GROWTH AND YIELD PERFORMANCE OF INBRED AND HYBRID RICE VARIETIES IN AEROBIC CONDITION

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CERTIFICATE

*This is to certify that the thesis entitled '**GROWTH AND YIELD PERFORMANCE OF INBRED AND HYBRID RICE VARIETIES IN AEROBIC CONDITION**' 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 in AGRICULTURAL BOTANY**, embodies the results of a piece of bona fide research work carried out by **SHAHANAZ AKTER**, Registration No. **11-04558** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: December, 2017
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DEDICATED

TO

MY BELOVED PARENTS &

FAMILY

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The Author

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ABSTRACT

The experiment was conducted in the research field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka from November, 2017 to May, 2018 to study growth and yield performance of inbred and hybrid rice varieties in aerobic condition season. Total 10 inbred and hybrid rice varieties were used in this experiment and they were BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI dhan28, BRRI dhan29, Binadhan 8, Binadhan 10, Tia, Moyna, Nobin and Heera 2. The single factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on different yield attributes and yield and statistically significant variation was observed for different rice varieties. The tallest plant (109.65 cm) and maximum number of tillers hill^{-1} (15.70) was observed in BRRI hybrid dhan3, whereas the shortest plant (91.19 cm) and minimum number of tillers hill^{-1} (9.67) was recorded in BRRI dhan28. At 30, 50 and 70 DAT (days after transplanting), the largest leaf area (36.48, 45.67 and 49.84 cm^2) and total dry matter m^{-2} (177.05, 546.13 and 875.16 g) was recorded in BRRI hybrid dhan3, whereas the smallest leaf area (25.53, 32.33 and 37.50 cm^2) and lowest total dry matter m^{-2} (117.84, 347.43 and 752.66 g) was observed in BRRI dhan28. At 30-50 DAT, the highest CGR (18.45 g m^{-2} day^{-1}) was recorded from BRRI hybrid dhan3, whereas the lowest CGR (10.84 g m^{-2} day^{-1}) from Nobin. At 50-70 DAT, the highest CGR (16.45 g m^{-2} day^{-1}) was recorded from BRRI hybrid dhan3, while the lowest CGR (9.32 g m^{-2} day^{-1}) from Heera 2. At 30-50 DAT, the highest NAR (7.85 g m^{-2} day^{-1}) was recorded from BRRI hybrid dhan3, whereas the lowest NAR (5.10 g m^{-2} day^{-1}) from Nobin. At 50-70 DAT, the highest NAR (2.76 g m^{-2} day^{-1}) was recorded from Tia, while the lowest NAR (1.60 g m^{-2} day^{-1}) from Heera 2. The maximum number of effective tillers hill^{-1} (12.33), was recorded in BRRI hybrid dhan3, while the minimum number (6.13) was found in BRRI dhan28. The highest spikelets fertility (93.82%) was recorded in BRRI hybrid dhan3, whereas the lowest (82.35%) in BRRI dhan28. The highest grain yield (5.17 t ha^{-1}) and highest straw yield (5.89 t ha^{-1}) was recorded in BRRI hybrid dhan3, while the lowest grain yield (2.48 t ha^{-1}) and lowest straw yield (3.72 t ha^{-1}) was found in BRRI dhan28. Above finding revealed that the BRRI hybrid dhan3 was superior from other in relation to crop growth characters, yield contributing characters and yield of rice.

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ABBREVIATIONS AND ACRONYMS

	FULL WORD	
%	=	Percent
^{0}C	=	Degree Celsius
AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BRRI	=	Bangladesh Rice Research Institute
CGR	=	Crop Growth Rate
cm	=	Centimeter
CV	=	Co-efficient of variation
DAT	=	Days After Transplanting
et al.	=	and others
etc	=	Etcetera
FAO	=	Food and Agriculture Organization
g	=	gram
HYV	=	High Yielding Variety
LSD	=	Least Significance Difference
m^2	=	Square meter
mm	=	Millimeter
MOP	=	Muriate of Potash
NAR	=	Net Assimilation Rate
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources Development Institute
t/ha	=	ton per hectare
TSP	=	Triple Super Phosphate

CHAPTER I

INTRODUCTION

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INTRODUCTION

Rice (*Oryza sativa* L.), belongs to the family Gramineae, is second most widely grown cereal and primary source of food for more than half of the world population, and about 90% of the world rice grown in Asia which is carrying about 60% of world population (Haque *et al*., 2015). It is grown in more than a hundred countries of the world and in the year 2014-15, worldwide total 474.86 million metric tons of rice has been produced from 159.64 million hectares of land (USDA, 2015). Rice contributes on an average 20% of apparent calorie intake of the world and also 30% of Asian populations (Hien *et al.*, 2006). In Bangladesh, annual production of rice is 34.71 million tons from the cultivation of 11.39 million hectares of land which is about 72.24% of total cropped area (BBS, 2017). Bangladesh ranks 4th in both area and production of rice and also 6th in per hectare production of rice yield (Sarkar *et al*., 2016).

In Bangladesh, the average production of rice is about 2.92 t ha^{-1} (FAO, 2014) which is very low compared to other rice growing countries of the world, like Japan (6.60 t ha^{-1}), China (6.30 t ha^{-1}) and Korea (6.30 t ha^{-1}). The population will swell progressively to 223 million by the year 2030 which will demand additional 48 million tons of food grains (Julfiquar *et al*., 2008). Increasing food demand to meet the global rice demand in the world is becoming challenged in terms of food security. It is generally estimated that about 114 million tonnes of additional milled rice will be produce by 2035 which is equivalent to overall increase of 26 percent in the next 25 years (Kumar and Ladha, 2011). Population growth of Bangladesh required continuous increase of rice production and the highest priority has been given to produce more rice in same land by increasing per hectare yield (Bhuiyan, 2004). Yearly increment of rice production in Bangladesh needs to be sustained to feed her ever increasing population although there are very little scope to increase rice area (Sarker *et al*., 2016) rather agricultural land is declining @ 0.7% per annum (BBS, 2017).

In post green revolution era total rice production are either stagnating/declining day by day mainly due to different factors that are related to crop production (Prakash, 2010). The reasons for low productivity of rice includes erratic rainfall, drought, weed, insect pest diseases, unavailability of quality seeds, non adoption of recommended production and plant protection technology but the major reason attributed to prevalence of local rice varieties instead of high yielding varieties (Mandira *et al*., 2016). In Bangladesh, due to the storage of land the possibility of horizontal expansion of rice production area has come to a standstill, so that the rice growers and scientists are diverting their attention towards vertical expansion of rice production. Therefore, efforts should be given to increase the rice production from per unit area of land. For vertical expansion of rice yield, it is necessary to use of modern production technologies such as use of quality high yielding modern varieties, optimum time of planting, appropriate number of seedling hill^{-1}, adopting proper plant protection measures, seedlings raising techniques, water management, use of appropriate doses of fertilizers, weed management and so on.

Generally, variety is the vital constituent for producing higher yield of rice depending upon their differences in genotypic characters, input requirements and off course the prevailing environmental conditions during the entire growing season of rice. In Bangladesh, BRRI, BINA, IRRI and different seed companies has been introduced high yielding rice variety and it gains positive monumentaion in rice production for the specific three distinct growing seasons (Haque and Biswas, 2011). Improving and increasing the world's rice supply will also depend upon the development and improvement of rice varieties with better yield potential, and to adopt various conventional and biotechnological approaches for the development of high yielding varieties that having resistance against different biotic and abiotic stresses (Khush, 2005). High yielding rice varieties produced yield around 10 to 20% more than conventional rice varieties on similar biotic and abiotic condition due to the heterotic effect (Li *et al*., 2009; Zhou *et al*., 2012).

Very recently various new rice varieties were developed by BRRI with exceptionally high yield potential. Now a day's different high yielding rice variety are available in Bangladesh which have more yield potential than different local varieties (Akbar, 2004). The growth process of rice plants under different agro-climatic condition differs due to the specific rice variety (Alam *et al*., 2012). Hossain and Deb (2003) reported that although farmers got about 16% yield advantage from hybrids compared to the popularly grown inbred varieties but it may not be stable. Compared with conventional cultivars, the high yielding varieties have larger panicles resulting in an average increase of rice grain is 7.27% (Bhuiyan *et al*., 2014). Rice is grown in three distinct seasons namely *Aus* (mid-March to mid-August), *Aman* (mid-June to November) and *Boro* (mid-December to mid-June). *Aus*, *Aman* and *Boro* rice covers about 8.35%, 30.75% and 33.14% of the total crop areas of Bangladesh (BBS, 2017).

Aerobic rice is a renewed way of growing rice in non-submerged unpuddled condition in aerated soil. Aerobic rice is a projected sustainable rice production methodology for the immediate future to address water scarcity and environment safety in scenario of global warming. Aerobic rice is grown on dry soils with surface irrigations provided when necessary with intensive agronomic practices (Jana *et al*., 2018). It involves rice system involves growing input-responsive, drought tolerant rice varieties in nonflooded and non-puddled soil using supplementary irrigation to achieve high yields (Bouman, 2001). It has been developed very recently where rice can be grown successfully with saving of 40-70% irrigation water (Bouman *et al*., 2005; Peng *et al*., 2006; Reddy, 2013). So, aerobic system of rice cultivation is economic through minimizing irrigation cost without reducing growth and yield of rice. With this background and situation the present study was conducted for fulfilling the following objectives:

1. To study the growth and yield characteristics of the varieties under aerobic condition.
2. To compare the variation of different rice variety under aerobic condition.

CHAPTER II

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Rice is the staple food more than three billion people in the world and around ninety percent of rice is grown and consumed in south and Southeast Asia. Bangladesh grown different yielding rice varieties and most of them have excellent production. Most of the high yielding rice varieties of Bangladesh have been developed by IRRI, BRRI and BINA. Variety itself is the genetical factor which contributes a lot for producing yield and yield components. Different researcher reported the effect of rice varieties on yield contributing component and grain yield. However, some of the important and informative works and research findings related to the morpho-physiological attributes, yield contributing characters and yield of different rice varieties, so far been done at home and abroad, reviewed in this chapter under the following headings-

2.1 Performance of different rice varieties

2.1.1 Plant height

Jisan *et al*. (2014) carried out and experiment at Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *Aman* rice varieties as influenced by different levels of nitrogen. The experiment consisted of four varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57 and four levels of nitrogen. Data revealed that among the varieties, BRRI dhan52 produced the tallest plant (117.20 cm), whereas the lowest plant height by BRRI dhan57.

An experiment was conducted by Haque and Biswash (2014) with five varieties of hybrid rice and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties was Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks was BRRI dhan28 and BRRI dhan29 and the highest plant height was 101.5 cm was recorded from BRRI dhan28 and the lowest plant height from Richer (82.5 cm).

Bhuiyan *et al*. (2014) carried out an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of plant growth. Based on the findings of the study it was revealed that the different hybrid rice varieties had significant effects on plant height at maturity.

To study the effect of nitrogen fertilizer and seedling age on Giza 178, H1 and Sakha 101 field experiments was conducted by Salem *et al*. (2011) at the Rice Research and Training Center (RRTC), Sakha, Kafr-El Sheikh Governorate, Egypt during summer seasons. The results indicated that Sakha 101 variety surpassed than other varieties in terms of plant height.

Khalifa (2009) conducted a field experiment at the experimental farm of Rice research and training centre (RRTC), Sakha, Kafr-El sheikh governorate, Egypt rice season for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 was evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties in terms of plant height.

Masum *et al*. (2008) observed that plant height of rice affected by varieties in *Aman* season where Nizershail produced the taller plant height than BRRI dhan44 at different days after transplanting (DAT).

Mandavi *et al.* (2004) found from their experiment 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.

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes namely Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and the findings revealed that the variety Mukti gave the longest plant compared to the others of their experiment.

Ghosh (2001) carried out an experiment with four rice hybrids and four high yielding rice cultivars and concluded that hybrids have higher plant height as compared with high yielding varieties. Pruneddu and Spanu (2001) conducted an experiment and found that plant height ranged from less than 65 cm to 80–85 cm in Mirto, Tejo, Gladio, Lamone and Timo.

Chen-Liang *et al.* (2000) reported that the cross between Peiai 64s and the new plant type lines had longest plant height compared to the others. On the other hand, Xu and Li (1998) observed that the maintainer lines was generally shorter than restorer line.

An experiment was carried out at Anonymous (1998) to find out varietal performance of advance line (BINA 8-110-2-6) along with three check varieties - Iratom 24, BR26 and BRRI Dhan27. The result indicated that BINA 8-110-2-6 appeared similar to BRRI Dhan27 in terms of plant height.

