in *Aman*season in consideration of morpho-physiological growth and yield attributes among the afore-mentioned popular inbred rice varieties. BRRI hybrid dhan4 ultimately leads to the higher dry matter production. Panicles hill^{-1}, filled grain panicle^{-1} and 1000-grain weight are the determinants for the higher grain yield of the studied *Aman* rice varieties.

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

- Hybrids are better than inbred rice varieties to ensure higher yield. Specially, BRRI hybrid dhan4 should be chosen to cultivate during *Aman*season.
- For wider acceptability, the same experiment should be repeated at different agro-ecological zones of the country.

Recommendations

- Although BRRI hybrid dhan4 has been recommended to cultivate during *Aman*season, the impact of climate change on the yield of this rice variety should further investigated.
- For wider acceptability, the same experiment should be repeated at different agro-ecological zones of the country.
- Low-input and climate-resilient high productive rice variety should be developed.

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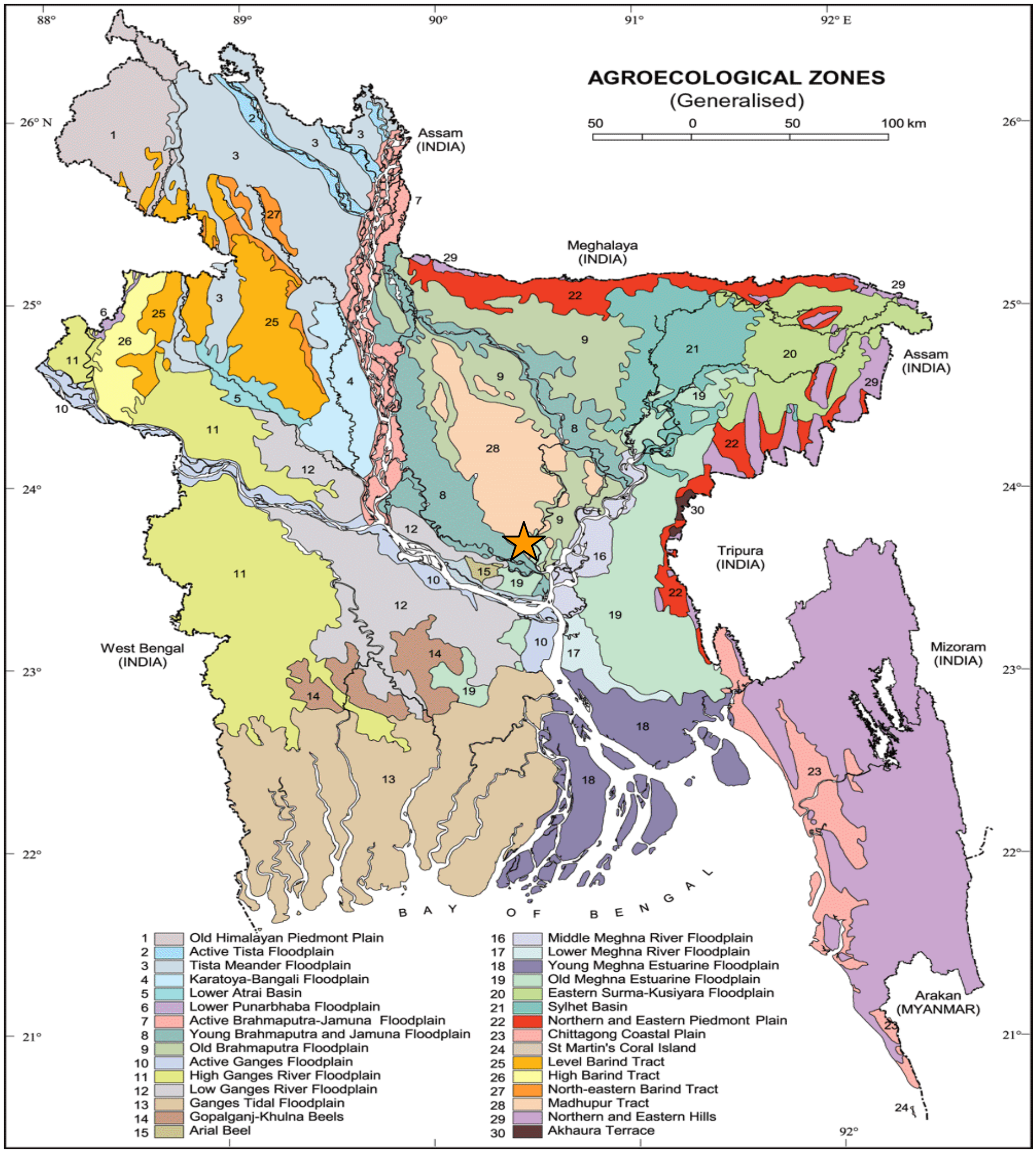
APPENDICES

Appendix I. Map showing the experimental site under study



The experimental site under study

Appendix II: Analysis of variance (mean square) of plant height of some modern rice varieties in *Aman* season.