Munoz *et al.* (1996) observed that IR8025A hybrid rice cultivar produced 16% longer plant than the commercial variety Oryzica Yacu-9. Performance of rice varieties (IRAATOM 24, BR14, BINA13 and BINA19) and the findings revealed that the varieties differed significantly in respect of plant height of rice.

Hosain and Alam (1991) found that the plant height in modern rice varieties BR3, BR11, BR14 and Pajam was 90.4, 94.5, 81.3 and 100.7 cm, respectively. It was recorded that the plant height differed significantly among BR3, BR11, BR14, Pajam and Zagali varieties in the *Boro* season.

Miah *et al*. (1990) conducted an experiment where rice cv. Nizersail and mutant lines Mutant NSI and Mutant NSS was planted and found that plant height was greater in Mutant NSI than Nizersail. Shamsuddin *et al*. (1988) conducted a field trial with nine different rice varieties and observed that plant height differed significantly among the varieties tested.

2.1.2 Tillering pattern

Sarkar *et al*. (2016) carried out an experiment to evaluate the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan 2 in *Aman* season with an inbred BRRI dhan33 as checked. The result showed that the hybrid varieties exhibited superiority in respect of tillers hill^{-1} and these hybrid varieties showed higher effective tillers hill^{-1}.

Haque and Biswash (2014) experimented with five varieties of hybrid rice which was collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks was BRRI dhan28 and BRRI dhan29. In case of no. of effective tillers, Hira showed the best performance (17.7) and Sonarbangla-1 showed the least performance (13.3).

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on number of tillers, number of productive tillers. RGBU010A × SL8R is therefore recommended as planting material among hybrid rice varieties because it produced more productive tillers.

Jisan *et al*. (2014) carried out and experiment at Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *Aman* rice varieties as influenced by different levels of nitrogen. The experiment consisted of four varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57 and four levels of N. Among the varieties, BRRI dhan52 produced the highest number of effective tillers hill^{-1} (11.28), while the lowest values of these parameters were produced by BRRI dhan57.

A field experiment was conducted by Khalifa (2009) at the experimental farm of Rice research and training centre (RRTC), Sakha, kafr-El sheikh governorate, Egypt for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 was evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties in consideration of effective and total tillers hill^{-1}.

Masum *et al*. (2008) stated that number of total tillers hill^{-1} was significantly influenced by cultivars at all stages of crop growth. Nizersail was achieved maximum (25.63) tiller at 45 DAT, then with advancement to age it declined up to maturity, whereas in the case of BRRI dhan44, maximum (18.92) tiller production was observed around panicle initiation stage at 60 DAT.

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and observed that Mukti gave the highest tillers hill^{-1} compared to the others. 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.

Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers. They observed that CNHR2 produced more number of productive tillers (413.4/m^2) than other tested varieties.

Devaraju *et al*. (1998) in a study with two rice hybrids, Karnataka Rice Hybrid 1 (KRHI) and Karnataka Rice Hybrid-2 (KRH2), using HYV IR20 as the check, found that IR20, the tiller number was higher than that of KRH2.

Islam (1995) in an experiment with four rice cultivars *viz*. BR10, BR11, BR22 and BR23 found that the highest number of non-bearing tillers hill^{-1} was produced by cultivar BR11 and the lowest number by BR10. Chowdhury *et al*. (1993) reported that the cultivar BR23 showed superior performance over Pajam in respect of number of productive tillers hill^{-1}.

2.1.3 Dry matter content

Sarkar *et al*. (2016) carried out an experiment to evaluate the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan 2 in *Aman* season with an inbred BRRI dhan33 as checked. The result showed that the hybrid varieties exhibited superiority in respect of total dry matter (TMD) hill^{-1} and the highest TDM hill^{-1} (84.0 g) was observed Tia and lowest TDM hill^{-1} (70.10 g) was observed in BRRI dhan33.

Field experiments were conducted by Haque *et al*. (2015) including two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Both hybrids accumulated higher amount of biomass before heading and exhibited greater remobilization of assimilates to the grain in early plantings compared to the inbred variety.

In order to evaluate the response to planting date in rice hybrids line dry method of working, was carried out by Shaloie *et al*. (2014) at the Agricultural Research Station, Agriculture and Natural Resources Research Center of Khuzestan Shavuor. Hybrid rice Hb2 and Hb1 was used in the sub plots. Results showed traits was significantly affected in terms of dry matter and mentioned trait was more in hybrid Hb_2 than Hb_1.

Xie *et al.* (2007) found that Shanyou-63 variety gave the higher yield (12 t ha^{-1}) compared to Xieyou46 variety (10 t ha^{-1}). Masum *et al*. (2008) found that total dry matter production differed due to varieties. Total dry matter of BRRI dhan44 Nizershail significantly varied at different sampling dates.

Amin *et al.* (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (*viz.* Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (*viz.* KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety.

Two field experiments was conducted by Salem *et al*. (2011) at the Rice Research and Training Center (RRTC), Sakha, Kafr-El Sheikh Governorate, Egypt during summer seasons to study the effect of nitrogen fertilizer and seedling age on Giza 178, H1 and Sakha 101. The results indicated that Sakha 101 variety surpassed than other varieties in terms dry matter accumulation.

Mandavi *et al.* (2004) carried out an experiment 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). Higher TDM was obtained from improved genotype than traditional genotypes (1445 and 1626 GDD, respectively). At flowering 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.

Sharma and Haloi (2001) conducted an experiment 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.

Evans and Fisher (1999) reported that 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.

Son *et al*. (1998) reported that dry matter production of four inbred lines of rice (low-tillering large panicle type), YR15965ACP33, YR17104ACP5, YR16510-B-B-B-9, and YR16512-B-B-B-10, and cv. Namcheonbyeo and Daesanbyeo, was evaluated at plant densities of 10 to 300 plants m^{-2} and reported that dry matter production of low-tillering large panicle type rice was lower than that of Namcheonbyeo, regardless of plant density.

2.1.4 Yield attributes

Sarkar *et al*. (2016) carried out an experiment to evaluate the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan2 in *Aman* season with an inbred BRRI dhan33 as checked and these hybrid varieties also showed higher 1000-grain over the inbred.

Dou *et al*. (2016) carried out an experiment with the objective to determine the effects of water regime/soil condition (continuous flooding, saturated, and aerobic), cultivar (‘Cocodrie’ and ‘Rondo’), and soil texture (clay and sandy loam) on rice grain yield, yield components and water productivity using a greenhouse trial. The spikelet number of Cocodrie was 29% greater than that of Rondo, indicating that rice cultivar had greater effect on spikelet number. Results indicated that cultivar selection is an important factors in deciding what water management option to practice.

Field experiments were conducted by Haque *et al*. (2015) including two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Filled grain (%) declined significantly at delayed planting in the hybrids compared to elite inbred due to increased temperature impaired inefficient transport of assimilates.

An experiment was conducted by Hosain *et al*. (2014) at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during *Aus* season to observe the effect of transplanting dates on the yield and yield attributes of exotic hybrid rice varieties. The experiment comprised of three rice varieties (two hybrids-Heera2, Aloron and one inbred- BRRI dhan48). Hybrid varieties Heera2 (3.03 t ha^{-1}) and Aloron (2.77 t ha^{-1}) gave the higher spikelet sterility.

Haque and Biswash (2014) experimented with five varieties of hybrid rice which was collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29. In panicle length status, Richer showed the best performance (27.7 cm) while BRRI dhan28 showed the least performance (26 cm). Number of filled grains panicle^{-1} was the highest for BRRI dhan29 (163.3), whereas, Jagoron only 118. Number of total grains was highest in BRRI dhan29 (201.7) and for Jagoron it was only 133.7. On the other hand, for 1000-grain weight, Aloron was the best than other hybrids.

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on number of filled and unfilled grains, length of panicle and yield. RGBU010A × SL8R is therefore recommended as planting material among hybrid rice varieties because it produced longer panicles and heavy seeds. In the absence of this variety, RGBU02A × SL8R, RGBU003A × SL8R and RGBU0132A × SL8R may also be used as planting material.

In order to evaluate the response to planting date in rice hybrids Line dry method of working, was carried out by Shaloie *et al*. (2014) at the Agricultural Research Station, Agriculture and Natural Resources Research Center of Khuzestan Shavuor. Hybrid rice Hb2 and Hb1 was used in the sub plots. Results showed traits was significantly affected in terms of panicle length, fertility percentage, and mentioned traits was more in hybrid Hb_2 than Hb_1.

Jisan *et al*. (2014) carried out and experiment at Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *Aman* rice varieties as influenced by different levels of nitrogen. The experiment consisted of four varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57 and four levels of N. Data revealed that variety exerted significant influence on yield contributing characters. Among the varieties, BRRI dhan52 produced the grains panicle^{-1} (121.5) and 1000-grain weight

(23.65 g), whereas the lowest values of these parameters was produced by BRRI dhan57.

Forty five aromatic rice genotypes were evaluated by Fatema *et al*. (2011) to assess the genetic variability and diversity on the basis of nine characters. Significant variations were observed among the genotypes for all the characters. Thousand grain weight have been found to contribute maximum towards genetic diversity in 45 genotypes of aromatic rice.

Two field experiments was conducted by Salem *et al*. (2011) at the Rice Research and Training Center (RRTC), Sakha, Kafr-El Sheikh Governorate, Egypt during summer seasons to study the effect of nitrogen fertilizer and seedling age on Giza 178, H1 and Sakha 101. The results indicated that Sakha 101 variety surpassed than other varieties in terms of 1000 seeds weight.

Islam *et al.* (2010) studied yield potential of 16 rice genotypes including 12 hybrids, 3 inbreds and 1 New Plant Type (NPT) at the International Rice Research Institute (IRRI) farm under optimum crop management to achieve maximum attainable yield during the wet season (WS) of 2004 and dry season (DS) of 2005. Yield and yield components was determined at maturity. Hybrid produced higher spikelets panicle^{-1} and 1000-grain weight than inbred rice. Spikelet filling percent was higher in inbred than hybrid rice. The NPT rice genotype had the lowest spikelet filling percent, but the highest 1000-grain weight across the season.

A field experiment was conducted by Khalifa (2009) at the experimental farm of Rice research and training centre (RRTC), Sakha, kafr-El sheikh governorate, Egypt rice season for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 was evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties for studied characters except for number of days to panicle initiation and heading date.

Islam *et al.* (2009) conducted pot experiments during T. *Aman* season in net house at Bangladesh Rice Research Institute (BRRI). Hybrid variety Sonarbangla-1 and inbred modern variety BRRI dhan31 was used in both the seasons. BRRI dhan3l had higher panicles plant^{-1} than Sonarbangla-1, but Sonarbangla-1 had higher number of grains panicle^{-1}, 1000-grain weight.

Wang *et al*. (2006) studied the effects of plant density and row spacing (equal row spacing and one seedling hill^{-1}, equal row spacing and 3 seedlings hill^{-1}, wide-narrow row spacing and one seedling hill^{-1}, and wide-narrow row spacing and 3 seedlings hill^{-1} on the yield and yield components of hybrids and conventional cultivars of rice. Compared with conventional cultivars, the hybrids had larger panicles, highest total grains, heavier seeds, resulting in an average yield increase of 7.27%.

Myung (2005) worked with four different panicle types of rice varieties and observed that the primary rachis branches (PRBs) panicle^{-1} and grains was more on Sindongjinbyeo and Iksan467 varieties, but secondary rachis branches (SRBs) was fewer than in Dongjin1 and Saegyehwa varieties.

Chaturvedi *et al.* (2004) evaluated newly released commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar Dhan 1) and two high yielding varieties as checks (Pant Dhan 4 and Pant Dhan 12) for their agronomic and morpho-physiological traits in a field experiment. Hybrids although could not excel the best HYV owing to high percentage of spikelet sterility but they showed potential for higher yield as these produced large sink (higher number of spikelets m^{-2}).

Obulamma *et al.* (2004) recorded hybrid APHR 2 significantly higher grain yield than hybrid DRRH 1. The increased grain yield was due to increase in number of panicles m^{-2} and number of filled grain panicle^{-1} in hybrid APHR 2 than hybrid DRRH 1.

Guilani *et al*. (2003) carried out an experiment on crop yield and yield components of rice cultivars (Anboori, Champa and LD183) in Khusestan, Iran. They observed that grain number panicle^{-1} was not significantly different among cultivars. The highest grain number panicle^{-1} was obtained with Anboori. Grain fertility percentages were different among cultivars. Among cultivars, LD183 had the highest grain weight.

Ahmed *et al*. (1997) conducted an experiment to compare the grain yield and yield components of seven modern rice varieties (BR4, BR5, BR10, BR11, BR22, BR23, and BR25) and a local improved variety, Nizersail. The fertilizer dose was 60-60-40 kg ha^{-1} of N, P_2O_5 and K_2O, respectively for all the varieties and found that percent filled grain was the highest in Nizersail followed by BR25 and the lowest in BR11 and BR23.

Anonymous (1994) studied the performance of BR14, BR5, Pajam, and Tulsimala and reported that Tulsimala produced the highest number of filled grains panicle^{-1} and BR14 the lowest.

Anonymous (1993) evaluated the performance of four varieties IRATOM 24, BR14, BINA13 and BINA19. They found that varieties differed significantly on panicle length and sterile spikelets panicle^{-1}. It was also reported that varieties BINA13 and BINA19 each had better morphological characters like more grains panicle^{-1} compared to their better parents which contributed to yield improvement in hybrid lines of rice.

Idris and Matin (1990) also observed that panicle length differed among the six rice varieties and it was longer in IR20 than in indigenous high yielding varieties.

2.1.5 Yield

Yield test of 41 entries, 32 new hybrids, 8 male parents restore lines and 1 inbred variety, was conducted by Huang and Yan (2016) on the farm of University of Arkansas at Pine Bluff (UAPB). Results showed that hybrid 28s/BP23R had the highest yield, 10846.6 kg/hectare and over check by 30.7%. The yield of hybrid 28s/PB-24, was 10628.9 kg/hectare and over check by 28.1%. The yields of hybrid 28s/PB-22 and 33A/PB24 were 10549.8 and 10539.8 kg/hectare and over check by 27.1% and 27.0%, respectively.

Sarkar *et al*. (2016) carried out an experiment to evaluate the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan 2 in *Aman* season with an inbred BRRI dhan33 as checked. The highest grain yield was achieved from Tia (7.82 t ha^{-1}), which was closely followed by Shakti 2 (7.65 t ha^{-1}). These two hybrid varieties produced 24.0% higher yield over the inbred BRRI dhan33.

A study was conducted by Mandira *et al*. (2016) in South Tripura district of Tripura for three consecutive kharif seasons to evaluate the performance of rice variety gomati at farmers field under rainfed conditions. The gomati variety of rice was found superior over farmers' existing practices with local varieties. Rice variety gomati with improved production technologies followed in FLDs, increased mean grain yield by 41.62% over farmers' existing practices with only Rs. 1817 ha^{-1} extra expenditure on inputs.

A study was design by Wagan *et al*. (2015) to compare the economic performance of hybrid and conventional rice production and reported that total costs per hectare of hybrid rice was 148992.23 Rs per hectare which was more then conventional rice was 140661.68 Rs per hectare. On an average higher yield (196.14 monds per hectare) was obtained from hybrid rice while conventional rice yield (140.14 monds per hectare) was less then hybrid rice. There was 16.64 percent increase in hybrid rice yield comparing with conventional rice which gives additional income to poor farmers.

Field experiments were conducted by Haque *et al*. (2015) including two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Both hybrid varieties out yielded the inbred. However, the hybrids and inbred varieties exhibited statistically identical yield in late planting. Results suggest that greater remobilization of shoot reserves to the grain rendered higher yield of hybrid rice varieties.

Kanfany *et al*. (2014) conducted an experiment by at the Africa Rice Sahel Regional Station during two wet seasons with the aim of assessing the performances of introduced hybrid cultivars along with an inbred check cultivar under low input fertilizer levels. There were significant cultivar effects for all traits. The grain yield of rice hybrids (bred by the International Rice Research Institute) was not significantly higher than that of the check cultivar widely grown in Senegal.

An experiment was conducted by Hosain *et al*. (2014) at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during *Aus* season (March to July 2010) to observe the effect of transplanting dates on the yield and yield attributes of exotic hybrid rice varieties. The experiment comprised of three rice varieties (two hybrids-Heera2, Aloron and one inbred- BRRI dhan48). BRRI dhan48 produced the highest grain yield (3.51 t ha^{-1}).

Jisan *et al*. (2014) carried out and experiment at, Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *Aman* rice varieties as influenced by different levels of nitrogen. The experiment consisted of four varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57 and four levels of N. Data revealed that highest grain yield (5.69 t ha^{-1}) was obtained from BRRI dhan52 followed by BRRI dhan49 (5.15 t ha^{-1}) and the lowest one (4.25 t ha^{-1}) was obtained from BRRI dhan57.

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Findings revealed that different hybrid rice varieties had significant effects on yield. RGBU010A × SL8R is therefore recommended as planting material among hybrid rice varieties because it produced favorable yield.

Haque and Biswash (2014) experimented with five varieties of hybrid rice which was collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29. In case of biological yield (g), BRRI dhan29 showed highest yield (49.6 g) and Hira only 18 g.

An experiment was carried out by Alam *et al*. (2012) at University of Rajshahi during the kharif season to study the effect of variety, spacing and number of seedlings hill^{-1} on the yield potentials of transplant *Aman* rice. The experiment consisted of three high yielding varieties viz. BRRI dhan32, BRRI dhan33 and BR11, four levels of spacing and four levels of number of seedlings hill^{-1} viz. 2 seedlings hill^{-1}, 3 seedlings hill^{-1}, 4 seedlings hill^{-1} and 5 seedlings hill^{-1}. Variety had significant effects on almost all the yield component characters and yield. Variety BR11 produced the highest grain yield (5.92 t ha^{-1}).

Samonte *et al*. (2011) reported that the two elite lines recommended for release are high yielding in Texas. RU0703190 is also very early maturing conventional long grain rice. The high yield potential of these new releases will impact grain production of rice farmers and their income.

Tabien and Samonte (2007) observed that several elite lines at the multi-state trials had high yield potential relative to the check varieties and these can be released as new varieties after series of yield trials. With improved yield, the new varieties are expected to increase rice production. The elite lines generated are also potential germplasm for rice improvement projects. The initial effort to identify high biomass rice will enhance the development of dedicated feedstock for bioenergy production.

Swain *et al*. (2006) reported from their experiment that the control cultivar IR64, with high translocation efficiency and 1000-grain weight and the lowest spikelet sterility recorded a grain yield of 5.6 t ha^{-1} that was statistically similar to the hybrid line PA6201.

Several *indica/japonica* (I/J) lines was screened and evaluated by Roy (2006) for higher grain yield in the *Boro* season. The highest grain yield of 9.2 t ha^{-1} was obtained from selected I/J line IR58565-2B-12-2-2, which was equal to that of indica hybrid CNHR3 and significantly higher than that of modern variety IR36.

Molla (2001) reported that Pro-Agro6201 (hybrid) had a significant higher yield than IET4786 (HYV), due to more mature panicles m^{-2}, higher number of filled grains $panicle^{-1}$ and greater seed weight.

Patel (2000) studied the varietal performance of Kranti and IR36. He observed that Kranti produced significantly higher grain and straw yield than IR36 did. The mean yield increased with Kranti over IR36 was 7.1 and 10.0% for grain and straw, respectively.

Julfiquar *et al*. (1998) reported that BRRI evaluated 23 hybrids along with three standard checks during *Boro* season. It was reported that five hybrids (IR58025A/IR54056, IR54883, PMS8A/IR46R) out yielded the check varieties (BR14 and BR16) with significant yield difference. Two hybrids out yielded the check variety of same duration yielded by more than 1 t ha^{-1}.

Kamal *et al.* (1998) conducted a study to assess the yield of 9 modern varieties (MV) and 6 local improved varieties (LIV) and observed that modern variety BR11 gave the highest grain yield followed by BR10, BR23, Binasail and BR4.

Chowdhury (1997) undertook a research on BINA-19, BR14, BR3 and Iratom-24 varieties with different methods of transplanting. He found that the yields for

BINA-19, BR14, BR3 and Iratom-24 was 6.49 t ha^{-1}, 6.22 t ha^{-1}, 6.22 t ha^{-1}, 5.75 t ha^{-1} and 5.60 t ha^{-1}, respectively.

Nematzadeh *et al*. (1997) reported that local high quality rice cultivars Hassan Sarai and Sang-Tarom was crossed with improved high yielding cultivars Amol 3, PND160-2-1 and RNR1446 in all possible combinations and released in 1996 under the name Nemat, which gave an average grain yield of 8 t ha^{-1}, twice as much as local cultivars.

Chowdhury *et al*. (1995) studied seven varieties of rice, of which three was native (Maloti, Nizersail and Chandrashail) and four was improved (BR3, BR11, Pasam and Mala). Straw and grain yields was recorded and found that both the grain and straw yields were higher in the improved than the native varieties.

Leenakumari *et al.* (1993) evaluated eleven hybrid cultivars against four standard check varieties-Jaya, Rasi, IR20 and Margala. They concluded that hybrid cultivar OR 1002 gave the highest yield of 7.9 t ha^{-1} followed by the hybrid cultivar OR 1001 (6.2 t ha^{-1}). Among the control varieties, Jaya gave the highest yield (8.4 t ha^{-1}).

2.2 Aerobic rice production

Traditional lowland rice with continuous flooding in Asia has relatively high water inputs. Because of increasing water scarcity, there is a need to develop alternative systems that require less water. “Aerobic rice” is a new concept of growing rice: it is high-yielding rice grown in non-puddled, aerobic soils under irrigation and high external inputs. To make aerobic rice successful, new varieties and management practices must be developed (Reddy, 2013).

Predeepa (2012) carried out an experiment and reported the overall water use efficiency of the rice crop has been estimated to be very poor in contrast to the actual use of the water required for the current level of bounteous productivity. The lowland rice crops will require only 500 to 1000 liters of water for producing 1 kg of rice which is almost on par with the dry land cereal crops. Therefore rice scientists are working on a new genre of rice cultivars "aerobic rice" which is expected to be irrigated or rainfed without puddling water in the field. This technology limits the use of water within the field capacity, which will serve as a better option than the current water cultivation technologies. This will also require breeding new rice cultivars.

Zhang *et al*. (2004) conducted an experiment to identify water saving technology for paddy rice irrigation in a demonstration region of the city of Yancheng, China and reported that dry-foot paddy irrigation saved 48.5% of water, and increased from 8.9 to 12.9% of yield, increasing 1302 Yaun of benefit per hectare, compared to traditional flooding irrigation. The technology has the advantages of clear index, notable effectiveness of water saving, reduction of soil loss and high production; besides, the rice was of good quality and the investment was economical. So, it is easy to be popularized in large areas.

Results are reported of field experiments and farmer-participatory research in the Huang-Huai-Hai plain, northern China, where newly developed aerobic rice varieties are compared with lowland rice. Highest recorded aerobic rice yields were 4.7 - 6.6 t ha^{-1}, compared with 8 - 8.8 of lowland rice. The variety Han Dao 502 is most promising because of its relatively high yield under both aerobic and flooded conditions and because of its good quality fetching a high market price. Compared with lowland rice, water inputs in aerobic rice were more than 50% lower (only 470 mm-650 mm), water productivities 64% - 88% higher, gross returns 28% - 44% lower (345 - 633 \$ ha^{-1}) and labor use 55% lower. Because of its low water use, aerobic rice can be produced in areas where lowland rice cannot (anymore) be grown. Since aerobic rice is targeted at water-short areas, socio-economic comparisons must include water-short lowland rice and other upland crops. The development of high-yielding aerobic rice is still in its infancy and germplasm still needs to be improved and appropriate management technologies developed (Bouman *et al*., 2002).

Patjoshi and Lenka (1998) attempted to determine the best water management in rice under five water management practices in low and high water table situations. Maintaining saturation condition throughout the growth period proved to be the best practice. High water table proved to be better than low water table. Water use efficiency was highest when the plots were maintained at saturation condition throughout, under high water table situation.

Sattar and Bhuiyan (1994) revealed that yield from all the treatments of direct seeded rice was significantly higher (0.6 tha^{-1}) than transplanted one using 20% less amount of water. Under continuous saturated condition, 30% water was saved during normal irrigation period over the amount used in farmers" water management practices (continuous 5-7 cm standing water) with the direct seeded methods without any significant yield reduction. In transplanted rice 1238 mm water used for farmers normal management practice whereas continuous saturated soil condition had the most water-saving regime requiring 917 mm (26% less) water for the whole growing season.

As per the above cited reviews, it may be concluded that rice variety are the important dynamics for attaining optimum growth and as well as highest yield of rice in aerobic condition. The literature revealed that the effects of rice variety have not been well studied and have no definite conclusion for the production of rice in aerobic condition in Bangladesh’s agro climatic condition.