Sources of variation	Degrees of freedom	Mean square values for plant height at different days after transplanting (DAT)			
		50	70	90	at harvest
Replication	2	83.05	11.36	0.03	0.39
Variety	5	261.04*	332.72*	97.57*	137.05*
Error	10	16.68	0.84	5.68	7.47

* Significant at 5% level

Appendix III: Analysis of variance (mean square) of number of tiller hill^{-1} of some modern rice varieties in *Aman* season.

Sources of variation	Degrees of freedom	Mean square values for number of tiller hill^{-1}at different days after transplanting (DAT)			
		50	70	90	at harvest
Replication	2	0.12	0.39	2.54	0.56
Variety	5	14.50*	35.06*	39.94*	53.37*
Error	10	2.26	5.0	6.51	2.69

* Significant at 5% level

Appendix IV: Analysis of variance (mean square) of number of leaves hill^{-1} of some modern rice varieties in *Aman* season.

Sources of variation	Degrees of freedom	Mean square values for number of leaves hill^{-1} at different days after transplanting (DAT)		
		50	70	90
Replication	2	7.48	7.83	3.39
Variety	5	109.92*	78.55*	97.49*
Error	10	6.28	7.63	3.55

* Significant at 5% level

Appendix V: Analysis of variance (mean square) of leaf area hill^{-1} of some modern rice varieties in *Aman* season.

Sources of variation	Degrees of freedom	Mean square valuesofleaf area hill^{-1} at different days after transplanting (DAT)		
		50	70	90
Replication	2	6000.8	5436	119.6
Variety	5	47912.3*	120538*	94805.3*
Error	10	1902.7	301	644.9

* Significant at 5% level

Appendix VI: Analysis of variance (mean square) of leaf area index of some modern rice varieties in *Aman* season.

Sources of variation	Degrees of freedom	Mean square valuesofleaf area index at different days after transplanting (DAT)		
		50	70	90
Replication	2	0.01	0.005	0.002
Variety	5	0.48*	0.38*	0.47*
Error	10	0.03	0.009	0.01

* Significant at 5% level

Appendix VII: Analysis of variance (mean square) of flag leaf chlorophyll content of some modern rice varieties in *Aman* season.

Sources of variation	Degrees of freedom	Mean square valuesofflag leaf chlorophyll contentat different days after flowering (DAF)			
		3	9	15	21
Replication	2	0.00074	0.00047	0.00082	0.00007
Variety	5	0.04369*	0.8681*	0.11153*	0.10598*
Error	10	0.00028	0.00029	0.00018	0.00021

* Significant at 5% level

Appendix VIII: Analysis of variance (mean square) of root dry weight, stem dry weight, leaf dry weight and total dry weight of some modern rice varieties in *Aman* season.

Sources of variation	Degrees of freedom	Mean square valuesRoot dry weight, stem dry weight, leaf dry weight and total dry weight at different days after flowering (DAT)											
		Root dry weight			Stem dry weight			Leaf dry weight			Total dry weight		
		50	70	90	50	70	90	50	70	90	50	70	90
Replication	2	0.07	0.07	0.08	0.06	0.22	0.43	0.12	0.18	0.01	0.04	1.27	0.83
Variety	5	2.52*	4.72*	28.16*	11.58*	73.20*	128.92*	1.80*	1.96*	1.60*	26.73*	137.21*	246.83*
Error	10	0.02	0.01	0.03	0.04	0.02	0.04	0.02	0.06	0.03	0.46	0.17	0.11

* Significant at 5% level

Appendix IX: Analysis of variance (mean square) of yield components of some modern rice varieties in *Aman* season.

Sources of variation	Degrees of freedom	Mean square values of yield components							
		Panicle length	Days to maturity	Panicle hill^{-1}	Effective tiller hill^{-1}	Non-effective tiller hill^{-1}	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000-grain weight
Replication	2	0.06	0.80	0.01	0.03	0.01	8.87	0.08	0.05
Variety	5	12.06*	164.75*	16.37*	16.40*	1.92*	319.36*	1.29*	12.44*
Error	10	0.06	0.56	0.07	0.11	0.01	1.55	0.19	0.04

* Significant at 5% level

Appendix X: Analysis of variance (mean square) of yield and harvest index of some modern rice varieties in *Aman* season.

Sources of variation	Degrees of freedom	Mean square valuesofyields and harvest index			
		Grain yield	Straw yield	Biological yield	Harvest index
Replication	2	0.01	0.02	0.02	0.67
Variety	5	3.26*	1.98*	10.09*	15.47*
Error	10	0.02	0.03	0.03	0.74

* Significant at 5% level