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CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to study growth and yield performance of inbreed and hybrid rice varieties in aerobic condition. The details of the materials and methods i.e. experimental period, location, soil and climatic condition of the experimental area, materials used, treatment and design of the experiment, growing of crops, data collection and data analysis procedure that followed in this experiment has been presented under the following headings:

3.1 Description of the experimental site

3.1.1 Experimental period

The field experiments were conducted during the period of November, 2017 to May, 2018.

3.1.2 Experimental location

The present research work was conducted in the farm area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^0 74^/$N latitude and $90^0 35^/$E longitude with an elevation of 8.2 meter from sea level. Experimental location presented in Appendix I.

3.1.3 Soil characteristics

The soil belonged to "The Modhupur Tract", AEZ-28 (FAO, 1988). Top soil was Silty Clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 6.3 and had organic carbon 0.41%. The experimental area was flat having available irrigation and drainage system and above flood level. The details have been presented in Appendix II.

3.1.4 Climatic condition

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by three distinct seasons, namely winter season from the month of November to February, the premonsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris *et al*., 1979). Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment has been presented in Appendix III.

3.2 Experimental details

3.2.1 Planting material

Total 10 hybrid and inbred rice varieties were used as the test crops in this experiment.

3.2.2 Treatment of the experiment

Ten hybrids and inbred used in this experiment and they were:

Table 1. List of rice varieties used in the experiment

#	Rice variety	#	Rice variety
01	BRRI hybrid dhan2	06	Binadhan 10
02	BRRI hybrid dhan3	07	Tia
03	BRRI dhan28	08	Moyna
04	BRRI dhan29	09	Nobin
05	Binadhan 8	10	Heera 2

3.2.3 Experimental design and layout

The single factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the hybrid and inbred rice varieties. There were 30 plots of size 4.0 m × 2.5 m in each. Layout of the experiment was done with inter plot spacing of 0.50 m and inter block spacing of 1.00 m. The 10 rice varieties were assigned at random into 10 plots of each replication. The layout of the experiment is shown in Figure 1.

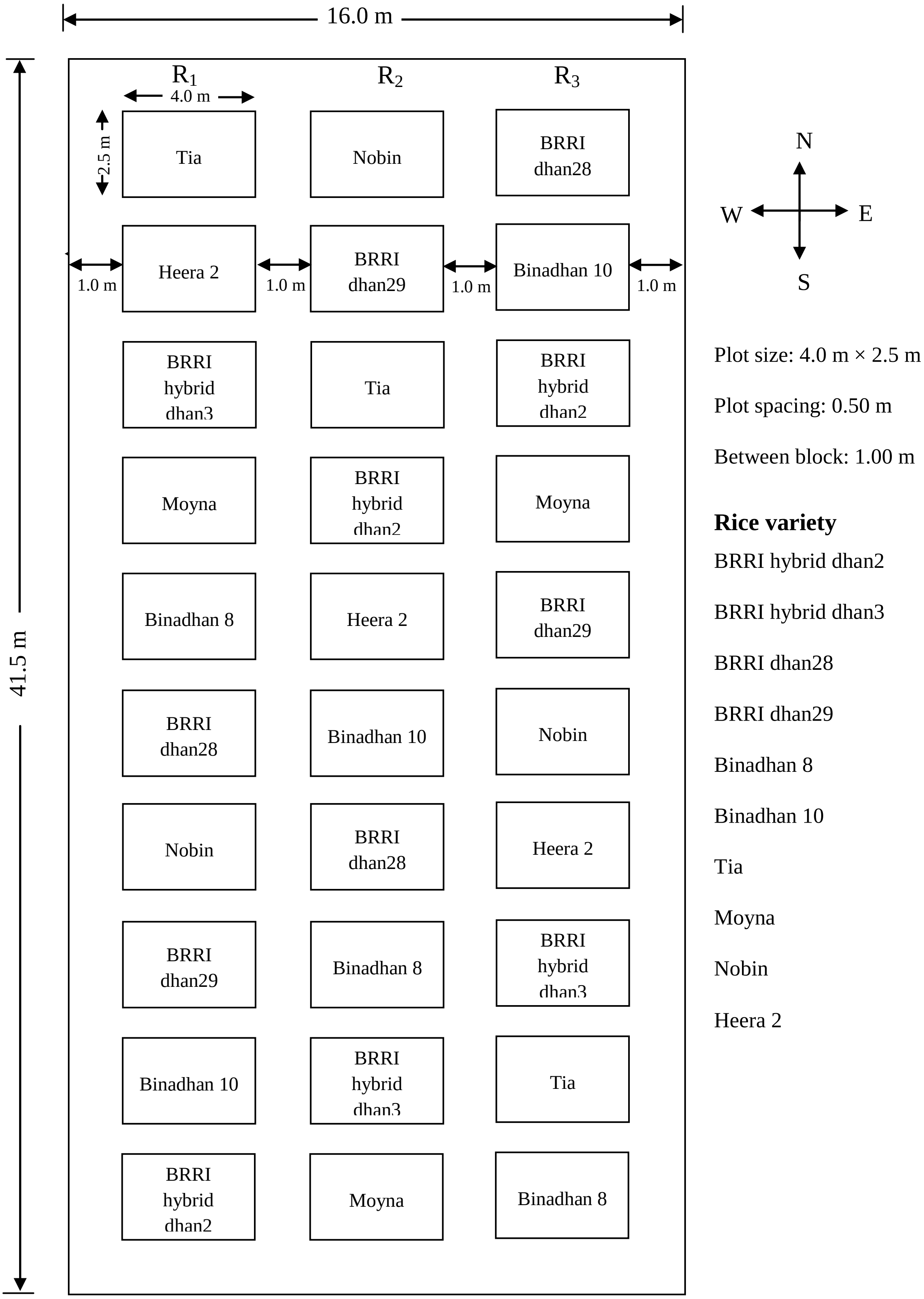

Figure 1. Layout of the experimental plot

3.3 Growing of crops

3.3.1 Seed collection and sprouting

Seeds were collected from BRRI (Bangladesh Rice Research Institute), Gazipur, Bangladesh Institute of Nuclear Agriculture (BINA) and some were procured from respected company just 20 days ahead of the sowing of seeds in seed bed. Seeds were immersed in water in a bucket for 24 hours. These were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 72 hours.

3.3.2 Raising of seedlings

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown in seed bed at 24 December, 2017 as uniformly as possible. Irrigation was gently provided to the bed as and when needed. No fertilizer was used in the seed bed.

3.3.3 Land preparation

The plot selected for conducting the experiment was opened in the first week of January 2018 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain until good tilth. Weeds and stubbles were removed and finally obtained a desirable tilth of soil was obtained for transplanting seedlings. The experimental plot was partitioned into unit plots in accordance with the experimental design. Organic and inorganic manures as indicated below were mixed with the soil of each unit plot.

3.3.4 Fertilizers and manure application

The fertilizers N, P, K, S, Zn and B in the form of urea, TSP, MP, gypsum, zinc sulphate and borax, respectively were applied. The entire amount of TSP, MP, gypsum, zinc sulphate and borax were applied during the final preparation of plot land. Mixture of cow dung and compost was applied @ 10 t ha^{-1} during 15 days before transplantation. Urea was applied in three equal installments at after recovery, tillering and before panicle initiation. The dose and method of application of fertilizers are shown in Table 2.

Table 2. Dose and method of fertilizers application in rice field

Fertilizers	Dose (kg ha^{-1})	Application (%)			
		Basal	1st installment	2nd installment	3rd installment
Urea	150	--	33.33	33.33	33.33
TSP	100	100	--	--	--
MP	100	100	--	--	--
Zinc sulphate	10	100	--	--	--
Gypsum	60	100	--	--	--
Borax	10	100	--	--	--

Source: BRRI, 2016, Adhunik Dhaner Chash, Joydevpur, Gazipur

3.3.5 Transplanting of seedling

The seedbeds were made wet by the application of water both in the morning and evening on the previous day before uprooting on January 13, 2018. The seedlings were then uprooted carefully to minimize mechanical injury to the roots and kept on soft mud in shade before they were transplanted. 22 days old seedlings were transplanted on the well puddled experimental plots on January 14, 2018 by using two seedlings $hill^{-1}$ having a line to line 30 cm and plant to plant 25 cm distance.

3.3.6 Intercultural operations

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

3.3.6.1 Gap filling

Seedlings in some hills were died off and those were replaced by healthy seedling within 10 days of transplantation.

3.3.6.2 Weeding

Weedings were done to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at 25 DAT and 45 DAT by sickles.

3.3.6.3 Creating aerobic condition

Light irrigation was given time to time in the field to keep the soil water content in top 20 cm soil around field capacity when soil water tension bellow 20 RPa. Excess rain water was drained out instantly.

3.3.6.4 Plant protection measures

There were negligible infestations of insect-pests during although to keep the crop growth in normal, Basudin was applied at tillering stage @ 17 kg ha^{-1} while Diazinon 60 EC @ 850 ml ha^{-1} were applied to control stem borer and rice bug.

3.4 Harvesting, threshing and cleaning

The maturity of crop was determined when 85% to 90% of the grains become golden yellow in color. From the centre of each plot 1 m^2 area was harvested to determine yield of individual treatment and converted into t ha^{-1}. The harvested crop of each plot was bundled separately, tagged properly and brought to threshing floor. The bundles were dried in open sunshine, threshed and then grains were cleaned. The grain and straw weights for each plot were recorded after proper drying in sun. Before harvesting, five hills were selected randomly outside the sample area of each plot and cut at the ground level for collecting data on yield contributing characters.

3.5 Data recording

3.5.1 Plant height

The height of plant was recorded in centimeter (cm) at 30, 50, 70 DAT (days after transplanting) and at harvesting stage. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the panicle or flag leaf.

3.5.2 Tillers hill^{-1}

Number of tillers hill^{1} was recorded at 30, 50, 70 DAT and harvest. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.5.3 Leaves hill^{-1}

Number of leaves hill^{1} was recorded at 30, 50, 70 DAT and harvest. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.5.4 Leaf area

Leaf area measured manually at the time of 30, 50 and 70 DAT. Data were recorded as the average of 05 plants selected at random the inner rows of each plots. The final data calculated multiplying by a correction factor 0.75 as per Yoshida (1981).

3.5.5 Total dry matter

Total dry matter hill^{-1} was recorded at 30, 50 and 70 DAT by drying plant sample. Data were recorded as the average of 5 sample hill^{-1} collected at random from the inner rows of each plot and expressed in gram (g).

3.5.6 Crop growth rate (CGR)

Crop growth rate was calculated using the following formula (Hunt, 1978):

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

Where,

A = Ground area (m^2)

W_1 = Total dry weight at time T_1 (g)

W_2 = Total dry weight at time T_2 (g)

T_1 = Initial time (day)

T_2 = Final time (day)

3.5.7 Net assimilation rate (NAR)

Net assimilation rate was calculated using the following formula (Hunt, 1978):

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

Where,

W_1 = Total dry weight at time T_1 (g)

W_2 = Total dry weight at time T_2 (g)

T_1 = Initial time (day)

T_2 = Final time (day)

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

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

L_n = Natural logarithm

3.5.8 Days from sowing to anthesis

Days from sowing to anthesis were recorded by counting the number of days required to starting anthesis in each plot.

3.5.9 Duration from anthesis to maturity

Duration from anthesis to maturity were recorded by counting the number of days required from anthesis to maturity in each plot.

3.5.10 Life duration from germination to maturity

Life duration from germination to maturity were recorded by counting the number of days required from germination to maturity in each plot.

3.5.11 Effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tiller during harvesting. Data on effective tillers hill^{-1} were counted from 5 selected hills and average value was recorded.

3.5.12 Non-effective tillers hill^{-1}

The total number of non-effective tiller hill^{-1} was counted as the number of non-panicle bearing tiller during harvesting. Data on non-effective tiller hill^{-1} were counted from 5 selected hills and average value was recorded.

3.5.13 Length of panicle

The length of panicle was measured with a meter scale from 5 selected panicle and the average length was recorded as per panicle in cm.

3.5.14 Filled grains panicle^{-1}

The total numbers of filled grain were collected randomly from selected 5 panicle of a plot on the basis of grain in the spikelet and then average numbers of filled grains panicle^{-1} was recorded.

3.5.15 Unfilled grains panicle^{-1}

The total numbers of unfilled grain was collected randomly from selected 5 plants of a plot on the basis of empty grain in the spikelet and then average numbers of unfilled grains panicle^{-1} was recorded.

3.5.16 Total grains panicle^{-1}

The total numbers of grain was collected randomly from selected 5 plants of a plot by adding filled and unfilled grain and then average numbers of grains panicle^{-1} was recorded.

3.5.17 Spikelets fertility

Spikelets fertility was computed using the formula:

$$\text{Spikelets fertility (\%)} = \frac{\text{Number of filled spikelets panicle}^{-1}}{\text{Number of total spikelets panicle}^{-1}} \times 100$$

3.5.18 Weight of 1000 grains

One thousand grains were counted randomly from the total cleaned harvested grains and then weighed in grams and recorded.

3.5.19 Grain yield

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

3.5.20 Straw yield

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of central 1 m^2 area was taken from each plot and finally converted to ton $hectare^{-1}$ ($t\ ha^{-1}$).

3.5.21 Biological yield

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

Biological yield = Grain yield + Straw yield.

3.5.22 Harvest index

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

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

3.6 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among different hybrid and inbred of rice. The mean values of all the characters were calculated and analysis of variance was performed using MSTAT-C software. The significance of the difference among the treatments means was estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the growth, development and yield of hybrid and inbreed rice varieties in aerobic condition. Data on different growth characters, yield contributing characters and yield are presented in Appendix IV-IX. The results have been presented and discussed under the help of following headings and sub-headings:

4.1 Crop growth characters

4.1.1 Plant height

Plant height of different rice variety at 30, 50 and 70 days after transplanting (DAT) and at harvest showed statistically significant differences (Appendix IV). Data revealed that at 30 DAT, the tallest plant (45.13 cm) was recorded from BRRI hybrid dhan3 which was statistically similar with other rice varieties under the study except BRRI dhan28 and Tia, whereas the shortest plant (35.76 cm) was observed from BRRI dhan28 which was statistically similar (39.22 cm) with Tia (Table 3). Similar trend of plant height was also recorded for 50, 70 and at harvest. At harvest, the tallest plant (109.65 cm) was observed from BRRI hybrid dhan3 which was statistically similar with other rice varieties of this experiment except BRRI dhan28 and which variety produced the shortest plant (91.19 cm). Generally different varieties produced different size of plant because plant height is a genetical character and it is controlled by the genetic make up of the specific variety. Variety is the key component to produce plant height of rice depending upon their differences in genotypic characters, input requirements and response, growth process and off course the prevailing environmental conditions during the growing season. Munoz *et al.* (1996) noted that IR8025A hybrid rice cultivar produced 16% longer plant than the commercial variety Oryzica Yacu-9. Khalifa (2009) reported that H_1 hybrid rice variety surpassed other varieties in terms of plant height. Bhuiyan *et al*. (2014) reported that the different hybrid rice varieties had significant effects on plant height at maturity.

Table 3. Plant height at different days after transplanting (DAT) and harvest for different hybrid and inbred rice varieties in aerobic condition

Rice variety	Plant height (cm) at			
	30 DAT	50 DAT	70 DAT	Harvest
BRRI hybrid dhan2	44.80 a	61.53 a	94.90 a	107.75 a
BRRI hybrid dhan3	45.13 a	62.29 a	95.15 a	109.65 a
BRRI dhan28	35.76 c	51.94 b	79.10 b	91.19 b
BRRI dhan29	44.07 a	61.83 a	94.37 a	106.98 a
Binadhan 8	44.03 a	62.10 a	97.63 a	108.46 a
Binadhan 10	43.63 ab	60.77 a	91.10 a	104.73 a
Tia	39.22 bc	56.86 ab	88.46 a	99.40 a
Moyna	42.13 ab	60.67 a	89.92 a	102.47 a
Nobin	41.90 ab	59.27 a	90.63 a	102.98 a
Heera 2	42.83 ab	60.86 a	93.80 a	107.57 a
$LSD_{(0.05)}$	4.133	5.179	6.762	10.10
CV(%)	5.62	4.87	4.33	5.52

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

4.1.2 Tillers hill^{-1}

Statistically significant variation was recorded in terms of tillers hill^{-1} of different rice variety at 30, 50 and 70 DAT and at harvest (Appendix V). At 30 DAT, the maximum number of tillers hill^{-1} (5.17) was recorded from BRRI hybrid dhan3 which was statistically similar (5.07, 4.93 and 4.50) with BRRI hybrid dhan2, BRRI dhan29 and Binadhan 8, while the minimum number (2.93) was observed from BRRI dhan28 which was statistically similar (3.47) with Moyna (Table 4). Similar trend of tillers hill^{-1} was also observed for 50, 70 and at harvest for different rice varieties. At harvest, the maximum number of tillers hill^{-1} (15.70) was recorded from BRRI hybrid dhan3 which was statistically similar (15.80, 14.53 and 13.73) with BRRI hybrid dhan2, BRRI dhan29 and Binadhan 10, while the minimum number (9.67) was recorded from BRRI dhan28 which was statistically similar (10.50) with Moyna. Masum *et al*. (2008) reported maximum (25.63) tiller at 45 DAT, then with advancement to age it declined up to maturity, whereas, in the case of BRRI dhan44, maximum (18.92) tiller production was observed around panicle initiation stage at 60 DAT. Khalifa (2009) reported that H_1 hybrid rice variety surpassed other varieties in consideration of tillers hill^{-1}.

Table 4. Tillers hill^{-1} at different days after transplanting (DAT) and harvest for different hybrid and inbred rice varieties in aerobic condition

Rice variety	Tillers hill^{-1} at			
	30 DAT	50 DAT	70 DAT	Harvest
BRRI hybrid dhan2	5.07 ab	10.77 a	16.73 a	15.80 a
BRRI hybrid dhan3	5.17 a	10.67 a	16.43 a	15.70 a
BRRI dhan28	2.93 g	5.23 c	8.60 c	9.67 e
BRRI dhan29	4.93 a-c	10.27 a	16.50 a	14.53 ab
Binadhan 8	4.50 a-e	9.30 ab	14.50 ab	13.17 bc
Binadhan 10	4.33 b-e	9.47 ab	13.90 ab	13.73 a-c
Tia	3.93 ef	8.93 ab	13.23 b	11.83 cd
Moyna	3.47 fg	7.53 b	11.60 b	10.50 de
Nobin	4.17 d-f	9.23 ab	13.23 b	13.25 bc
Heera 2	4.20 c-f	9.10 ab	13.83 ab	13.17 bc
$LSD_{(0.05)}$	0.679	2.186	2.707	1.982
CV(%)	9.32	13.88	11.32	8.71

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

4.1.3 Leaves plant^{-1}

Number of leaves plant^{-1} showed statistically significant differences for different rice variety at 30, 50 and 70 DAT and at harvest (Appendix VI). At 30 DAT, the maximum number of leaves plant^{-1} (23.16) was recorded from BRRI hybrid dhan3 which was statistically similar with other rice variety except BRRI dhan28 and Tia, whereas the minimum number (16.41) was observed from

BRRI dhan28 which was statistically similar (17.50) with Tia (Table 5). Similar trend of number of leaves plant^{-1} was also observed for 50, 70 and at harvest for different rice varieties. At harvest, the maximum number of leaves plant^{-1} (65.88) was recorded from BRRI hybrid dhan3 which was statistically similar (64.67, 61.95 and 61.32) with BRRI hybrid dhan2, BRRI dhan29 and Binadhan 8, while the minimum number (48.04) was recorded from BRRI dhan28. Masum *et al*. (2008) reported that H_1 hybrid rice variety produced highest number of leaves compared in inbred.

Table 5. Number of leaves plant^{-1} at different days after transplanting (DAT) and harvest for different hybrid and inbred rice varieties in aerobic condition

Rice variety	Number of leaves plant^{-1} at			
	30 DAT	50 DAT	70 DAT	Harvest
BRRI hybrid dhan2	23.12 a	42.38 ab	58.90 ab	64.67 a
BRRI hybrid dhan3	23.16 a	46.11 a	59.80 a	65.88 a
BRRI dhan28	16.41 c	31.71 e	46.35 c	48.04 e
BRRI dhan29	22.39 ab	39.35 bc	56.40 ab	61.95 ab
Binadhan 8	22.18 ab	39.07 bc	56.04 ab	61.32 ab
Binadhan 10	22.12 ab	38.78 bc	54.73 b	59.29 bc
Tia	17.50 c	32.74 de	48.81 c	52.66 de
Moyna	21.17 ab	34.00 c-e	48.82 c	55.92 cd
Nobin	21.44 ab	37.20 b-d	50.28 c	57.06 b-d
Heera 2	22.04 ab	38.74 bc	54.59 b	52.82 de
$LSD_{(0.05)}$	2.038	4.932	4.190	4.428
CV(%)	5.46	7.51	5.70	4.34

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

4.1.4 Leaf area

Leaf area of different rice variety at 30, 50 and 70 DAT showed statistically significant variation under the trial (Appendix VII). At 30, 50 and 70 DAT, the highest leaf area (36.48, 45.67 and 49.84 cm^2) was recorded from BRRI hybrid dhan3 which was statistically similar (36.17, 45.39 and 48.84 cm^2) with BRRI hybrid dhan2, whereas the lowest leaf area (25.53, 32.33 and 37.50 cm^2) was observed from BRRI dhan28 (Table 6).

Table 6. Leaf Area at different days after transplanting (DAT) for different hybrid and inbred rice varieties in aerobic condition

Rice variety	Leaf area (cm^2) at		
	30 DAT	50 DAT	70 DAT
BRRI hybrid dhan2	36.17 a	45.39 a	48.84 ab
BRRI hybrid dhan3	36.48 a	45.67 a	49.84 a
BRRI dhan28	25.53 e	32.33 d	37.50 e
BRRI dhan29	35.23 ab	44.28 a	47.58 a-c
Binadhan 8	34.27 a-c	42.67 a	46.54 bc
Binadhan 10	32.77 b-d	37.52 b	45.16 c
Tia	28.02 e	33.34 cd	37.99 de
Moyna	30.56 d	34.17 cd	39.09 de
Nobin	31.16 d	35.22 b-d	40.20 de
Heera 2	32.08 cd	36.16 bc	40.58 d
$LSD_{(0.05)}$	2.438	2.908	2.623
CV(%)	4.61	6.35	5.58

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

4.1.5 Total dry matter

Statistically significant differences was observed in terms of total dry matter m^{-2} of different rice variety at 30, 50 and 70 DAT (Appendix VIII). At 30, 50 and 70 DAT, the highest total dry matter m^{-2} (177.05, 546.13 and 875.16 g) was recorded from BRRI hybrid dhan3 which was followed (156.72, 466.90 and 716.82 g) by BRRI hybrid dhan2, while the lowest total dry matter m^{-2} (117.84, 347.43 and 752.66 g) was found from BRRI dhan28 (Table 7).

Table 7. Total Dry Matter (TDM) m^{-2} at different days after transplanting (DAT) for different hybrid and inbred rice varieties in aerobic condition

Rice variety	Total dry matter m^{-2} (g) at		
	30 DAT	50 DAT	70 DAT
BRRI hybrid dhan2	156.72 b	466.90 b	716.82 bc
BRRI hybrid dhan3	177.05 a	546.13 a	875.16 a
BRRI dhan28	117.84 f	347.70 d	549.16 d
BRRI dhan29	152.01 bc	429.43 bc	752.66 ab
Binadhan 8	149.83 bc	436.22 bc	722.52 bc
Binadhan 10	145.57 bcd	391.09 cd	719.63 bc
Tia	121.93 ef	352.91 d	675.12 bcd
Moyna	125.94 ef	397.86 cd	602.50 bcd
Nobin	132.03 def	348.79 d	663.77 bcd
Heera 2	137.89 cde	395.52 cd	581.89 cd
$LSD_{(0.05)}$	16.12	58.04	139.60
CV(%)	6.63	8.23	11.87

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

4.1.6 Crop growth rate (CGR)

Crop growth rate (CGR) showed statistically significant variation of different rice variety at 30-50 DAT and 50-70 DAT (Appendix IX). At 30-50 DAT, the highest CGR (18.45 g m^{-2} day^{-1}) was recorded from BRRI hybrid dhan3 which was followed (15.51, 14.32, 13.87 and 13.60 g m^{-2} day^{-1}, respectively) by BRRI hybrid dhan2, Binadhan 8, BRRI dhan29 and Moyna, whereas the lowest CGR (10.84 g m^{-2} day^{-1}) was found from Nobin which was statistically similar (11.49, 11.55, 12.88 and 12.28 g m^{-2} day^{-1}) with BRRI dhan28, Tia, Heera 2 and Binadhan 10 (Figure 2). At 50-70 DAT, the highest CGR (16.45 g m^{-2} day^{-1}) was recorded from BRRI hybrid dhan3 which was statistically similar with other rice varieties of this experiment except Heera 2, while the lowest CGR (9.32 g m^{-2} day^{-1}) was found from Heera 2.

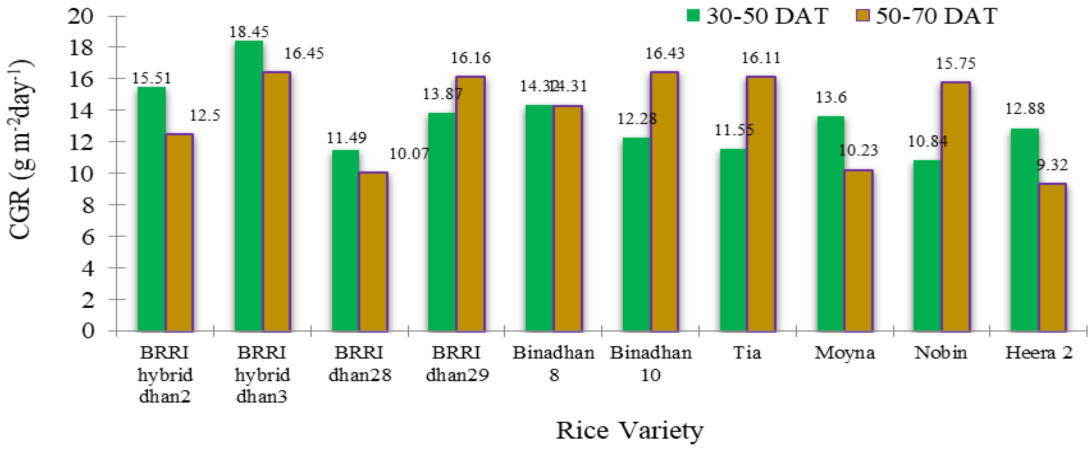

Figure 2. Crop Growth Rate (CGR) for different hybrid and inbred rice varieties in aerobic condition

4.1.7 Net assimilation rate (NAR)

Net assimilation rate (NAR) showed statistically significant variation of different rice variety at 30-50 DAT and 50-70 DAT (Appendix IX). At 30-50 DAT, the highest NAR (7.85 g m^{-2} day^{-1}) was recorded from BRRI hybrid dhan3 which was statistically similar (7.17 g m^{-2} day^{-1}) with BRRI hybrid dhan2, whereas the lowest NAR (5.10 g m^{-2} day^{-1}) was found from Nobin which was statistically similar with other rice varieties except BRRI hybrid dhan3, BRRI hybrid dhan2 and Moyna (Figure 3). At 50-70 DAT, the highest NAR (2.76 g m^{-2} day^{-1}) was recorded from Tia which was statistically similar with other rice varieties except Heera 2, while the lowest NAR (1.60 g m^{-2} day^{-1}) was found from Heera 2.

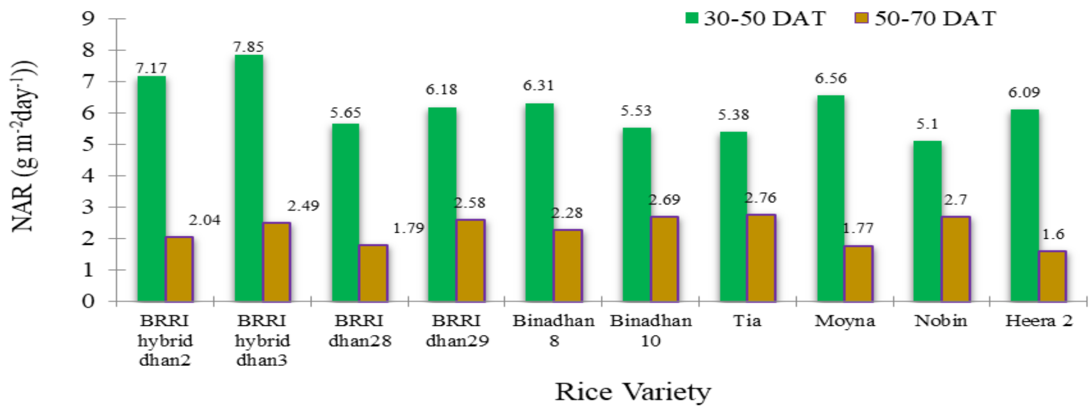

Figure 3. Net Assimilation Rate (NAR) for different hybrid and inbred rice varieties in aerobic condition

4.1.8 Days from sowing to anthesis

Days from sowing to anthesis showed statistically significant differences for different rice variety (Appendix X). The highest days from sowing to anthesis (103.67) was observed from BRRI dhan29 which was followed by other rice variety except Tia and this variety have lowest (83.00 days) from sowing to anthesis (Table 8).

Table 8. Days from sowing to anthesis, duration from anthesis to maturity and life duration from germination to maturity for different hybrid and inbred rice varieties in aerobic condition

Rice variety	Days from sowing to anthesis	Duration from anthesis to maturity (days)	Life duration from germination to maturity (days)
BRRI hybrid dhan2	98.67 b	46.67 b	145.33 b
BRRI hybrid dhan3	97.00 b	47.67 b	144.67 b
BRRI dhan28	93.33 c	45.00 b	138.33 c
BRRI dhan29	103.67 a	52.33 a	156.00 a
Binadhan 8	96.33 b	47.00 b	143.33 b
Binadhan 10	95.66 b	47.67 b	143.33 b
Tia	83.00 d	44.67 b	127.67 d
Moyna	92.67 c	45.67 b	138.33 c
Nobin	93.00 c	46.00 b	139.00 c
Heera 2	93.33 c	45.33 b	138.67 c
$LSD_{(0.05)}$	2.341	2.413	2.681
CV(%)	4.55	5.27	3.78

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

4.1.9 Duration from anthesis to maturity

Duration from anthesis to maturity showed statistically significant differences for different rice variety (Appendix X). The highest duration from anthesis to maturity (52.33 days) was observed from BRRI dhan29 and the lowest (45.33 days) was recorded from Heera 2 which was statistically similar with other varieties (Table 8).

4.1.10 Life duration from germination to maturity

Life duration from germination to maturity varied significantly for different rice variety (Appendix X). The highest life duration from germination to maturity (156.00) was observed from BRRI dhan29 which was followed by other rice variety except Tia and this variety have lowest (127.67 days) life (Table 8).

4.2 Yield contributing characters

4.2.1 Effective tillers hill^{-1}

Statistically significant variation was observed in terms of number of effective tillers hill^{-1} of different rice variety (Appendix XI). The maximum number of effective tillers hill^{-1} (12.33) was recorded from BRRI hybrid dhan3 which was statistically similar (12.17, 11.20 and 11.13, respectively) with BRRI hybrid dhan2, BRRI dhan29 and Binadhan 8, while the minimum number (6.13) was found from BRRI dhan28 (Table 9). Khalifa (2009) reported that H_1 hybrid rice variety surpassed other varieties in consideration of effective tillers hill^{-1}.

Table 9. Number of effective, non-effective tillers hill^{-1} and length of panicle for different hybrid and inbred rice varieties in aerobic condition

Rice variety	Number of effective tiller hill^{-1}	Number of in-effective tiller hill^{-1}	Length of panicle (cm)
BRRI hybrid dhan2	12.17 ab	3.53 ab	22.83 a
BRRI hybrid dhan3	12.33 a	3.47 a-c	22.96 a
BRRI dhan28	6.13 f	3.53 ab	19.64 c
BRRI dhan29	11.20 abc	3.33 a-d	22.19 ab
Binadhan 8	11.13 abc	2.60 de	22.03 ab
Binadhan 10	10.33 bcd	2.83 b-e	21.97 ab
Tia	8.33 e	2.17 e	20.92 ab
Moyna	9.13 de	2.70 c-e	21.23 b
Nobin	10.07 cde	3.10 a-d	21.19 ab
Heera 2	10.32 bcd	2.94 a-e	21.30 ab
$LSD_{(0.05)}$	1.687	0.712	2.238
CV(%)	6.89	13.72	6.89

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

4.2.2 Non-effective tillers hill^{-1}

Number of non-effective tillers hill^{-1} showed statistically significant differences of different rice variety (Appendix XI). The minimum number of non-effective tillers hill^{-1} (2.17) was recorded from Tia which was statistically similar (2.60, 2.70 and 2.83, respectively) with Binadhan 8, Moyna and Binadhan 10, while the maximum number (3.53) was found from BRRI hybrid dhan2 and BRRI dhan28 (Table 9).

4.2.3 Length of panicle

Statistically significant variation was observed in terms of length of panicle of different rice variety (Appendix XI). The longest panicle (22.96 cm) was recorded from BRRI hybrid dhan3 which was statistically similar with other rice variety except Moyna and BRRI dhan28, while the shortest panicle (19.64 cm) was found from BRRI dhan28 which was followed (21.23) by Moyna (Table 9).

4.2.4 Filled grains panicle^{-1}

Number of filled grains panicle^{-1} showed statistically significant differences of different rice variety (Appendix XII). The maximum number of filled grains panicle^{-1} (86.50) was recorded from BRRI hybrid dhan3 which was statistically similar with other rice variety except Moyna, Tia and BRRI dhan28, whereas the minimum number (56.00) was found from BRRI dhan28 (Table 10). Obulamma *et al.* (2004) recorded highest number of filled grain panicle^{-1} in hybrid APHR 2 than hybrid DRRH 1.

4.2.5 Unfilled grains panicle^{-1}

Statistically significant variation was recorded in terms of number of unfilled grains panicle^{-1} for different rice variety (Appendix XII). The minimum number of unfilled grains panicle^{-1} (5.70) was recorded from BRRI hybrid dhan3 which was statistically similar (6.67, 7.20 and 7.47, respectively) with BRRI hybrid dhan2, BRRI dhan29 and Binadhan 10, whereas the maximum number (12.00) was found from BRRI dhan28 (Table 10). Hosain *et al*. (2014) reported that hybrid varieties Heera2 and Aloron gave the higher spikelet sterility.

Table 10. Number of filled, unfilled, total grains and fertility for different hybrid and inbred rice varieties in aerobic condition

Rice variety	Number of filled grain plant^{-1}	Number of unfilled grain plant^{-1}	Number of total grain plant^{-1}
BRRI hybrid dhan2	85.43 ab	6.67 c-e	92.10 a
BRRI hybrid dhan3	86.50 a	5.70 e	92.20 a
BRRI dhan28	56.00 d	12.00 a	68.00 c
BRRI dhan29	85.33 ab	7.20 b-e	92.53 a
Binadhan 8	82.70 abc	8.10 bc	90.80 ab
Binadhan 10	79.33 abc	7.47 b-e	86.80 ab
Tia	74.07 c	9.07 b	83.13 b
Moyna	76.43 bc	8.20 bc	84.63 ab
Nobin	77.60 abc	8.00 b-d	85.60 ab
Heera 2	78.35 abc	7.87 b-d	86.22 ab
$LSD_{(0.05)}$	8.244	1.760	6.853
CV(%)	8.45	13.45	4.66

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

4.2.6 Total grains panicle^{-1}

Number of total grains panicle^{-1} showed statistically significant variation of different rice variety (Appendix XII). The maximum number of total grains panicle^{-1} (92.20) was recorded from BRRI hybrid dhan2 which was statistically similar with other rice variety except Tia and BRRI dhan28, whereas the minimum number (68.00) was found from BRRI dhan28 which was followed (83.13) by Tia (Table 10). Guilani *et al*. (2003) observed that grain number panicle^{-1} was not significantly different among cultivars.

4.2.7 Spikelets fertility

Spikelets fertility of rice grains varied significantly for different rice variety (Appendix XII). The highest spikelets fertility (93.82%) was recorded from BRRI hybrid dhan3 which was statistically similar with other rice variety except BRRI dhan28, whereas the lowest (82.35%) from BRRI dhan28 (Figure 4). Similar results also reported by Guilani *et al*. (2003) from earlier experiment.

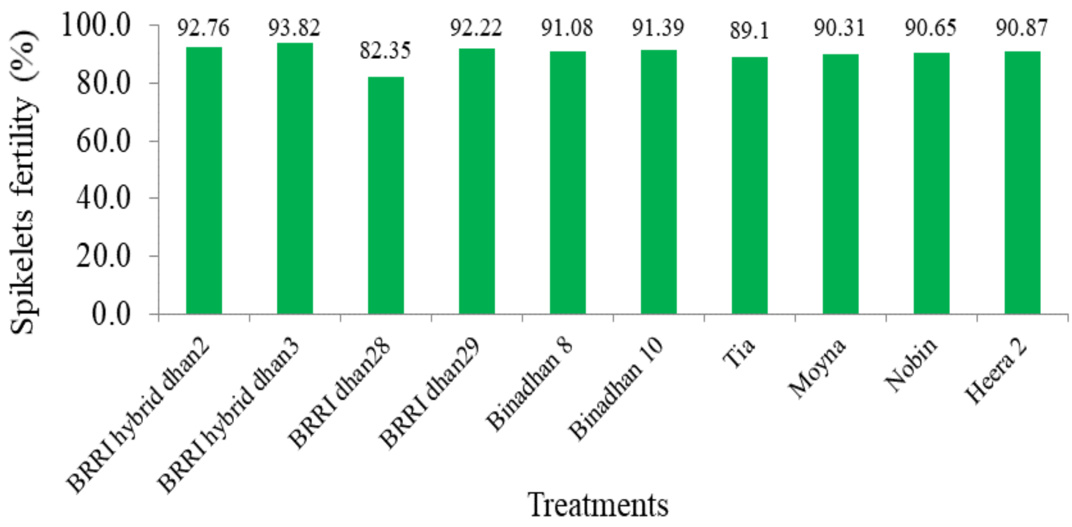

Figure 4. Spikelets fertility for different hybrid and inbred rice varieties in aerobic condition

4.2.8 Weight of 1000 grains

Statistically significant variation was observed in terms of weight of 1000 grains of different rice variety (Appendix XIII). The highest weight of 1000 grains (21.47 g) was recorded from BRRI hybrid dhan3 which was statistically similar with other rice varieties except BRRI dhan28, while the lowest weight (17.77 g) was found from BRRI dhan28 (Figure 5). Wang *et al*. (2006) reported that compared with conventional cultivars, the hybrids had heavier seeds.

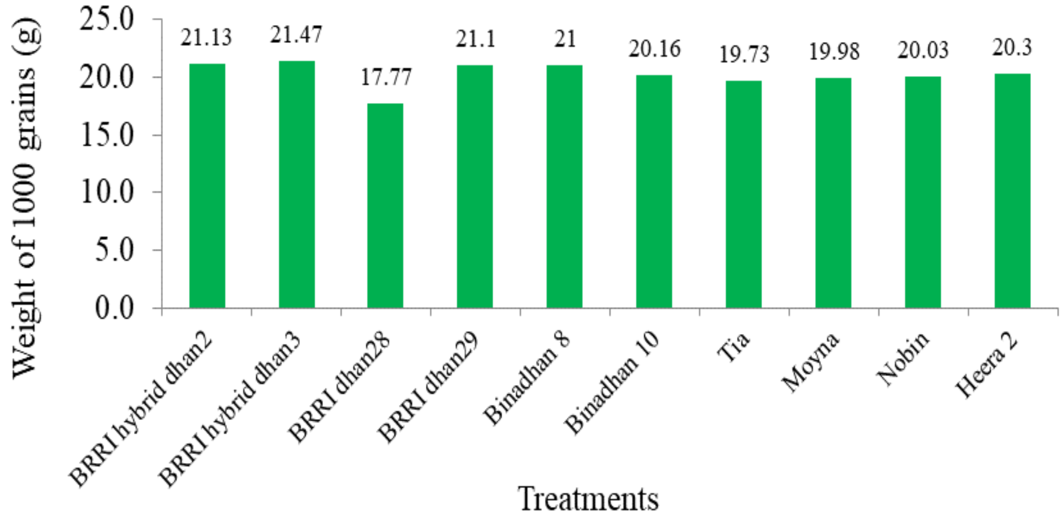

Figure 5. Weight of 1000 grains for different hybrid and inbred rice varieties in aerobic condition

4.2.9 Grain yield

Grain yield of different rice variety showed statistically significant differences under the present trial (Appendix XIII). The highest grain yield (5.17 t ha^{-1}) was recorded from BRRI hybrid dhan3 which was statistically similar (5.11, 4.90 and 4.83 t ha^{-1}) with BRRI hybrid dhan2, BRRI dhan29 and Binadhan 8 and followed (3.98 and 4.12 t ha^{-1}) by Heera and Binadhan 10, while the lowest grain yield (2.48 t ha^{-1}) was found from BRRI dhan28 which was statistically similar (3.37 and 3.39 t ha^{-1}) with Tia and Moyna (Table 11). Probably the highest grain yield of BRRI hybrid dhan3 were attained due to the production of highest number of total tillers $plant^{-1}$, total dry matter, crop growth rate, number of effective tillers $plant^{-1}$, panicle length, number of grans per $plant^{-1}$, 1000 grain weight, biological yield and harvest index by this rice variety in boro season. Wang *et al*. (2006) earlier reported that compared with conventional cultivars, the hybrids had larger panicles, heavier seeds, resulting in an average yield increase of 7.27%. Kanfany *et al*. (2014) reported that grain yield of rice hybrids (bred by the International Rice Research Institute) was not significantly higher than that of the check cultivar. Swain *et al*. (2006) reported that the control cultivar IR64, with high translocation efficiency and 1000-grain weight and lowest spikelet sterility recorded a grain yield of 5.6 t ha^{-1} that was statistically similar to the hybrid line PA6201. Xie *et al.* (2007) reported different yield for different variety.

4.2.10 Straw yield

Statistically significant variation was recorded in terms of straw yield of different rice variety (Appendix XIII). The highest straw yield (5.89 t ha^{-1}) was found from BRRI hybrid dhan3 which was statistically similar (5.85, 5.61 and 5.48 t ha^{-1}) with BRRI hybrid dhan2, Binadhan 8 and BRRI dhan29 and followed (5.07 t ha^{-1}) by Binadhan 10, while the lowest straw yield (3.72 t ha^{-1}) was found from BRRI dhan28 which was statistically similar (3.99 and 4.35 t ha^{-1}) with Tia and Moyna (Table 11). Patel (2000) observed significantly higher grain and straw yield from Kranti than IR36.

Table 11. Grains, straw and biological yield and harvest index for different hybrid and inbred rice varieties in aerobic condition

Rice variety	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
BRRI hybrid dhan2	5.11 a	5.85 a	10.96 a
BRRI hybrid dhan3	5.17 a	5.89 a	11.06 a
BRRI dhan28	2.48 e	3.72 f	6.21 f
BRRI dhan29	4.90 ab	5.48 a-d	10.38 abc
Binadhan 8	4.83 a-c	5.61 a-c	10.44 abc
Binadhan 10	4.12 b-d	5.07 b-e	9.19 bcd
Tia	3.37 de	3.99 f	7.36 ef
Moyna	3.39 de	4.35 ef	7.73 de
Nobin	3.90 cd	4.85 de	8.76 de
Heera 2	3.98 b-d	4.98 c-e	8.95 cd
$LSD_{(0.05)}$	0.875	0.682	1.423
CV(%)	12.07	7.88	7.89

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

4.2.11 Biological yield

Biological yield of different rice variety showed statistically significant differences under the present trial (Appendix XIII). The highest biological yield (11.06 t ha^{-1}) was found from BRRI hybrid dhan3 which was statistically similar (10.96, 10.44 and 10.38 t ha^{-1}) with BRRI hybrid dhan2, Binadhan 8 and BRRI dhan29 and followed (9.19 t ha^{-1}) by Binadhan 10, while the lowest biological yield (6.21 t ha^{-1}) was recorded from BRRI dhan28 which was statistically similar (7.36 t ha^{-1}) with Tia (Table 11). Haque *et al*. (2015) reported that greater remobilization of shoot reserves to the grain rendered also higher biological yield of hybrid rice varieties.

4.2.12 Harvest index

Statistically significant variation was recorded in terms of harvest index of different rice variety (Appendix XIII). The highest harvest index (47.07%) was observed from BRRI dhan29 which was statistically similar with other rice variety except BRRI dhan28, whereas the lowest harvest index (39.86%) was found from BRRI dhan28 (Figure 6). Patel (2000) observed significantly higher harvest index from rice variety Kranti than IR36.

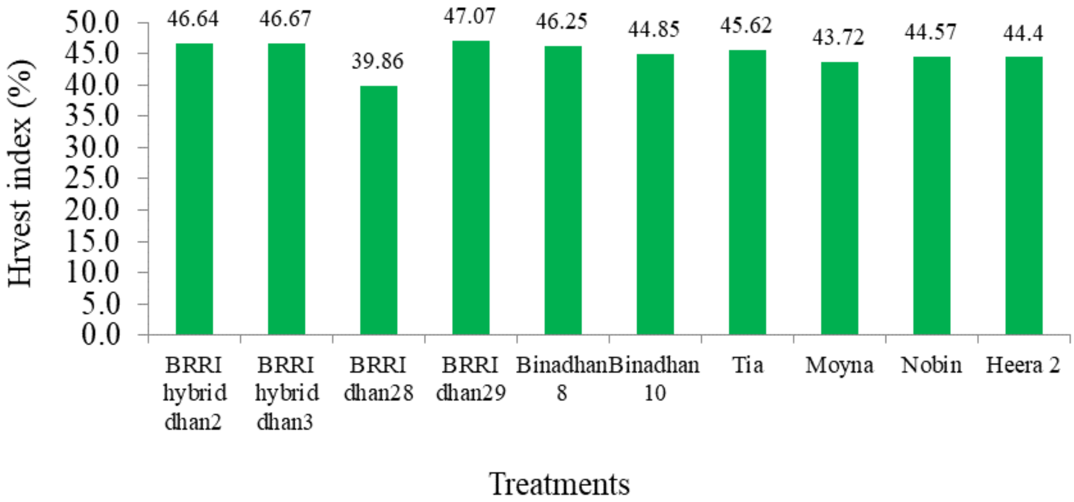

Figure 6. Harvest index for different hybrid and inbred rice varieties in aerobic condition

CHAPTER V

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the research field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka from November, 2017 to May, 2018 to study growth and yield performance of inbred and hybrid rice varieties in aerobic condition. Total 10 inbred and hybrid rice varieties were used in this experiment and they were BRRI hybrid dhan2, BRRI hybrid dhan3, BRRI dhan28, BRRI dhan29, Binadhan 8, Binadhan 10, Tia, Moyna, Nobin and Heera 2. The single factor experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were recorded on different yield attributes and yield and statistically significant variation was observed for different rice varieties.

At harvest, the tallest plant (109.65 cm) was observed from BRRI hybrid dhan3 and the shortest plant (91.19 cm) was recorded from BRRI dhan28. At harvest, the maximum number of tillers hill^{-1} (15.70) was recorded from BRRI hybrid dhan3, while the minimum number (9.67) was recorded from BRRI dhan28. At harvest, the maximum number of leaves plant^{-1} (65.88) was recorded from BRRI hybrid dhan3, while the minimum number (48.04) was recorded from BRRI dhan28. At 30, 50 and 70 DAT, the highest leaf area (36.48, 45.67 and 49.84 cm^2) was recorded from BRRI hybrid dhan3, whereas the lowest leaf area (25.53, 32.33 and 37.50 cm^2) was observed from BRRI dhan28. At 30, 50 and 70 DAT, the highest total dry matter m^{-2} (177.05, 546.13 and 875.16 g) was recorded from BRRI hybrid dhan3, while the lowest total dry matter m^{-2} (117.84, 347.43 and 752.66 g) was found from BRRI dhan28. At 30-50 DAT, the highest CGR (18.45 g m^{-2} day^{-1}) was recorded from BRRI hybrid dhan3, whereas the lowest CGR (10.84 g m^{-2} day^{-1}) was found from Nobin. At 50-70 DAT, the highest CGR (16.45 g m^{-2} day^{-1}) was recorded from BRRI hybrid dhan3, while the lowest CGR (9.32 g m^{-2} day^{-1}) was found from Heera 2. At 30-50 DAT, the highest NAR (7.85 g m^{-2} day^{-1}) was recorded from BRRI hybrid dhan3, whereas the lowest NAR (5.10 g m^{-2} day^{-1}) was found from Nobin At 50-70 DAT, the highest NAR (2.76 g m^{-2} day^{-1}) was recorded from Tia, while the lowest NAR (1.60 g m^{-2} day^{-1}) was found from Heera 2. The highest days from sowing to anthesis (103.67) was observed from BRRI dhan29 and the lowest (83.00 days) from Tia. The highest days from anthesis to maturity (52.33 days) was observed from BRRI dhan29 and the lowest (45.33 days) from Heera 2. The highest life duration from germination to maturity (156.00 days) was observed from BRRI dhan29 and the lowest (127.67 days) from Tia.

The maximum number of effective tillers $hill^{-1}$ (12.33) was recorded from BRRI hybrid dhan3, while the minimum number (6.13) was found from BRRI dhan28. The minimum number of non-effective tillers $hill^{-1}$ (2.17) was recorded from Tia, while the maximum number (3.53) was found from BRRI hybrid dhan2 and BRRI dhan28. The longest panicle (22.96 cm) was recorded from BRRI hybrid dhan3, while the shortest panicle (19.64 cm) was found from BRRI dhan28. The maximum number of filled grains $panicle^{-1}$ (86.50) was recorded from BRRI hybrid dhan2, whereas the minimum number (56.00) was found from BRRI dhan28. The minimum number of unfilled grains $panicle^{-1}$ (5.70) was recorded from BRRI hybrid dhan2, whereas the maximum number (12.00) was found from BRRI dhan28. The maximum number of total grains $panicle^{-1}$ (92.20) was recorded from BRRI hybrid dhan2, whereas the minimum number (68.00) was found from BRRI dhan28. The highest spikelets fertility (93.82%) was recorded from BRRI hybrid dhan3, whereas the lowest (82.35%) from BRRI dhan28.

The highest weight of 1000 grains (21.47 g) was recorded from BRRI hybrid dhan3, while the lowest weight (17.77 g) was found from BRRI dhan28. The highest grain yield (5.17 t ha^{-1}) was recorded from BRRI hybrid dhan3, while the lowest grain yield (2.48 t ha^{-1}) was found from BRRI dhan28. The highest straw yield (5.89 t ha^{-1}) was found from BRRI hybrid dhan3, while the lowest straw yield (3.72 t ha^{-1}) was found from BRRI dhan28 The highest biological yield (11.06 t ha^{-1}) was found from BRRI hybrid dhan3, while the lowest biological yield (6.21 t ha^{-1}) was recorded from BRRI dhan28. The highest harvest index (47.07%) was observed from BRRI dhan29, whereas the lowest harvest index (39.86%) was found from BRRI dhan28.

Conclusion:

1. Different growth and yield characteristics of different rice varieties differed significantly;
2. Among all the varieties BRRI hybrid dhan3 performed better in aerobic condition due to its highest number of effective tillers $plant^{-1}$, largest leaf area, highest total dry matter, highest crop growth rate, highest Net Assimilation Rate, highest panicle length, maximum number of grains $panicle^{-1}$, highest spikelet fertility that contribute higher yield.
3. BRRI hybrid dhan2 also performed better in aerobic condition due to its highest number of effective tillers $plant^{-1}$, largest leaf area, highest total dry matter, highest crop growth rate, highest Net Assimilation Rate, highest panicle length, maximum number of grains $panicle^{-1}$, highest spikelet fertility that contribute higher yield.

Recommendations:

Considering the situation of the present experiment, further studies in the following areas may be suggested:

1. More study is needed in different agro-ecological zones (AEZ) of Bangladesh for confirmation of the findings.
2. A comparative study is suggested between aerobic cultivation and traditional cultivation procedure.

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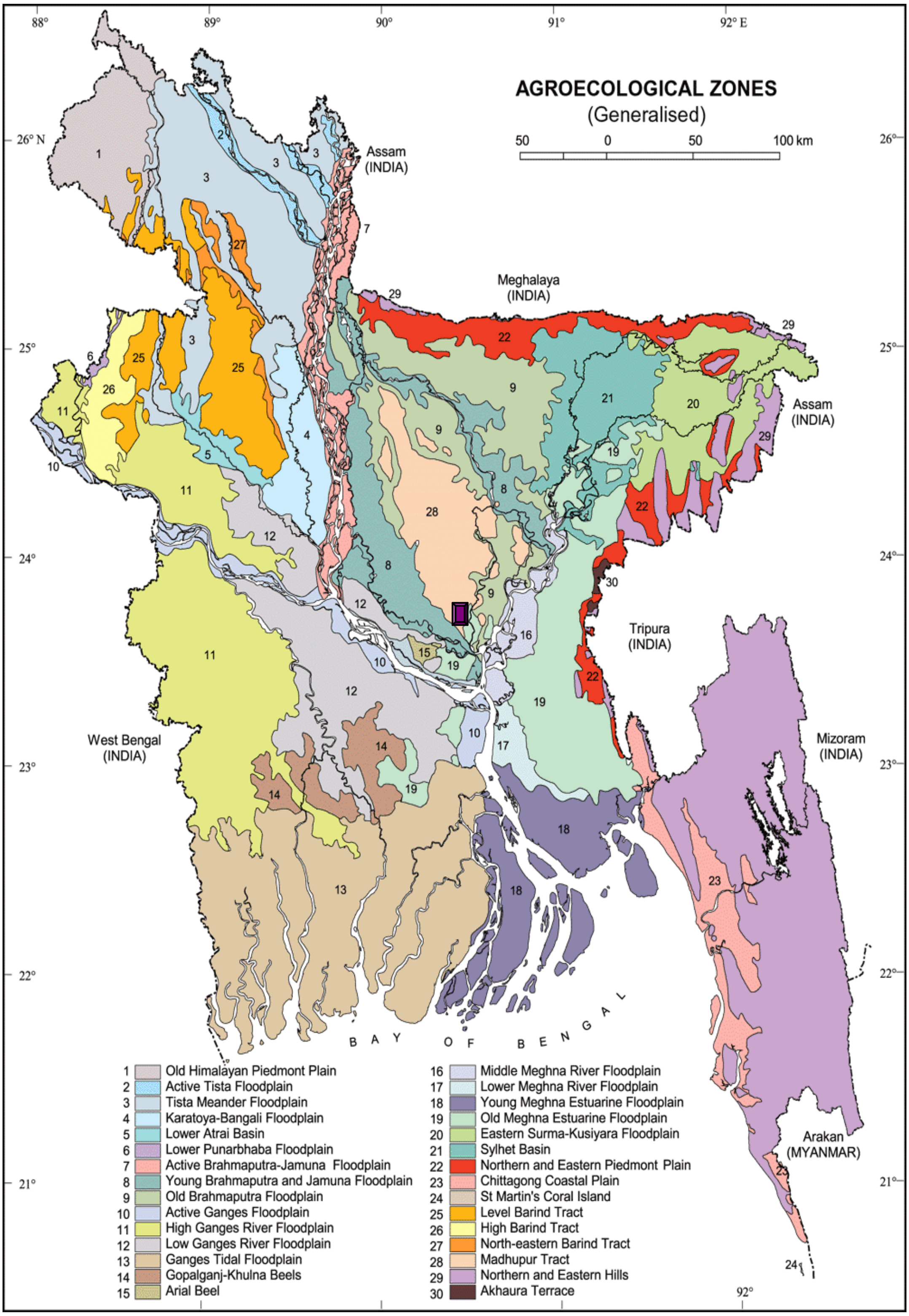
APPENDICES

APPENDICES

Appendix I. The Map of the experimental site



Appendix II. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2017 to May 2018

Month	Air temperature (ºc)		Relative humidity (%)	Total Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
November, 2017	25.8	16.0	78	00	6.8
December, 2017	22.6	13.4	78	05	6.6
January, 2018	24.9	12.2	64	00	5.8
February, 2018	27.7	16.9	69	30	6.7
March, 2018	31.4	19.6	67	18	8.4
April, 2018	34.4	23.1	79	128	8.3
May, 2018	34.8	25.3	70	183	7.7

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

Appendix III. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture farm 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

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	26
% Silt	43
% clay	31
Textural class	Sandy loam
pH	5.9
Catayan exchange capacity	2.64 meq 100 g/soil
Organic matter (%)	1.15
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI, Khamarbari, Farmgate, Dhaka

Appendix IV. Analysis of variance of the data on plant height of rice at different days after transplanting (DAT) and harvest as influenced by different variety

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm) at			
		30 DAT	50 DAT	70 DAT	at harvest
Replication	2	1.119	0.962	0.354	9.286
Rice Variety	9	20.506**	25.130*	58.770**	109.959**
Error	18	5.957	9.356	15.947	35.557

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on tillers hill^{-1} of rice at different days after transplanting (DAT) and harvest as influenced by different variety

Source of variation	Degrees of freedom	Mean square			
		Tillers hill^{-1} at			
		40 DAT	60 DAT	80 DAT	at harvest
Replication	2	0.085	0.493	1.166	0.800
Rice Variety	9	1.337**	7.901**	17.073**	17.474**
Error	18	0.161	1.667	2.477	2.556

**: Significant at 0.01 level of probability

Appendix VI. Analysis of variance of the data on number of leaves plant^{-1} of rice at different days after transplanting (DAT) and harvest as influenced by different variety

Source of variation	Degrees of freedom	Mean square			
		Number of leaves plant^{-1} at			
		40 DAT	60 DAT	80 DAT	at harvest
Replication	2	0.575	0.112	0.680	0.136
Rice Variety	9	25.191**	124.640**	59.497**	118.341**
Error	18	1.387	8.118	6.122	6.837

**: Significant at 0.01 level of probability

Appendix VII. Analysis of variance of the data on leaf area of rice at different days after transplanting (DAT) as influenced by different variety

Source of variation	Degrees of freedom	Mean square		
		Leaf area (cm^2) at		
		40 DAT	60 DAT	80 DAT
Replication	2	1.102	0.182	2.116
Rice Variety	9	54.691**	68.850**	10.417**
Error	18	2.073	2.950	2.399

**: Significant at 0.01 level of probability

Appendix VIII. Analysis of variance of the data on total dry matter (TDM) m^{-2} of rice at different days after transplanting (DAT) as influenced by different variety

Source of variation	Degrees of freedom	Mean square		
		Total dry matter m^{-2} (g) at		
		40 DAT	60 DAT	80 DAT
Replication	2	25.547	1640.718	3107.890
Rice Variety	9	992.932**	11473.304**	26929.432**
Error	18	88.352	1144.662	6625.508

**: Significant at 0.01 level of probability

Appendix IX. Analysis of variance of the data on Crop Growth Rate (CGR) and Net Assimilation Rate (NAR) of rice at different days after transplanting (DAT) as influenced by different variety

Source of variation	Degrees of freedom	Mean square			
		Crop Growth Rate-CGR ($g\ m^{-2} day^{-1}$) at		Net Assimilation Rate-NAR ($g\ m^{-2} day^{-1}$) at	
		30-50 DAT	50-70 DAT	30-50 DAT	50-70 DAT
Replication	2	3.145	2.362	0.979	0.477
Rice Variety	9	15.398**	25.758*	2.146**	1.575*
Error	18	1.826	11.749	0.443	0.322

**: Significant at 0.01 level of probability;

Appendix X. Analysis of variance of the data on days from sowing to anthesis, duration from anthesis to maturity and life duration from germination to maturity as influenced by different variety

Source of variation	Degrees of freedom	Mean square		
		Days from sowing to anthesis	Duration from anthesis to maturity (days)	Life duration from germination to maturity (days)
Replication	2	3.561	1.453	2.672
Rice Variety	9	44.562*	37.562*	69.563*
Error	18	10.451	8.452	13.782

*: Significant at 0.05 level of probability

Appendix XI. Analysis of variance of the data on number of effective, non-effective tillers hill^{-1} and length of panicle of rice as influenced by different variety

Source of variation	Degrees of freedom	Mean square		
		Number of effective tiller hill^{-1}	Number of in-effective tiller hill^{-1}	Length of panicle (cm)
Replication	2	0.675	0.082	1.131
Rice Variety	11	9.726**	0.639**	11.535**
Error	22	0.993	0.177	1.747

**: Significant at 0.01 level of probability

Appendix XII. Analysis of variance of the data on filled, unfilled, total grains and fertility of rice as influenced by different variety

Source of variation	Degrees of freedom	Mean square			
		Number of filled grain plant^{-1}	Number of unfilled grain plant^{-1}	Number of total grain plant^{-1}	Fertility (%)
Replication	2	20.243	0.916	12.791	2.1672
Rice Variety	11	207.04**	8.323**	136.37**	128.672**
Error	22	23.703	1.080	16.377	15.453

**: Significant at 0.01 level of probability

Appendix XIII. Analysis of variance of the data on weight of 1000 grains, grains, straw and biological yield and harvest index of rice as influenced by different variety

Source of variation	Degrees of freedom	Mean square				
		Weight of 1000 Seed (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
Replication	2	0.426	0.251	0.177	0.791	2.428
Rice Variety	11	2.986*	2.295**	1.686**	7.844**	12.367**
Error	22	1.204	0.267	0.162	0.706	4.166

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability