PERFORMANCE OF HYBRID AND MODERN INBRED RICE VARIETIES UNDER AEROBIC CONDITION

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CERTIFICATE

This is to certify that the thesis entitled "**PERFORMANCE OF HYBRID AND MODERN INBRED RICE VARIETIES UNDER 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 (M.S.) in AGRICULTURAL BOTANY, embodies the results of a piece of bona-fide research work carried out by DILRUBA AKTER LUCKY, Registration No. **17-08285**, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

I further certify that any help or sources of information received during the course of this investigation have duly been acknowledged**.**

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ABSTRACT

The field experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka during November, 2017 to June, 2018 to study the performance of hybrid and modern rice varieties under aerobic condition. The experimental treatments comprised of five varieties (V_1= BRRI dhan 29, V_2= Hybrid-3, V_3= Moina, V_4= Nobin and V_5= Hira-2) and different cultivation methods T_1 =SRI Method, T_2 = raised upland and T_3= Traditional). The experiment was laid out in Randomized Complete Block Design (RCBD) with 3 replications. The unit size of the plot was 4.0 m × 2.5 m. Data on plant height, number of tillers and leaves hill^{-1} were recorded at 45 DAT, 60 DAT, 75 DAT, 85 DAT and at harvest. And leaf length and leaf breath were at 60 DAT, 75 DAT and 85 DAT. The variety Nobin (V_4) provided the highest significant performance in respect of plant height (36.24, 66.01, 82.94, 96.57 and 112.78 cm), number of tillers (6.58, 13.78, 15.58, 18.87 and 14.98), number of effective tillers hill^{-1} (13.56), leaves hill^{-1} (20.34, 44.29, 40.83, 54.84 and 50.28), leaf length (38.56, 35.56 and 48.20cm), leaf breath (0.88, 1.39 and 1.68cm), flag leaf length (34.18cm), flag leaf breadth (1.57cm), penultimate leaf length (41.68cm), dry weight of three leaves (0.63 g), penultimate leaf breadth (1.42cm), dry weight of leaves (16.48 g), chlorophyll content (50.36 mg g^{-1}), dry stem weight (55.59 g), number of panicle (10.06), panicle height (101.22cm), panicle length (25.60 cm), panicle weight (17.91g), 1000-grain weight (26.14 g), highest grain yield (5.20 t ha^{-1}) and highest straw yield (5.20 t ha^{-1}). T_3 (traditional method) exhibited the highest significant performance in respect of number of tillers (6.65, 13.68,15.98,15.51 and 14.20), number of effective tillers hill^{-1} (13.27), number of leaves hill^{-1} (21.13, 45.62, 41.15, 46.20 and 49.26), number of leaves hill^{-1} (21.13, 45.62, 41.15, 46.20 and 49.26), leaf length (38.50, 35.70 and 46.03cm), leaf breadth (0.82, 1.35 and 1.64cm, flag leaf length (33.24cm) , flag leaf breadth (1.45cm) , penultimate leaf length (38.55cm), penultimate leaf breadth (1.44cm), dry weight of leaves (15.77g), dry weight of three leaves (0.63g), dry stem weight (51.04g), chlorophyll content (50.62 mg g^{-1}), number of panicle (8.40), panicle height (96.21cm), panicle weight (16.13g), 1000-grain weight (26.38g), highest grain yield (5.38 t ha^{-1}) and highest straw yield (5.54t ha^{-1}). The highest plant height obtained from T_2 (raised upland) was recorded 35.44, 61.70, 76.51, 88.31 and 105.27cm. The maximum (1.60) number of effective tillers hill^{-1} was obtained from T_1. There was significant effect of variety and aerobic condition. The interaction V_4T_3 showed the highest significant performance in respect of plant height 37.97, 70.17, 51, 87.40, 101.23 and 115.67 cm, number of tiller (7.67, 17.57, 17.07, 19.97 and 18.33), number of effective tillers hill^{-1} (16.67), number of leaves hill^{-1} (23.00, 47.67, 53.07, 60.30 and 62.00), leaf length (42.33, 37.67 and 54.13cm), flag leaf length (39.80cm), flag leaf breadth (1.80cm), penultimate leaf length (44.00cm), penultimate leaf breadth (1.82cm), dry weight of leaves (20.50g), dry weight of three leaves (0.80g), dry stem weight (61.10g), chlorophyll content (61.00 mg g^{-1}), number of panicle (11.17), panicle height (103.00cm), panicle length (26.73 cm), panicle weight (20.63g), 1000-grain weight (26.23g), highest grain yield (5.60 t ha^{-1}) and highest straw yield (5.73 t ha^{-1}). The highest leaf length of rice plants that received from V_3T_3. So, it may be concluded that the V_4 (Nobin) and T_3 (traditional) as singly or their interaction were more successful for produce the highest results.

CONTENT

CONTENTS (Contd.)

LIST OF TABLES

LIST OF APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

AEZ	Agro Ecological Zone
Anon.	Anonymous
AIS	Agriculture Information Service
BARC	Bangladesh Agricultural Research Council
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BNNC	Bangladesh National Nutrition Council
BRRI	Bangladesh Rice Research Institute
CV%	Percentage Coefficient Variance
cv.	Cultivar (s)
cm	Centi-meter
DAT	Days After Transplanting
DOASL	Department of Agriculture Government of Sri Lanka
et al.	Et alii (And others)
etc.	Et cetra (And other similar things)
FAO	Food and Agriculture Organization
g	Gram
Ha	Hectare
HI	Harvest Index
i.e.	Id est (that is)
IRRI	International Rice Research Institute
Kg	Kilogram
L	Liter
L.	Linnaeus
LSD	Least Significant Differences
M	Meter
MoP	Muriate of Potash
RCBD	Randomized Completely Block Design
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
ssp.	Sub-species
TSP	Triple Super Phosphate
viz.	Namely

CHAPTER

INTRODUCTION

Rice (*Oryza sativa* L.) is an annual cereal crop belonging to the family of Poaceae. Rice is the most important food crop of the world and the staple food of more than half of the world's population (IRRI, 2015). Millions of people in Asia subsist entirely on rice and over 90% of the world's rice is grown and eaten in Asia (BBS, 2013). It plays a vital role in the economy of Bangladesh providing significant contribution to the GDP, employment generation and food availability. In Bangladesh, rice is the most extensively cultivated cereal crop. At present, rice along constitutes about 93% of the total food grains produced annually in the country (BER, 2013). It provides about 62% of the calorie and 46% of the protein in the average daily diet of the people (HIES, 2010). It also ensures political stability for the country and provides a sense of food security to the people. The climatic and edaphic conditions of Bangladesh are favorable for rice cultivation throughout the year. It provides nearly 48% of rural employment, about two-third of total calorie supply and about one-half of the total protein intakes of an average person in the country (BBS, 2013). Thus, rice plays a vital role in the livelihood of the people of Bangladesh. Among the rice growing countries, Bangladesh occupies third position in rice area and fourth position in rice production (BRRI, 2013). But the average yield is quite low compared to that in other leading rice growing countries.

In Bangladesh, agriculture is dominated by intensive rice cultivation. Globally, rice is the second most important cereal crop to wheat in terms of area but as food it is the most important since it provides more calorie than any other cereals. Rice, as the single most important human energy source, feeds about half of the world's population (IRRI, 1989). Among the major rice growing countries of the world, Bangladesh ranks third in respect of growing area and fourth in respect of production. In Bangladesh, rice ranks first in terms of both area and production. Rice is not only the foremost staple food, it also provides nearly 40% of total national employment (48% of total rural employment), about two-thirds of total calorie supply and about half of the total protein intake of an average person in the country (Bhuiyan and Karim, 1999).

Rice is cultivated in Bangladesh throughout the year as *Aus, Aman* or *Boro* seasons. Among these *Boro* is most important and occupied about 41% of the rice cultivated land in 2009-10.

The rest 46, 9 and 4 percent of the land is occupied by *Aman, Aus* and Sown *Aman* respectively (BRRI, 2017). According to Annual Report 2016-17 statistics, rice is grown in 114 countries across the world in an area of 161.35 million hectares with a production of 480.13 million metric tons and the productivity is 4.44 t ha^{-1}. The production of total rice in Bangladesh is about 31.98 million metric tons where *Boro* covers the largest part of about the production of 18.06 million metric tons. In *Boro* season hybrid rice covers about 6.86 lac hectares area with production of 32.2 lac metric tons, respectively (BBS, 2010). There has been a three-fold increase in rice production in Bangladesh, which jumped from nearly 11 MT in 1971-72 to about 34.86 MT in 2014-15 (AIS, 2016). Among the rice growing countries, Bangladesh occupies third position in rice area and fourth position in rice production (BRRI, 2012).

Bangladesh is a densely populated country and at present its population growth rate is 1.37%. Rice crop area is decreasing day by day due to high population pressure. Therefore, attempts should be taken to increase the yield per unit area by applying improved technology and proper management of fertilizers to achieve the goal of self-sufficiency in rice production. About 84.67% of cropped area of Bangladesh is used for rice production, with annual production of34.42 million tons from 10.4 million ha of land (BBS, 2013). It grows in all the three crop growing seasons (*Aman, Boro* and *Aus*) of the year and occupies about 77% (11.42 M ha) of the total cropped area of about 14.94 M ha. Aus rice covers 1.05 million hectares of land with a production of 2.16 million tons rice (BBS, 2013). The Government of Bangladesh has given top priority for increasing the area and production of Aus rice to reduce the pressure on electricity for irrigation needed for *Boro* rice production during dry season. But the main drawback is that average yield of Aus rice (2.16 tha^{-1}) is lower than *Aman* and *Boro* season.

Hybrid rice varieties have 15-30% yield advantage over modern inbred one (Julfiquar *et al.*, 2009; Abou Khalifa, 2009). Slow senescence and more strong photosynthetic capability of flag leaf, higher LAI at grain filling period and higher post heading-CGR plays major role for higher yield formation in hybrid rice (Tang *et al*., 2010; Haque *et al*., 2015). Greater biomass accumulation before heading and higher shoot reserve translocation are the decisive factors of higher yield in hybrids (Chen *et al.*, 2012; Haque *et al.*, 2015).

Bangladesh Rice Research Institute (BRRI) has developed 73 inbred and 4 hybrid rice varieties (AIS, 2016) adaptive for production in different agro-ecological zones of Bangladesh. Rice covers 11372.071 hectare of our land area which is 78.16% of total cropped area in Bangladesh (BBS, 2014).

Aerobic system of rice cultivation 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) i. e. it requires less water than lowland rice. In aerobic system, water is made available (through rain-fed or irrigation practice) to a level when the plant really deserves it to maintain its sound physiological system.

In general, hybrids are known to have more tolerance to abiotic stresses because of their genetic plasticity (BRRI, 2013). As far as it is known, no hybrid rice variety has been released in Bangladesh considering the case of aerobic condition. So, suitability of hybrid rice varieties is to be found out for aerobic situation. Since hybrid rice is a new introduction to our country and for the same reason, not much research works have been done on it. Research on aerobic cultivation of hybrid rice is absent or meager in Bangladesh. So, it is imperative/ needed to generate information on agronomic and physiological performance of hybrid rice varieties in aerobic condition for extending/ intensify its cultivation at irrigation limited area in *Boro* season. Under these circumstances, the present research work were designed and under taken to evaluate the performance of hybrid and modern inbred rice varieties under aerobic conditions.

OBJECTIVES:

- To compare the growth behaviour and yield performance of hybrid and modern inbred rice varieties under aerobic condition.
- To find out the suitable of hybrid and modern inbred varieties for aerobic condition.

CHAPTER II

REVIEW OF LITERATURE

Rice (*Oryza sativa* L.) is one of the most labour intensive crops of the world. Growth and development of rice plants are greatly influenced by the environmental factors i.e. air, day length or photoperiod, temperature, variety and agronomic practices like transplanting time, spacing, number of seedlings, age of seedlings, depth of planting, PGS and fertilizer management etc. In this chapter the available relevant reviews related to the research done elsewhere in the world in the recent past have been presented below under the following heads.

Effect of varieties

Hasan (2007) has found that plant height, effective tillers hill^{-1}, grains panicle^{-1} and straw yield t ha^{-1} differed significantly among the varieties. Islam (1995) found that among the four modern rice varieties (viz., BR10, BR11, BR22 and BR23), the highest and the lowest number of non-bearing tillers hill^{-1} were produced by cultivar BR11 and BR10, respectively.

Sarkar *et al*. (2014) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, to study the yield and quality of aromatic fine rice as affected by variety and nutrient management during the period from June to December 2013. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38, and eight nutrient managements viz. control (no manures and fertilizers), recommended dose of inorganic fertilizers, cow-dung at 10 t ha^{-1}, poultry manure at 5 t ha^{-1}, 50% of recommended dose of inorganic fertilizers + 50% cow-dung, 50% of recommended dose of inorganic fertilizers + 50% poultry manure, 75% of recommended dose of inorganic fertilizers + 50% cow-dung and 75% of recommended dose of inorganic fertilizers + 50% poultry manure. He reported that the tallest plant (142.7 cm), the highest number of effective tillers hill^{-1} (10.02), number of grains panicle (152.3), panicle length (22.71cm), 1000-grain weight (15.55g) and grain yield (3.71 hill^{-1}) were recorded in BRRI dhan34. He also showed that the highest grain yield (4.18 hill^{-1}) was found in BRRI dhan34 combined with 75% recommended dose of inorganic fertilizers + 50% cow-dung, which was statistically identical to BRRI dhan34 combined with 75% of recommended dose of inorganic fertilizers + 50% poultry manure and the lowest grain yield (2.7 t ha^{-1}) was found in BRRI dhan37 in control (no manures and fertilizers).

Koffi Djaman *et al*. (2016) conducted an experiment at Ndiaye and Fanaye (Senegal) during the hot and dry season 2012 and the wet season 2012 to evaluate the effect of nitrogen on rice yield and nitrogen use efficiency under phosphorus and potassium omission management. Five rates of nitrogen (0, 60, 90, 120 and 150 kg ha^{-1}) were associated with P (26 kg P ha^{-1}); or P-K (26 kg P ha^{-1} and 50 kg K ha^{-1}). Four aromatic rice varieties Pusa Basmati, Sahel 329, Sahel 177 and Sahel 328 and a non-aromatic variety Sahel 108 were evaluated. He found that the highest grain yield was obtained by Sahel 177 among the aromatic rice varieties.

Hossain (2007) conducted an experiment during the *Aman* season of 2006 with five varieties of transplant *Aman* rice (viz., BRRI dhan30, BRRI dhan32, BRRI dhan34, BRRI dhan39, and Nizershail). The varieties showed significant variation on all the yield contributing characters and yield except panicle length.

Rahman (2006) found that number of effective and non-effective tillers $hill^{-1}$, panicle length and 1000 grain failed to show any significant difference in BRRI dhan28 and BRRI dhan29 varieties of rice.

Chowdhury *et al.* (1993) observed that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters such as number of productive tillers $hill^{-1}$, length of panicle, 1000-grain weight, grain yield and straw yield.

Hossain *et al*. (2003) conducted experiment with rice *cv.* Sonar Bangla-1, BRRI dhan39 and Nizershail and reported that the highest grain yield was obtained from Sonar Bangla-1 followed by BRRI dhan39 and Nizershail. Roman (1997) reported that all the five rice cultivars studied significantly differed for the yield contributing characters and BR11 produced the highest grain yield followed by BR10, BR22, BR23 and Nizershail.

Hasan *et al*.(2002) observed that BRRI dhan34 produced the highest number of grains $panicle^{-1}$, grain yield (4.87 t ha^{-1}) and straw yields (7.72 t ha^{-1}) compared to Sonar Bangla-1 and Alok 6201 (4.28 t ha^{-1} and 3.86 t ha^{-1}, respectively).

Rahman *et al.* (2002) carried out an experiment with 4 varieties of transplant *Aman* rice viz., BR11, BR22, BR23 and Tulshimala and found that 1000-grain weight and grain yield were highest in BR23 and these were the lowest in Tulshimala.

BRRI (2000) evaluated yield performance of three high yielding varieties namely BRRI dhan30, BRRI dhan31, BRRI dhan32 in *Aman* season and revealed that effective tillers hill^{-1} of the above mentioned varieties were 7, 8 and 8, respectively. BRRI (1991) concluded that plant height, total tillers hill^{-1} and the number of spikelets panicle^{-1} differed significantly among BR3, BR11, Pajam and Jagali varieties in *Boro* season.

Kamal *et al.* (1999) conducted an experiment with 17 modern rice cultivars grown under irrigated condition in December 1993-April 1994 at the Agronomy Field Laboratory of Bangladesh Agricultural University, Mymensingh. The highest grain yield was obtained in BR18 (4.94 t ha^{-1}) followed by BR9, BR14 and BR3. They also found that straw yield was the highest in BR18 (6.25 t ha^{-1}) followed by BR3, BR14 and BR9.

Julfiquar *et al.* (1998) evaluated the thirteen rice hybrids at three locations of BADC farm during the *Boro* season of 1995-96. Two hybrids out yielded the check variety of same duration by more than 1 t ha^{-1}.

Shamsuddin *et al*. (1988) conducted a field trial with 9 different rice varieties and observed that plant height; panicle number hill^{-1} and 1000grain weight differed significantly among the varieties.

BRRI (1997) reported that the weight of 1000-grain of Halio, Tilockachari, Nizershail and Latishail was 26.5 g, 27.7 g and 25.0 g, respectively. The average plant height of BRRI dhan 30,BR22, BR23 and IRATOM-24 were 120 cm, 125 cm and 80 cm, respectively (BRRI, 1995).

Wong *et al*. (1997) reported that plant height significantly differed among high yielding and local varieties. Khisha (2002) observed that the plant height was significantly influenced by variety. He found the highest plant height (128.44 cm) in BINA dhan5, which was significantly higher than those of Sonar Bangla^{-1} and BRRI dhan29.

BRRI (1994) found out the performance of BR14, Pajam, BR5 and Tulshimala. The variety Tulshimala produced the highest and BR14 produced the lowest number of spikelet. They observed that the finer the grain size, the higher was the number of spikelet.

Babiker (1986) carried out an experiment with rice *cv.* Giza 171 and Giza 180 and reported that total tillers hill^{-1} were significantly affected by the cultivars.

BINA (1993) evaluated the performance of three advanced rice line and one variety viz. IRATOM24, BR14, BINA13 and BINA19. It was found that varieties/advanced lines differed significantly for plant height, number of non-bearing tillers, panicle length and sterile spikelet panicle^{-1} except grain yield.

Haque *et al*. (2013) conducted in 2009 and 2010 to evaluate some physiological traits and yield of three hybrid rice varieties (BRRI hybrid dhan2, Heera2, and Tia) in comparison to BRRI dhan48 in Aus season. The experiments involved four planting dates (1 April, 16 April, 1 May and 16 May). Compared to BRRI dhan48, hybrid varieties accumulated greater shoot dry matter at anthesis, higher flag leaf chlorophyll at 2, 9, 16 and 23 days after flowering (DAF), flag leaf photosynthetic rate at 2 DAF and longer panicles. However, hybrid varieties demonstrated smaller remobilization of shoot reserve to grain and photosynthetic rate of its flag leaf at 9 and 16 DAF than BRRI dhan48. Heera2 and BRRI hybrid dhan2 maintained significantly higher chlorophyll a, b ratio over Tia and BRRI dhan48 at 2, 9, 16 and 23 DAF in their flag leaf. Shoot reserve remobilization to grain exhibited higher degree of sensitivity to rising of minimum temperature in the studied hybrids compared to the inbred.

Main *et al*. (2007) stated that in south and Southeast Asia, floodwater may remain for more than a month during the period of *Aman* rice grown with maximum submergence reaching to about 50-400 cm in depth. Comparative submergence by flash floods has been reported as a major production constraint in about 25 million ha of low land in this region. Although rice is adapted to lowland, complete submergence for more than 2-3 days killed most of the rice cultivars. This type of damage would be rather serious for dwarf and semi dwarf varieties, which cause total crop losses. Horizontal expansion of *Aman* rice area is not possible due to high human population pressure on land. Therefore, it is an urgent need of the time to increase rice production through increasing the yield of *Aman* rice at farmers level using inbreed and hybrid varieties. There are different methods of planting such as direct seedlings (haphazard and line sowing), transplanting of seedlings (haphazard and line sowing), transplanting of clonal tillers. The vegetative propagation of using clonal tillers separated from previously established transplanted crop was beneficial for restoration of a damaged crop of *Aman* rice where maximum number of filled grain per panicle (173.67), the highest grain yield (4.96 t ha^{-1}) was obtained with the clonal tillers followed by nursery seedlings the highest harvest index (49.04%) was found from the clonal tillers those were statistically similar with nursery seedlings.

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.

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, heavier seeds, resulting in an average yield increase of 7.27%.

Chowdhury *et al*. (2005) conducted an experiment with 2, 4 and 6 seedlings hill^{-1} to study their effect on the yield and yield components of rice varieties BR23 and Pajam during the *Aman* season. They reported that the cv. BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e. number of productive tillers hill^{-1}, length of panicle, l000-grain weight, grain yield and straw yield. On the other hand, the cultivar Pajam produced significantly the tallest plant, total number of grains panicle^{-1}, number of filled grains panicle^{-1} and number of unfilled grains panicle^{-1}.

Islam *et al*. (2009) conducted pot experiments during T. *Aman* 2001 and 2002 (wet season) at Bangladesh Rice Research Institute (BRRI) in net house. Hybrid variety Sonarbangla-1 and inbred modern variety BRRI dhan31 were used in both the seasons and BRRI hybrid dhan l was used in 2002.

Abou-Khalif (2009) conducted in the experimental farm of Rice Research and Training Center (RRTC)- Sakha, Kafr- El Sheikh Governorate, and Egypt during rice season in 2008 for physiological evaluation of some hybrid rice varieties in different sowing dates. Four hybrid rice H1, H2, GZ 6522 and GZ 6903 were used. Seeds were sown on six different sowing dates April 10th, April 20th, May 1st, May 10th, May 20th and June 1st; and seedlings of 26 days old were transplanted at 20×20 cm spacing. All agricultural practices recommended for each cultivar were applied. Nitrogen fertilizer was used as urea (46.5% N) in two splits; that is, 2/3 were added and mixed in dry soil before flooding of irrigation water and the other 1/3 was added at panicle initiation stage. Experimental design was spilt plot design, with sowing dates as main and varieties as sub plot treatments. Results indicated that early date of sowing (April 20th) was superior to other dates of sowing for MT, PI, HD, number of tillers m^{-2}, (plant height and root length) at PI and HD stage, chlorophyll content, number of days up to PI and HD, leaf area index, sink capacity , number of grains $panicle^{-1}$, panicle length(cm), 1000-grain weight (g), number of panicles m^{-2}, panicle weight (g) and grain yield (ton ha^{-1}). Sterility percentage was the lowest in sowing 20th April. 1st of June, sowing gave the lowest with all traits under study. H1 hybrid rice variety surpassed other varieties for all characters studied except for number of days to PI and HD.

Anwar and Begum (2004) reported that time of tiller separation of rice significantly influenced plant height, total number of tiller $hill^{-1}$, number of bearing tillers and panicle length but grain and straw yields were unaffected. Therefore, Sonarbangla-1 appeared to be tolerant to tiller separation and separation should be done between 20 to 40 DAT without hampering grain yield.

Bokyeong *et al*. (2003) reported that applied with same nitrogen dose Sindongjinbyeo and Iksan467 gave high primary rachis branches than Sindongjinbyeo and Dongjin No. 1 varieties.

Dongarwar *et al*. (2003) comprised an experiment to investigate the response of hybrid rice KJTRH-1 in comparison with 2 traditional cultivars, Jaya and Swarna, to 4 fertilizer rates, i.e. 100:50:50, 75:37.5:37.5, 125:62.5:62.5 and 150:75:75 kg NPK ha^{-1} and reported that KJTRH-1 produced significantly higher yield (49.24 q ha^{-1}) than Jaya (39.64 q ha^{-1}) and Swarna (46.06 q ha^{-1}).

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

Swain *et al.* (2006) evaluated in a field experiment the performance of rice hybrids NRH1, NRH3, NRH4, NRH5, PA6111, PA6201, DRRH1, IR64, CR749-20-2 and Lalat conducted in Orissa, India during 1999-2000. Among the hybrids tested, PA 6201 recorded the highest leaf area index.

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 (5268 kg ha^{-1}) out yielded the other genotypes and recorded the maximum number of filled grains and had lower spikelet sterility (25.85%) compared to the others.

Sumit *et al*. (2004) worked with newly released four commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar dhan1) and two high yielding cultivars (HYV) as controls (Pant dhan4 and Pant dhan12) and reported that KHR 2 gave the best yield (7.0 t/ha) among them.

Obulamma *et al*. (2002) performed an experiment with hybrid rice DRRHI and APHR-2 at Andhra Pradesh, India. The treatments were 4 spacing (15cm x10cm, 20cm x 10cm, 15cm x 15cm and 20cm x15 cm) and 3 seedling densities (1, 2 and 3 seedlings hill-1). APHR-2 was found to produce higher yield than DRRH-l.

Xu and Wang (2001) evaluated ten restorer and ten maintainer lines. They observed that the restorer lines showed more spikelet fertility than maintainer lines. They studied growth duration, number of effective tillers, number of spikelets $panicle^{-1}$ and adaptability.

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.

Dwarfness may be one of the most important agronomic characters, because it is often accompanied by lodging resistance and thereby adapts well to heavy fertilizer application (Futsuhara and Kikuchi, 1984).

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}) and filled grains $panicle^{-1}$ (111.0) than other varieties, whereas IR36 gave the highest 1000-grain weight (21.07 g) and number of panicles m^{-2}than other tested varieties. In a trial, varietal differences inharvest index and yield examined using 60 Japanese varieties and 20 high yielding varieties bred in Asian countries.

It was reported that harvest index varied from 36.8% to 53.4%. Mean values of harvest index were 43.5% in the Japanese group and 48.8% in high yielding group. Yield ranged from 22.6 g $plant^{-1}$ to 40.0 g $plant^{-1}$.

Chen-Liang *et al*. (2000) showed that the cross between Peiai 64s and the new plant type lines had strong heterosis for filled grains $plant^{-1}$, number of spikes $plant^{-1}$ and grain weight $plant^{-1}$, but heterosis for spike fertility was low.

Julfiquar *et al*. (1998) reported that BRRI evaluated 23 hybrids along with three standard checks during Boro season 1994-95 as preliminary yield trial at Gazipur and it was reported that five hybrids (IR58025A/IR54056, IR54883, PMS8A/IR46R) out yielded the check varieties (BR14 and BR16) with significant yield difference. They also reported that thirteen rice hybrids were evaluated in three locations of BADC farm during Boro season of 1995-96. Two hybrids out yielded the check variety of same duration by more than 1 t ha^{-1}.

Om *et al*. (1999) conducted a field experiment with four varieties (3 hybrids: ORI 161, PMS 2A, PMS 10A and I inbred variety HKR 126) during rainy season and observed that hybrid ORI 161 exhibited superiority to other varieties in grain yield and straw yield.

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, were 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.

Devaraju *et al*. (1998) in a study with hybrid rice cultivar KRH2 and 1R20 as a check variety having different levels of N from 0 to 200 kg N ha^{-1} found that KRH2 out yielded IR20 at all levels of N.

Devaraju *et al*. (1998) in a study with two rice hybrids such as Karnataka Rice Hybrid 1 (KRH1) and Karnataka Rice Hybrid-2(KRI42) using HYV IR20 as the check variety and found that KRH2 out yielded than IR20. In IR20, the tiller number was higher than that of KRH2.

Mishra and Pandey (1998) evaluated standard heterosis for seed yield in the range of 44.7 to 230.9% and 42.4 to 81.4%, respectively. Plant height, panicles $plant^{-1}$, grains panicle-1 and 1000 grain weight increase the yield in modern varieties.

Tac *et al*. (1998) conducted an experiment with two rice varieties, Akitakomachi and Hitombore in Tohoku region of Japan. It was found that Hitombore yielded the highest (7.10 g m-2) and Akitakomachi yielded the lowest (660 g m^{-2}).

Munoz *et al*. (1996) noted that IR8025A hybrid rice cultivar produced an average yield of 7.1 t ha^{-1} which was 16% higher than the commercial variety Oryzica Yacu-9.

BRRI (1995) conducted three experiments to find out the performance of different rice varieties. Results of the first experiment indicated that BR4, BR10, BR11, Challish and Nizersail produced grain yield of 4.38, 3.12, 3.12, 3.12 and 2.70 t ha^{-1}, respectively. Challish cultivar flowered earlier than all other varieties. BR22 and BR23 showed poor performance. Second experiment with rice cv. BR10, BR22, BR23 and Rajasail at three locations in *Aman* season. It was found that BR23 yielded the highest (5.17 t ha^{-1}), and Rajasail yielded the lowest (3.63 t ha^{-1}). Growth duration of BR22, BR23 and Rajasail were more or less similar (152-155 days). Third experiment with BR22, BR23, BR25 and Nizersail during *Aman* season at three locations-Godagari, Noahata, and Putia where BR25 yielded the highest and farmer preferred it due to its fine grain and desirable straw qualities.

BRRI (1994) also reported that among the four varieties viz.BRRI dhan14, Pajam, BRRI dhan 5 and Tulsimala, BRRI dhan 14 produced the highest tillers hill-1 and the lowest number of spikelet panicle-1 respectively. They also observed that the finer the grain size, the higher was the number of spikelet $panicle^{-1}$.

Aerobic rice production

Rice crop scientists are aware of three facts: a) rice is the second most staple food crop, b) there is an increase in food demand and freshwater crises, and c) rice is a semi-aquatic crop requiring flooding of fields. 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 1kg 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. The leading pioneers in breeding these kinds of rice cultivars are China (backed by IRRI), Brazil and India (Predeepa, 2012).

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.

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 (Boumanet 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.

Zhang *et al*. (2004) carried out an experiment to identify water saving technology for paddy rice irrigation in a demonstration region of the city of Yancheng, China. Test results showed 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.

CHAPTER III

MATERIALS AND METHODS

The field experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka from November, 2017 to June, 2008 to study the performance of hybrid and modern rice varieties under aerobic conditions. This chapter deals with a brief description on experimental period, experimental site, climate, soil, and land preparation, layout of the experimental design, intercultural operations, data recording and their analyses. Details of materials and methods used in this experiment are given below:

3.1 Site Description

The experimental field located at 23074/N latitude and 90035/E longitude and at an elevation of 8.4 m from sea level (Anon., 1988). The study locations also lie under the Agro-ecological zone of Modhupur Tract, AEZ-28. The study area was the location the Sher-e-Bangla Agricultural University farm, Dhaka. The site of the experiment has been presented in Appendix I.

Climate and weather

The experimental area was under the sub-tropical climate characterized by three individual seasons. The monsoon or rainy season extending from May to October, with high temperature and humidity with heavy rainfall; the winter or dry season from November to February, with relatively low temperature and the pre-monsoon season from March to April, with some rainfall and irregular breeze. Information in respect of monthly maximum and minimum temperature, relative humidity, rainfall and sunshine of the experimental site for the time of experimentation was collected from Bangladesh Meteorological Department, Agargaon and is presented in Appendix II.

Soil

The experiment was carried out in earthen pots and in land. The pot was filled with typical rice growing soil of the Madhupur Tract, AEZ No. 28 (Appendix II). It has non-calcarious dark grey soil in a medium high land with soil pH 5.7 and 0.47% organic carbon. The land was well drained with well irrigation facilities. The morphological, physical and chemical properties of the soil are presented in Appendix III.

Crop / Planting materials

In this research work, five popular samples of hybrid rice varieties were used as plant materials. The rice varieties used in the experiments were BR -29, Hybrid-3, Moina, Nobin and Hira-2. The seeds were collected from the Bangladesh Rice Research Institute (BRRI) at Joydebpur, Gazipur.

Details of the experimental materials

Two factor experiments were conducted to evaluate the performance of some hybrid rice varieties in *Boro* season. The test varieties that were used in the present study were as follows:

Factor A: Variety

i. V_1=BRRI dhan 29
ii. V_2=Hybrid-3
iii. V_3=Moina
iv. V_4=Nobin
v. V_5=Hira-2

Factor B: cultivation method

i. T_1 =SRI method (25 days old seedling)
ii. T_2 = Raised upland (35 days old seedling)
iii. T_3 = Traditional method

3.5.1 Treatments

T_1 and T_2 could be designated as aerobic as they were not submerged. Unit plots were divided from each other with free flow irrigation and drainage channel. Most of time the channel was filled with water in such a level that the traditional treatment were kept ponded up to the hard dough stage of the crop. Rest two plots were saturated with free horizontal flow of water from channel. However, the whole field was encircled with an outlet to drain excess water if there was rain.

Experimental design

The experiment was laid out in a double factor randomized complete block design with three replications. There were 45 plots of size 2.5 m × 4 m in each of 3 replications. The treatments will be randomly distributed to the plots in each block. The plots were surrounded by 30cm wide and 10cm high earthen bunds. One meter wide path was made in-between two blocks. The experimental plot was divided into three blocks each representing a replication. Again, each replication was divided into 15 unit plots where the treatment combinations were allocated at random. The complete layout of the experiment has been presented in Appendix IV.

Growing of crops

Seed collection

Healthy and vigorous seeds of BR-29, Hybrid-3, Moina, Nobin and Hira-2 were collected from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur.

Seed sprouting

The seeds were dipped in water in a bucket for 24 hours. The seeds were then taken out of water and kept thickly in gunny bags. The seeds started sprouting after 24 hours and completed within 48 hours and become suitable for sowing in the seed bed by 72 hours.

Preparation of seedling nursery and seed sowing

High land was selected for raising seedlings. The land was puddled well with country plough followed by cleaning and leveling with ladder. It was then ploughed and cross ploughed three times followed by laddering to obtain a desirable puddle condition. The corners of the land were spaded well. Sprouted seeds were sown in the wet nursery bed on 28 November 2017. Proper care was taken to raise the seedlings in the nursery bed. Weeds were removed and proper irrigation was given in the seedbed when necessary.

Preparation of experimental land

The experimental land was prepared with a power tiller 10 days before transplanting. It was then ploughed and cross ploughed three times followed by laddering to obtain a puddle condition. The corners of the land were spaded well. Weeds and stubbles were removed from the field prior to transplanting of seedlings. Finally, the individual plots were prepared before transplanting. Forty days old rice seedlings were transplanted maintaining the spacing 20cm × 15cm. Three seedlings were transplanted in each hill.

Fertilizers application

The calculated entire amount of all fertilizers was applied during final plot preparation. The applied fertilizers were mixed properly with the soil in the plot. The whole amount of cow-dung, TSP, MP and Gypsum were applied as basal dose at the time of final land preparation. Urea was applied in three equal splits at final land preparation, 20 and 45 days after transplanting. Half of the rest two third of urea was applied at 20 days after transplanting and the rest amount of urea was applied at 45 days after transplanting.

The following doses of manure and fertilizers (BRRI, 2013) were used.

i. Cow-dung : 5 t ha^{-1}
ii. Urea (N) : 220 kg ha^{-1}
iii. TSP (P_2O_5) : 165 kg ha^{-1}
iv. MP (K_2O) : 180 kg ha^{-1}
v. Gypsum : 70 kg ha^{-1}
vi. Zinc : 10 kg ha^{-1}

Uprooting of seedlings and transplanting

Seedlings were uprooted from the seed bed early in the morning of 9th January, 2018 and transplanted in the same day. Nursery bed was made wet by watering one day before uprooting the seedlings. The seedlings were uprooted carefully to minimize mechanical injury to the roots and were kept in shade before they were transplanted. Forty days old rice seedlings were transplanted maintaining the spacing 20cm × 15cm. three seedlings were transplanted in each hill. Transplanting of seedlings was done on 9thJanuary.

Intercultural operations

Thinning and Gap Filling

After one week of transplantation, dead seedlings were replaced with healthy seedlings from the same source to ensure 100% plant population before submergence. After transplanting the seedlings of the research field, gap filling was done whenever it was necessary using the seedling.

Weeding

Four weeding were done on 20, 35, 40, 55 and 70 days after transplanting to keep the crops free from weeds.

Application of Irrigation Water

Irrigation water was added to each plot according to the recommended treatments of inbred and hybrid cultivar by their originated characteristics. Required amount of water was applied to keep the soil moist and it was even allowed to dry out for 2 to 4 days during tillering stage. This was done to keep the soil well aerated, to allow better root growth. From panicle initiation (PI) to hard dough stage, a thin layer of water (2–3 cm) was kept on the plots. Again water was drained from the plots during ripening stage.

Plant Protection Measures

The crop was infested by rice stem borer and green leaf hopper, which were successfully controlled by applying Hezinon 60 EC, Sidial ACI 5 g and Virtako as per recommended dose.

3.9 Harvesting, threshing and cleaning

Maturity of the plants was determined when 80-85% of the grains become golden yellow in color or filled properly. Harvesting was done manually from each plot and plot area was harvested, bundled separately, tagged properly and brought to the threshing floor. Then the harvested crop was threshed. Threshing was done using pedal thresher. The grains were cleaned and samples were collected for measuring the optimum moisture content to adjust the moisture content at 14% level. Straw samples were also collected for oven dry and calculated the straw weight. Finally grain and straw yields plot^{-1} were determined and converted to tha^{-1}.

3. 10 Data recording

Plant height

The height of plant was taken in centimeter (cm) at the time of 25, 40, 55,65 DAT. Data were recorded as the average of same 5 hills selected at random from the outer side rows of each plot and from the plants of each pot. Plant height was measured from the ground level to the top of the leaf of plant. The average height of five hills was considered the height of the plant for each plot.

Total leaves hill^{-1}

Leaf numbers were counted from selected hills and from each pot at 25, 40, 55, 65 DAT. Flag leaf length and breadth, penultimate leaf length and breadth were also measured.

Total tillers hill^{-1}

The number of total tillers hill^{-1} were counted from selected hills and from each plot at 25, 40, 55 DAT.

Number of effective tillers hill^{-1}

The panicle which had at least one grain was considered as effective tiller from each sample and then average of five samples was taken.

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

The panicle which had no grain was considered as non-effective tiller. Only the non-bearing tillers were counted from each sample and then average of five samples was taken.

Panicle length

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 5 panicles.

Panicle weight

Panicle weight was collected from the randomly selected 5 panicles in each plot and from plants of each pot. Then the air dried panicle was weighed with a digital electric balance.

Number of filled grains panicle^{-1}

Presence of any food material in the spikelet was considered as grain. Total number of grains of five randomly selected panicles was counted. Average mean of filled grains of these five panicles was taken as number of filled grains panicle^{-1}.

Number of unfilled grain panicle^{-1}

Spikelets that lacked any food materials inside were considered as sterile spikelets and such present on the each panicle was counted.

Leaves dry weight

Leaves dry weight was recorded at the time of harvest by drying plant sample. Data were recorded as the average of 5 sample hill plot^{-1} selected at random.

Stem dry weight

Stem dry weight was recorded at the time of harvest by drying plant sample. Data were recorded as the average of 5 sample hill plot^{-1} selected at random.

Grain yield: Grain yield was recorded from central 4.8 m2 area of each plot. The grain yield was adjusted at 14% moisture content by the following formula:

Adjusted Grain yield,

$$Y \text{ (at 14\% moisture content)} = [(100- M)/86] \times W$$

Where,

W = Fresh weight of the grain

M = Moisture % of the fresh grain

Grain moisture content was measured by using a digital moisture meter. It is adjusted to t ha^{-1}.

Straw yield: The fresh weight of straw of 4.8 m2 area of each plot was recorded and then representative sample was taken. The sample was then oven dried at 70°C for 72 hours. Then the oven dried sample was weighted and used to adjusting the straw yield in tha^{-1}.

Chlorophyll content

Flag leaves were sampled at 6 days after flowering and a segment of 20 mg from middle portion of leaf was used for chlorophyll analysis. Chlorophyll content was measured on fresh weight basis extracting with 80 % acetone and used doubled beam spectrophotometer (Model: U-2001, Hitachi, Japan) according to Witham et al. (1986). Amount of chlorophyll was calculated using following formulae.

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

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

Where,

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

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

W = Fresh weight in gram of the tissues extracted.

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

3.11. Statistical analysis

The recorded data for different parameters were compiled and tabulated in proper form for statistical analysis. Analysis of variance was done with the help of computer software package MSTAT-C program (Russel, 1986). The mean differences among the treatments were compared by Least Significant Difference (LSD) Test at 5% level of significant (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

Results are presented and discussed in this chapter. Data are shown in various tables and figures. For convenience of presentation and discussion, the performance of hybrid and modern inbred rice varieties under aerobic condition is shown in different sections.

4.1 Plant height

Effect of variety

Plant height was significantly affected by different hybrid rice varieties (Table 1). Plant height is one of the most efficient traits for greater yield of rice which was also directly related to straw yield increase of the tallest plant produce the higher yield of straw. Plant height is a vertical spatial distribution of plant. Results showed that at 45 DAT, 60 DAT, 75 DAT, 85 DAT and at harvest showed the highest plant height (36.24, 66.01, 82.94, 96.57 and 112.78 cm) was obtained from the variety of Nobin (V_4). The shortest plant was observed with BR-29 and Hybrid-3 (32.54, 56.06, 70.64, 83.30 and 97.43 cm at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest.

Similar findings were also obtained by Islam et al. (2013) who found also significant and genetic variation among the varieties regarding plant height. Mahamud *et al.* (2013), who found that the variation in plant height was indicated by the differentiation of genotypic characters and their genetic makeup also. Similar findings were also obtained by Panwar *et al.* (2012); Oka *et al*. (2012); Sritharan and Vijayalakshmi (2012); Uddin *et al.* (2010), Hossain *et al.* (2005), Ashrafuzzaman *et al.* (2009) and many other scientists. Besides, the climatic and soil condition of the studied area were farvourable for better growth of Heera-4 which ultimately showed highest plant height than BRRI dhan29.

Table 1. **Effects of different variety on plant height of hybrid rice**

Variety	Plant height (cm)				
	At 45 DAT	At 60 DAT	At 75 DAT	At 85 DAT	At harvest
V_1	32.54 c	56.06 c	70.64 c	85.13 bc	103.70 b
V_2	35.33 ab	59.74 b	71.67 c	83.30 b	97.43 c
V_3	34.14 bc	56.93 c	75.21 b	86.76 b	98.00 c
V_4	36.24 a	66.01 a	82.94 a	96.57 a	112.78 a
V_5	33.14 c	57.00 c	75.28 b	86.09 bc	105.22 b
LSD $_{(0.05)}$	1.669	1.647	2.527	2.819	3.028
CV %	5.04	2.88	3.48	3.33	3.03

Means with the same letter are not significantly different. CV= Coefficient of variation; V_1= BRRI Dhan - 29, V_2=Hybrid-3, V_3=Moina, V_4=Nobin and V_5=Heera-2

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Table 2. Effects of different aerobic condition on plant height in hybrid rice

Treatment	Plant height (cm)				
	At 45 DAT	At 60 DAT	At 75 DAT	At 85 DAT	At harvest
T_1	33.35 c	56.43 c	73.17 c	86.43 b	104.29a
T_2	35.44 a	61.70 a	76.51 a	88.31 a	105.27a
T_3	34.05 b	59.32 b	75.76 b	88.17 a	102.37b
LSD $_{(0.05)}$	1.669	1.647	2.527	2.819	3.028
CV %	5.04	2.88	3.84	3.33	3.03

Means with the same letter are not significantly different. CV= Coefficient of variation; T_1 =SRI method, T_2 = Raised upland and T_3 = Traditional method

Effect of aerobic condition

The plant height (cm) was differed significantly under aerobic condition at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest (Table 2). At harvest, the plant height of V_2 was higher than that of other treatments. The highest plant height obtained from V_2 was recorded 35.44, 61.70, 76.51, 88.31 and 105.27cm at 45 DAT,60 DAT,75 DAT, 85DAT and at harvest, respectively. The lowest plant height (33.35, 56.43, 73.17, 86.43 and 102.37cm at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest) obtained from V_1 and V_3. The result was in line with findings of Mannan *et al.* (2010) who reported that, increasing the different levels of N in soil significantly influenced growth in rice crop.

Table 3. Interaction effect of variety and aerobic condition on plant height of hybrid rice

Interaction	Plant height (cm)				
	At 45 DAT	At 60 DAT	At 75 DAT	At 85 DAT	At harvest
V_1T_1	31.67 g	53.43 j	70.10 h	75.80 j	92.00 i
V_1T_2	33.80 d	55.07 i	70.97 h	86.50 fg	103.33 e
V_1T_3	32.17 efg	59.67 e	70.47 h	80.60 i	101.33 f
V_2T_1	32.27 efg	57.17 g	67.37 i	88.30 de	98.13 g
V_2T_2	37.90 a	60.57 d	75.07 def	87.73 ef	95.67 h
V_2T_2	35.83 b	61.50 c	72.57 g	86.37 fg	98.50 g
V_3T_1	32.83 e	55.80 hi	76.07 d	86.03 g	100.67 f
V_3T_2	37.80 a	56.07 h	75.17 de	87.70 ef	101.33 f
V_3T_3	31.80 fg	58.93 ef	74.40 ef	86.53 fg	104.67 cde
V_4T_1	36.00 b	58.67 f	78.03 c	92.80 c	112.00 b
V_4T_2	34.87 c	69.20 b	83.40b	95.90 b	110.67 b
V_4T_3	37.97 a	70.17 a	87.40a	101.23 a	115.67 a
V_5T_1	34.00 d	57.07 g	73.90 f	89.23 d	106.00 c
V_5T_2	32.83 e	55.70 hi	73.97 ef	82.90 h	105.33 cd
V_5T_3	32.60 ef	58.23 f	77.97 c	86.13 g	104.33 de
LSD $_{(0.05)}$	0.7465	0.7364	1.130	1.261	1.354
CV%	5.04	2.88	3.84	3.33	3.03

Means with the same letter are not significantly different. CV= Coefficient of variation

Interaction effect of variety and aerobic condition

The interaction effect of variety and aerobic condition on plant height of hybrid rice was found significant (Table 3). The highest plant height obtained from V_4T_3 was recorded 37.97, 70.17, 51, 87.40, 101.23 and 115.67 cm at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest, respectively.

The lowest plant height (31.67, 53.43, 70.10, 75.80 and 92.00 cm at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest) obtained from V_1T_1.

4.2 Number of tillers

Effect of variety

It was evident from (Table 4) that number of tiller was significantly influenced by variety. Among five varieties, V_4 (Nobin) produced the maximum number of tiller(6.58, 13.78,15.58,18.87 and 14.98 at 45 DAT,60 DAT,75 DAT,85DAT and at harvest) and minimum number of tiller (5.83, 11.61, 14.76, 11.81and 11.56 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest). Islam *et al.* (2009), Bisne *et al*. (2006), Chowdhury *et al.* (2005), Akbar (2004) and Bhowmick and Nayak (2000) reported similar trend of tillering habits with different varieties of rice.

Table 4. Effects of different variety on number of tiller of hybrid rice

Variety	Number of tillers				
	At 45 DAT	At 60 DAT	At 75 DAT	At 85 DAT	At harvest
V_1	5.83 c	11.61 b	14.76 a	11.81 c	11.56 b
V_2	6.00 bc	11.69 b	15.17 a	12.69 c	13.56 a
V_3	6.44 ab	12.29 b	15.00 a	12.32 c	14.22 a
V_4	6.58 a	13.78 a	15.48 a	18.87 a	14.89 a
V_5	5.94 bc	12.53 b	14.84 a	14.02 b	14.11 a
LSD $_{(0.05)}$	0.4914	0.9752	0.7992	1.000	1.621
CV%	8.25	8.16	5.50	7.43	12.29

Means with the same letter are not significantly different. CV= Coefficient of variation; V_1=BRRRI Dhan 29, V_2=Hybrid-3, V_3=Moina, V_4=Nobin and V_5=Hira-2

Effect of aerobic condition

Number of tiller was significantly affected by aerobic condition (Table 5). The highest number of tiller (6.65, 13.68, 15.98, 15.51 and 14.20 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest) and lowest number of tiller (5.25, 11.67, 14.16, 12.72 and 12.93 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest).

Table 5. Effects of different aerobic condition on number of tiller of hybrid rice

Treatment	Number of tillers				
	At 45 DAT	At 60 DAT	At 75 DAT	At 85 DAT	At harvest
T_1	5.25 b	11.67 b	14.16 c	12.72 c	12.93 c
T_2	6.58 a	11.79 b	15.01 b	13.60 b	13.87 b
T_3	6.65 a	13.68 a	15.98 a	15.51 a	14.20 a
$LSD_{(0.05)}$	0.4914	0.9752	0.7992	1.000	1.621
CV%	8.25	8.16	5.50	7.43	12.29

Means with the same letter are not significantly different. CV= Coefficient of variation; T_1 =SRI method, T_2 = Raised upland and T_3 = Traditional method

Interaction effect of variety and aerobic condition

The interaction effect of variety and aerobic condition on number of tiller of hybrid rice was found significant (Table 6). The highest number of tiller obtained from V_4T_3 was recorded 7.67, 17.57, 17.07, 19.97 and 18.33 at 45 DAT,60 DAT,75 DAT,85DAT and at harvest, respectively. The lowest number of tiller (4.50, 10.73, 12.73, 10.30 and 10.67 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest) obtained from V_1T_1.

Table 6. Interaction effect of variety and aerobic condition on number of tiller of hybrid rice

Interaction	Number of tillers				
	At 45 DAT	At 60 DAT	At 75 DAT	At 85 DAT	At harvest
V_1T_1	4.50 i	10.73 g	12.73 h	10.30 i	10.67 f
V_1T_2	5.92 e	11.97 de	16.30 c	20.23 a	13.67 c
V_1T_3	7.42 b	11.80 de	15.23 d	16.40 c	16.33 b
V_2T_1	4.75 h	12.23 cd	16.70 b	12.20 gh	16.33 b
V_2T_2	7.58 ab	10.80 g	12.57 h	12.40 fgh	12.67 de
V_2T_2	5.67 f	12.03 de	15.00 de	13.47 e	13.67 c
V_3T_1	6.25 d	12.67 c	16.00 c	11.97 h	16.33 b
V_3T_2	6.67 c	11.57ef	14.13 f	12.80 f	13.67 c
V_3T_3	6.83 c	12.63 c	16.30 c	12.20 gh	12.33 e
V_4T_1	5.75 ef	12.13 d	13.63 g	10.50 i	13.00 cde
V_4T_2	5.92 e	11.97 de	15.07 de	14.63 d	13.33 cd
V_4T_3	7.67 a	17.57 a	17.07 a	19.97 a	18.33 a
V_5T_1	5.00 g	13.80 b	14.73 e	12.53 fg	11.00 f
V_5T_2	6.83 c	12.67 c	13.97 fg	17.46 b	11.33 f
V_5T_3	5.67 f	11.13 fg	16.30 c	12.07 gh	12.33 e
$LSD_{(0.05)}$	0.2198	0.4361	0.3574	0.4473	0.2503
CV%	8.25	8.16	5.50	7.43	12.29

Means with the same letter are not significantly different. CV= Coefficient of variation

4.3 Effective tillers

Effect of variety

There was a significant effect of variety of rice on production of number of effective tillers hill^{-1} (Table 7). The maximum number of effective tillers hill^{-1} was produced by Nobin (13.56). The minimum number of effective tillers hill^{-1} (10.44) was obtained from BRRI dhan29. The probable reason of the differences in producing the effective tillers hill^{-1} is the genetic make-up of the variety which is primarily influenced by heredity. This finding corroborates with those reported by Hasan (2007) who found that effective tillers hill^{-1} differed significantly among the varieties.

Effect of aerobic condition

Aerobic condition had significant effect on number of effective tillers hill^{-1} (Table 8). Rice plant produced the maximum (13.27) number of effective tillers hill^{-1} was obtained from T_3. The lowest number (11.73) of effective tillers hill^{-1} was obtained from T_1treatment. The lowest number of effective tillers hill^{-1} of more nutrients in comparison to others. The findings are confirmed by the results of Mannan *et al.* (2010) who observed that N application had significantly pronounced effect production of productive tillers.

Interaction effect of variety and aerobic condition

The interaction effect of variety and aerobic condition showed significant variation in respect of number of effective tillers (Table 9). The table 9 showed that Nobin (V_4) produced statistically maximum number of effective tillers hill^{-1} when treated with nitrogen fertilizers @ 8 kg N ha^{-1} (16.67). BRRI dhan29 produced minimal (9.33) number of effective tillers hill^{-1} fertilized with 5 kg N ha^{-1} (T_1).

Table 7. Effects of different variety on effective tiller,non-effective tiller and no. of leaves of hybrid rice

Variety	Effective tiller	Non Effective tiller	No. of leaves				
			At 45 DAT	At 60 DAT	At 75 DAT	At 85 DAT	At harvest
V_1	10.44 c	1.00 ab	16.11 c	38.30 c	35.02 c	36.27 d	41.33 d
V_2	13.11 ab	1.78 a	18.79 b	44.17 a	38.79 b	37.72c	46.21 b
V_3	11.89 b	1.67 ab	18.82 b	43.04 ab	35.33 c	37.13 c	44.17 c
V_4	13.56 a	0.78 b	20.34 a	44.29 a	40.83 a	54.84 a	50.28 a
V_5	13.11 ab	1.22 ab	18.76 b	41.57 b	36.81 c	45.53 b	48.28 a
LSD (0.05)	1.435	0.8262	1.314	1.794	1.792	1.539	2.013
CV%	11.96	6.37	7.33	4.40	4.97	3.77	4.53

Means with the same letter are not significantly different. CV= Coefficient of variation; V_1= BRRI Dhan 29, V_2=Hybrid-3, V_3=Moina, V_4=Nobin and V_5=Hira-2

4.4 Non-Effective tiller

Effect of variety

There was a significant effect of variety of rice on production of number of non-effective tillers hill^{-1} (Table 7). The maximum number of non-effective tillers hill^{-1} was produced by V_2 (1.78). The minimum number of non-effective tillers hill^{-1} (0.78) was obtained from V_4.

Effect of aerobic condition

Aerobic condition had significant effect on number of non-effective tillers hill^{-1} (Table 8). The maximum (1.60) number of effective tillers hill^{-1} was obtained from T_1. The lowest number (1.07) of effective tillers hill^{-1} was obtained from T_3 treatment.

Interaction effect of variety and aerobic condition

The interaction effect of variety and aerobic condition showed significant variation in respect of number of non-effective tillers (Table 9). The highest number of non-effective tiller obtained from V_2T_2 (2.67). The lowest number of non-effective tiller (0.00) obtained from V_1T_1.

Table 8. Effects of different aerobic condition on effective tiller, non-effective tiller and no. of leaves of hybrid rice

Treatment	Effective tillers	Non Effective tiller	No. of leaves				
			At 45 DAT	At 60 DAT	At 75 DAT	At 85 DAT	At harvest
T_1	11.73 c	1.60 a	15.65 c	40.01c	35.43 b	39.20 c	39.93 b
T_2	12.27 b	1.20 b	18.93 b	41.07b	35.49 b	41.49 b	48.97 a
T_3	13.27 a	1.07 c	21.13 a	45.62 a	41.15 a	46.20 a	49.26 a
LSD (0.05)	1.435	0.8262	1.314	1.794	1.792	1.539	2.013
CV%	11.96	6.37	7.33	4.40	4.97	3.77	4.63

Means with the same letter are not significantly different. CV= Coefficient of variation; T_1 =SRI method, T_2 = Raised upland and T_3 = Traditional method

4.5 Number of leaves

Effect of variety

Results showed that the highest leaves hill^{-1} (20.34, 44.29, 40.83, 54.84 and 50.28 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest, respectively) was produced from V_4. The lowest number of leaves hill^{-1} (16.11, 38.30, 35.02, 36.27 and 41.33 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest, respectively) was obtained from V_1. The results substantiate with the findings of Luh (1980) who observed highest tiller and leaf number in rice occurred at 40 to 60 days after transplanting, depending upon the tailoring capacity of the variety, the spacing used and the fertility level.

Table 9. Interaction effect of variety anaerobic condition on effective tiller, non-effective tiller and no. of leaves of hybrid rice

Interaction	Effective tiller	Non Effective tiller	No. of leaves				
			At 45 DAT	At 60 DAT	At 75 DAT	At 85 DAT	At harvest
V_1T_1	9.33 j	0.00 h	13.13 j	34.43 j	32.47 i	31.00 l	36.33 k
V_1T_2	13.00 e	0.67 fg	13.83 i	47.13 a	35.30 g	55.33 b	40.33 i
V_1T_3	14.00 d	2.33 ab	21.37 c	43.10 f	34.13 h	33.83 k	45.17 fg
V_2T_1	16.00 b	1.67 cd	14.30 i	41.27 g	36.73 e	34.37 k	44.30 g
V_2T_2	11.67 gh	1.00 ef	23.33 a	35.47 i	33.57 h	36.67 i	57.67 c
V_2T_2	11.00 hi	2.67 a	18.73 f	45.00 d	35.87 efg	42.13 f	36.67 k
V_3T_1	14.67 c	1.67 cd	18.56 f	46.17 bc	39.67 c	35.47 j	45.83 ef
V_3T_2	11.67 gh	2.00 bc	19.47 e	39.47 h	35.73 fg	40.57 g	38.50 j
V_3T_3	12.33 efg	1.33 de	22.33 b	46.63 b	40.97 b	35.37 j	43.00 h
V_4T_1	12.00 fg	1.33 de	17.07 g	39.43 h	36.47 ef	48.90 d	55.67 d
V_4T_2	12.67 ef	0.67 fg	17.07 g	42.03 g	35.97 efg	43.97 e	38.33 j
V_4T_3	16.67 a	0.33 gh	23.00 a	47.67 a	53.07 a	60.30 a	62.00 a
V_5T_1	10.67 i	0.67 fg	15.17 h	44.07 e	39.80 c	43.47 e	41.17 i
V_5T_2	9.67 j	1.67 cd	20.97 c	34.93 ij	38.00 d	54.47 c	46.50 e
V_5T_3	11.00 hi	1.33 de	20.13 d	45.70 cd	32.63 i	38.67 h	59.33 b
LSD $_{(0.05)}$	0.6417	0.3695	0.5875	0.8021	0.8015	0.6882	0.9002
CV%	11.96	6.37	7.33	4.40	4.97	3.77	4.53

Means with the same letter are not significantly different. CV= Coefficient of variation

Effect of aerobic condition

Significant variation was observed in case number of leaves as influenced by aerobic condition of hybrid rice at different growth stages (Table 7). Results showed that at all growth stage the highest number of leaves hill^{-1}was recorded by T_3 (21.13, 45.62, 41.15, 46.20 and 49.26 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest, respectively). The results obtained from T_1 showed the lowest number of leaves (15.65, 40.01, 35.43, 39.20 and 39.93 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest, respectively) (Table 8).

Interaction effect of variety and aerobic condition

Interaction effect of variety and aerobic condition had significant influence on leaves hill-^{1} at different growth stages of the five varieties of hybrid rice (Table 9). Results indicated that the highest number of leaves hill^{-1} (23.00, 47.67, 53.07, 60.30 and 62.00 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest) was recorded from V_4T_3. The results recorded from V_1T_1 showed the lowest number of leaves hill^{-1}(13.13, 34.43, 32.47, 31.00 and 36.33 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest). The results obtained from all other treatments showed significantly different results compared to the highest and the lowest result of number of leaves hill^{-1}.

4.6 Leaf length

Effect of variety

Leaf length varied significantly due to the effect of hybrid rice variety (Table 10). The maximum leaf length (38.56, 35.56 and 48.20cm at 60 DAT, 75 DAT and 85 DAT) was found from the V_4 (Nobin) and the varietyV_1 (BR-29) was recorded the minimum leaf length (34.52, 33.61 and 42.16cm at 60 DAT, 75 DAT and 85 DAT).

Effect of aerobic condition

The response of leaf length of hybrid rice variety to aerobic condition varied significantly (Table 11). There were significant differences in leaf length of hybrid rice. The highest leaf length of rice plants that received from T_3(38.50, 35.70 cm and 46.03 at 60 DAT, 75 DAT and 85 DAT), while the lowest leaf length of rice plants that received from T_1 (35.40, 33.70 and 42.98cm at 60 DAT, 75 DAT and 85 DAT).

Interaction effect of variety and aerobic condition

The interaction effect of variety and aerobic condition was found significant (Table 12). The highest leaf length of rice plants that received from V_4T_3 (42.33, 37.67 and 54.13cm at 60 DAT, 75 DAT and 85 DAT), while the lowest leaf length of rice plants was received from V_1T_1 (32.83, 32.33 and 39.60cm at 60 DAT, 75 DAT and 85 DAT).

Table 10. Effects of different variety on leaf length and leaf breadth of hybrid rice

Variety	Leaf length (cm)			Leaf breadth (cm)		
	At 60 DAT	At 75 DAT	At 85 DAT	At 60 DAT	At 75 DAT	At 85 DAT
V_1	34.52 c	33.61 c	42.16 d	0.75 b	1.32 a	1.56 b
V_2	36.44 b	34.72 abc	45.10 b	0.76 b	1.33 a	1.59 b
V_3	37.28 ab	33.94 bc	43.26 c	0.79 b	1.37 a	1.58 b
V_4	38.56 a	35.56 a	48.20 a	0.88 a	1.39 a	1.68 a
V_5	38.47 a	35.00 ab	44.49 b	0.84 a	1.34 a	1.57 b
$LSD_{(0.05)}$	1.315	1.209	0.6153	0.04391	0.06107	0.7480
CV%	3.68	3.62	1.43	5.10	4.65	4.78

Means with the same letter are not significantly different. CV= Coefficient of variation

V_1=BR -29, V_2=Hybrid-3, V_3=Moina, V_4=Nobin and V_5=Hira-2

Table 11. Effects of different aerobic condition on leaf length and leaf breadth of hybrid rice

Treatment	Leaf length (cm)			Leaf breadth (cm)		
	At 60 DAT	At 75 DAT	At 85 DAT	At 60 DAT	At 75 DAT	At 85 DAT
T_1	35.40 c	33.70 b	42.98 c	0.77 b	1.34 a	1.56 c
T_2	37.14 b	34.30 b	44.91 b	0.82 a	1.34 a	1.60 b
T_3	38.50 a	35.70 a	46.03 a	0.82 a	1.35 a	1.64 a
$LSD_{(0.05)}$	1.315	1.209	0.6153	0.04391	0.06107	0.7480
CV%	3.68	3.62	1.43	5.10	4.65	4.78

Means with the same letter are not significantly different. CV= Coefficient of variation; T_1 =SRI method, T_2 = Raised upland and T_3 = Traditional method

Table 12. Interaction effect of variety and aerobic condition on leaf length and leaf breadth of hybrid rice

Interaction	Leaf length (cm)			Leaf breadth (cm)		
	At 60 DAT	At 75 DAT	At 85 DAT	At 60 DAT	At 75 DAT	At 85 DAT
V_1T_1	32.83 k	32.33 h	39.60 j	0.72 g	1.30 e	1.47 i
V_1T_2	34.83 i	32.83 gh	46.33 c	0.81 bc	1.34 bcd	1.65 cd
V_1T_3	35.83 g	34.17 ef	40.53 i	0.72 g	1.37 ab	1.62 de
V_2T_1	33.57 j	34.50 de	43.10 f	0.76 f	1.32 de	1.59 efg
V_2T_2	33.33 jk	34.83 cd	47.87 b	0.77 ef	1.39 a	1.56 gh
V_2T_2	36.67 f	34.17 ef	44.33 de	0.75 f	1.30 e	1.61 ef
V_3T_1	35.33 ghi	33.00 g	46.27 c	0.92 a	1.38 a	1.49 i
V_3T_2	41.00 b	34.17 ef	41.63 h	0.81 bc	1.35 bcd	1.54 h
V_3T_3	35.50 gh	33.67 f	41.87 h	0.94 a	1.39 a	1.72 a
V_4T_1	37.73 e	36.67 b	46.13 c	0.93 a	1.29 e	1.67 bc
V_4T_2	35.00 hi	33.83 f	44.57 d	0.79 cd	1.36 abc	1.68 b
V_4T_3	42.33 a	37.67 a	54.13 a	0.64 h	1.33 cd	1.67bc
V_5T_1	40.40 c	36.33 b	42.77 g	0.78 de	1.36 abc	1.57 gh
V_5T_2	38.67 d	35.33 c	44.13 e	0.93 a	1.34 bcd	1.57 g
V_5T_3	42.17 a	35.00 cd	46.33 c	0.82 b	1.33 cd	1.58 fg
LSD $_{(0.05)}$	0.5880	0.5406	0.2752	0.01931	0.02731	0.03345
CV%	3.68	3.62	1.43	5.10	4.65	4.78

Means with the same letter are not significantly different. CV= Coefficient of variation

4.7 Leaf breadth

Effect of variety

Leaf breadth varied significantly due to the effect of hybrid rice variety (Table 10). The maximum leaf breadth (0.88, 1.39 and 1.68cm at 60 DAT, 75 DAT and 85 DAT) was found from the V_4 (Nobin) and the variety V_1 (BR-29) was recorded the minimum leaf breadth (0.75, 1.34 and 1.57cm at 60 DAT, 75 DAT and 85 DAT).

Effect of aerobic condition

The response of leaf length of hybrid rice variety to aerobic condition varied significantly (Table 11). There were significant differences in leaf breadth of hybrid rice. The highest leaf breadth of rice plants that received from T_3 (0.82, 1.35 and 1.64cm at 60 DAT, 75 DAT and 85 DAT), while the lowest leaf breadth of rice plants that received from T_1 (0.77, 1.34 and 1.56 at 60 DAT, 75 DAT and 85 DAT).

Interaction effect of variety and aerobic condition

The interaction effect of variety and aerobic condition was found significant (Table 12). The highest leaf breadth of rice plants that received from V_3T_3 (0.94, 1.39 and 1.72 cm at 60 DAT, 75 DAT and 85 DAT), while the lowest leaf breadth of rice plants was received from V_1T_1 (0.72, 1.30 and 1.47 at 60 DAT, 75 DAT and 85 DAT).

4.8 Flag leaf length

Effect of variety

Flag leaf length was significantly influenced by hybrid rice variety (Table 13). V_4 produced highest flag leaf length (34.18cm) which was statistically similar to V_3 (34.11cm) and V_1 produced the lowest flag leaf length with the value 27.94cm.

Effect of aerobic condition

The effect of aerobic condition on number of flag leaf length of hybrid rice is presented in Table (14). A significant difference in flag leaf length was detected among the three treatments. The highest flag leaf length (33.24cm) were produced from $T_3$and T_1produced the lowest flag leaf length with the value 30.89cm.

Interaction effect of variety and aerobic condition

The interaction effect of variety and aerobic condition was found significant (Table 15). The highest flag leaf length (39.80cm) was obtained from V_4T_3. The lowest flag leaf length (26.70cm) was obtained from V_1T_1 which was statistically similar to $V_2T_2$with the value 26.77cm.

Table 13. Effects of different variety on flag leaf length, flag leaf breadth, penultimate leaf length, penultimate leaf breadth, dry wt. of leaves and dry wt. of 3 leaves of hybrid rice

Variety	Flag leaf length (cm)	Flag leaf breadth (cm)	Penultimate leaf length (cm)	Penultimate leaf breadth (cm)	Dry wt. of leaves (g)	Dry wt. of three leaves (g)
V_1	27.94 c	1.32 b	33.30e	1.17 c	12.96 d	0.54 b
V_2	31.16 b	1.39 b	35.96 d	1.38 a	15.01 b	0.54 b
V_3	34.11 a	1.34 b	39.56b	1.23 b	14.66 c	0.62 a
V_4	34.18 a	1.57 a	41.68a	1.42 a	16.48 a	0.63 a
V_5	32.52 ab	1.33 b	38.26 c	1.25 b	15.13 b	0.61 a
LSD $_{(0.05)}$	1.705	0.06107	1.740	0.06107	0.2989	0.03054
CV%	5.52	4.63	4.77	4.90	6.59	5.60

Means with the same letter are not significantly different. CV= Coefficient of variation V_1= BRRI Dhan -29, V_2=Hybrid-3, V_3=Moina, V_4=Nobin and V_5=Hira-2

4.9 Flag leaf breadth

Effect of variety

Flag leaf breadth was significantly influenced by hybrid rice variety (Table 13). V_4 produced highest flag leaf breadth (1.57cm) and V_1 produced the lowest flag leaf breadth with the value 1.32cm that was statistically similar to V_2,V_3 and V_5 with the value (1.39,1.34 and 1.33cm).

Effect of aerobic condition

The effect of aerobic condition on number of flag leaf breadth of hybrid rice is presented in Table (14).A significant difference in flag leaf breadth was detected among the three treatments. The highest flag leaf breadth (1.45cm) were produced from T_3 that is statistically similar to T_2 (1.41cm) and T_1produced the lowest flag leaf length with the value 1.35cm.

Interaction effect of variety and aerobic condition

The interaction effect of variety and aerobic condition was found significant (Table 15). The highest flag leaf breadth (1.80cm) was obtained from V_4T_3. The lowest flag leaf breadth (1.12cm) was obtained from V_1T_1.

4.10 Penultimate leaf length

Effect of variety

Penultimate leaf length was significantly influenced by different hybrid rice variety (Table 13). V_4 produced highest penalty leaf length (41.68cm) and the V_1 produced the lowest penalty leaf length (33.30cm).

Effect of aerobic condition

The effect of aerobic condition penalty leaf length of different hybrid rice variety is presented in Table (14). A significant difference in penalty leaf length was detected among the three treatments. The highest penalty leaf length (38.55cm) produced from T_3 that is statistically similar to T_2 (38.21cm) and T_1 produced the lowest penalty leaf length (36.49cm).

Interaction effect of variety and aerobic condition

The interaction effect of variety and aerobic condition was found significant (Table 15). The penalty leaf length varied from 29.90 to 44.00cm. The highest penalty leaf length (44.00 cm) was obtained from V_4T_3. The lowest penultimate leaf length (29.90cm) was obtained from V_1T_1.

Table 14. Effects of different aerobic condition on flag leaf length, flag leaf breadth, penultimate leaf length, penultimate leaf breadth, dry wt. of leaves and dry wt. of 3 leaves of hybrid rice

Treatment	Flag leaf length (cm)	Flag leaf breadth (cm)	penultimate leaf length (cm)	penultimate leaf breadth (cm)	Dry wt. of leaves (g)	Dry wt. of three leaves (g)
T_1	30.89 c	1.35 b	36.49 b	1.10 c	13.30 b	0.59b
T_2	31.76 b	1.41 a	38.21 a	1.34b	15.47 a	0.61 a
T_3	33.24 a	1.45 a	38.55 a	1.44a	15.77 a	0.63a
LSD $_{(0.05)}$	1.705	0.06107	1.740	0.06107	0.298 9	0.0305 4
CV%	5.52	4.63	4.77	4.90	6.59	5.60

Means with the same letter are not significantly different. CV= Coefficient of variation; T_1 =SRI method, T_2 = Raised upland and T_3 = Traditional method

4.11 Penultimate leaf breadth

Effect of variety

Penultimate leaf breadth was significantly influenced by different hybrid rice variety (Table 13). V_4 produced highest penultimate leaf breadth (1.42cm) that is statistically similar to V_2 (1.38cm) and the V_1 produced the lowest penultimate leaf breadth (1.17cm).

Effect of aerobic condition

The effect of aerobic condition on penultimate leaf breadth of different hybrid rice variety is presented in Table 14. A significant difference in penultimate leaf length was detected among the three treatments. The highest penultimate leaf breadth (1.44cm) produced from T_3 and T_1 produced the lowest penalty leaf breadth (1.10cm).

Interaction effect of variety and aerobic condition

The interaction effect of variety and aerobic condition was found significant (Table 15). The penultimate leaf breadth varied from 1.04 to 1.82cm. The highest penultimate leaf breadth (1.82cm) was obtained from V_4T_3. The lowest penultimate leaf breadth (1.04cm) was obtained from V_1T_1.

4.12 Dry weight of leaves and three leaves

Effect of variety

The dry weight of leaves and three leaves was significantly varied due to varietal differences. The dry weight of leaves and three leaves of the varieties was varied with the advancement of harvest (Table 13). The highest dry weight of leaves (16.48 g) was observed in V_4. The lowest dry matter of leaves (12.96 g) was observed in V_1 treatment. The highest dry weight of three leaves (0.63 g) was obtained from V_4 that is similar to V_3 and V_5 with the value 0.62g and 0.61g. The lowest dry weight of three leaves was produced from V_1 and V_2 treatment (0.54 g). The results uphold with the findings of Islam *et al.* (2009), Amin *et al*. (2006), Son *et al.* (1998) and Patnaik *et al.* (1990)who reported that dry matter accumulation capacity depends mainly on varietal performance.

Effect of aerobic condition

Significantly varied results were observed in terms of dry weight of leaves and three leaves as influenced by different treatments (Table 14). Results showed that the highest dry weight of leaves was recorded by T_3 (15.77g). The results obtained from T_1 showed the lowest dry weight of leaves (13.30g).The highest dry weight of three leaves was recorded by T_3 (0.63g) which was similar to T_2 (0.61g). The results obtained from T_1 showed the lowest dry weight of three leaves (0.59g). The results obtained from all other treatments showed significantly different results compared to the highest and the lowest result of leaves and three leaves.

Table 15. Interaction effect of variety and aerobic condition on flag leaf length, flag leaf breadth, Penultimate leaf length, Penultimate leaf breadth, dry wt. of leaves and dry wt. of 3 leaves of hybrid rice

Interaction	Flag leaf length (cm)	Flag leaf breadth (cm)	Penultimate leaf length (cm)	Penultimate leaf breadth (cm)	Dry wt. of leaves (g)	Dry wt. of three leaves (g)
V_1T_1	26.70 i	1.12 i	29.50 e	1.04j	13.73 j	0.46 h
V_1T_2	31.33 f	1.66 b	38.90 bc	1.33 d	15.67 f	0.48 g
V_1T_3	35.33 c	1.35 e	31.50 d	1.29 e	13.17 l	0.54 f
V_2T_1	29.23 g	1.44 d	34.20 c	1.07i	11.77 n	0.60 de
V_2T_2	27.83 h	1.43 d	40.20 b	1.13 h	18.03 b	0.55 f
V_2T_2	26.77 i	1.48 c	33.47 c	1.29 e	9.07 o	0.46 h
V_3T_1	33.50 e	1.30 f	34.40 c	1.26 g	15.17 g	0.64 b
V_3T_2	31.30 f	1.45 cd	40.87 b	1.45 c	16.37 e	0.62 c
V_3T_3	31.50 f	1.28 f	43.40 a	1.64 b	12.43 m	0.61 cde
V_4T_1	38.83 b	1.48 c	40.28 b	1.06 ij	17.17 d	0.60 de
V_4T_2	29.90 g	1.25 g	40.77 b	1.33 d	13.43 k	0.55 f
V_4T_3	39.80 a	1.80 a	44.00 a	1.82 a	20.50 a	0.80 a
V_5T_1	31.53 f	1.34 e	34.67 c	1.16 g	14.27 i	0.62 c
V_5T_2	34.33 d	1.44 d	36.50 bc	1.25 f	14.43 h	0.60 e
V_5T_3	31.70 f	1.21 h	43.60 a	1.34 d	17.40 c	0.61 cd
LSD $_{(0.05)}$	0.7625	0.02731	1.0210	0.02732	0.1337	0.01366
CV%	5.52	4.63	4.77	4.90	6.59	5.60

Means with the same letter are not significantly different. CV= Coefficient of variation

Interaction effect of variety and aerobic condition

The significant variation was observed on dry weight of leaves and three leaves due to variety and aerobic condition (Table 15). The highest dry weight of leaves (20.50g) was obtained from V_4T_3. The lowest dry weight of leaves (9.07g) was obtained from V_2T_2 and The highest dry weight of three leaves (0.80g) were obtained from V_4T_3. The lowest dry weight of leaves (0.46g) was obtained from V_1T_1.

4.13 Stem dry weight

Effect of variety

The dry stem weight was significantly varied due to varietal differences (Table 16). The highest dry stem weight (55.59 g) was observed in V_4. The lowest dry stem weight (43.03 g) was observed in V_2 treatment. The results uphold with the findings of Islam *et al.* (2009), Amin *et al.* (2006), Son *et al.* (1998) and Patnaik *et al.* (1990) who reported that dry matter accumulation capacity depends mainly on varietal performance.

Effect of aerobic condition

Significantly varied results were observed in terms of dry stem weight as influenced by different treatments (Table 17). Results showed that the highest dry stem weight was recorded by T_3 (51.04g). The results obtained from T_1 showed the lowest dry stem weight (44.68g).

Interaction effect of variety and aerobic condition

The significant variation was observed on dry stem weight due to variety and aerobic condition (Table 18). The highest dry stem weight (61.10g) was obtained from V_4T_3. The lowest dry stem weight (39.33g) was obtained from V_2T_2.

4.14 Chlorophyll content

Effect of variety

The production of chlorophyll content was significantly influenced by the tested different varieties (Table 16). Hybrid rice variety of Nobin showed the highest chlorophyll content (50.36 mg g^{-1}). The minimum chlorophyll content was found in V_5 (44.84 mg g^{-1}) treatment.

Effect of aerobic condition

Significantly varied result was observed in case of chlorophyll content as influenced by aerobic condition (Table 17). Results showed that the highest chlorophyll content was recorded by T_3 (50.62 mg g^{-1}). The results obtained from T_1 showed the lowest chlorophyll content (44.14 mg g^{-1}).

Interaction effect of variety and aerobic condition

Interaction effect of variety and aerobic condition significantly influenced the chlorophyll content (Table 18). Results indicated that the highest chlorophyll content (61.00 mg g^{-1}) was with V_4T_3. The results recorded from V_5T_1 showed the lowest chlorophyll content (37.90 mgg^{-1}).

Table 16. Effects of different variety on chlorophyll content, stem weight, no. of panicle, panicle height, panicle length and panicle weight of hybrid rice

Variety	Stem weight (g)	Chlorophyll content (mg g^{-1})	No. of panicle	Panicle height (cm)	Panicle length (cm)	Panicle weight (g)
V_1	46.78 c	49.01 a	6.78 d	92.00 c	24.78 a	12.20 d
V_2	43.03 d	49.74 a	7.22 c	90.43 c	25.08 a	15.64 b
V_3	48.49 b	46.88 b	7.17 c	93.78 bc	25.41 a	14.16 c
V_4	55.59 a	50.36 a	10.06 a	101.22 a	25.52 a	17.91 a
V_5	43.07 d	44.84 c	8.72 b	96.31 b	25.02 a	14.94 bc
$LSD_{(0.05)}$	1.552	1.671	0.08219	3.821	1.104	0.9914
CV%	3.39	3.59	6.91	4.18	4.59	6.86

Means with the same letter are not significantly different. CV= Coefficient of variation; V_1= BRRI Dhan -29, V_2=Hybrid-3, V_3=Moina, V_4=Nobin and V_5=Hira-2

4.15 Number of panicles

Effect of variety

Number of panicle was significantly influenced by different hybrid rice variety (Table 16). V_4 produced highest number of panicle (10.06) and the V_1 produced the lowest number of panicle (6.78).

Effect of aerobic condition

The effect of aerobic condition on number of panicle of different hybrid rice variety is presented in Table 17. A significant difference in number of panicle was detected among the three treatments. The highest number of panicle (8.40) produced from T_3 that is similar to T_2 (8.37) and T_1 produced the lowest number of panicle (7.20).

Interaction effect of variety and aerobic condition

The interaction effect of variety and aerobic condition was found significant (Table 18). The number of panicle varied from 6.00 to 11.17. The highest number of panicle (11.17) was obtained from V_4T_3. The lowest number of panicle (6.00) was obtained from V_1T_1.

4.16 Panicle height

Effect of variety

Panicle height was significantly influenced by different hybrid rice variety (Table 16). V_4 produced highest panicle height (101.22cm) and the V_2 produced the lowest panicle height (90.43cm) that is similar to T_1 (92.00cm).

Effect of aerobic condition

The effect of aerobic condition on panicle height of different hybrid rice variety is presented in Table 17. A significant difference in panicle height was detected among the three treatments. The highest panicle height (96.21cm) produced from T_3 and T_1 produced the lowest panicle height (93.61cm) that is similar to T_2 (94.43cm).

Interaction effect of variety and aerobic condition

The interaction effect of variety and aerobic condition was found significant (Table 18). The panicle height varied from 87.97 to 103.00cm. The highest panicle height (103.00cm) was obtained from V_4T_3. The lowest panicle height (87.97cm) was obtained from V_1T_1.

Table 17. Effects of different aerobic condition on chlorophyll content, stem weight, no. of panicle, panicle height, panicle length and panicle weight of hybrid rice

Treatment	Stem weight (g)	Chlorophyll content (mgg^{-1})	No. of panicle	Panicle height (cm)	Panicle length (cm)	Panicle weight (g)
T_1	44.68 c	44.14 b	7.20 b	93.61 b	24.15 b	14.39 b
T_2	46.45 b	49.73 a	8.37 a	94.43 b	24.96 b	14.40 b
T_3	51.04 a	50.62 a	8.40 a	96.21 a	25.60 a	16.13 a
$LSD_{(0.05)}$	1.552	1.671	0.08219	3.821	1.104	0.9914
CV%	3.39	3.59	6.91	4.18	4.59	6.86

Means with the same letter are not significantly different. CV= Coefficient of variation; T_1 =SRI method, T_2 = Raised upland and T_3 = Traditional method

4.17 Panicle length

Effect of variety

Analysis of variance data on panicle length was not significantly influenced by the variety (Table 16). From the Table 16, it was found that the highest panicle length (25.52 cm) was observed from the cultivar V_4 that is similar to V_1,V_2,V_3 and V_5 (24.78, 25.08,25.41 and 25.02 Respectively). This result is in agreement with the findings Ali et al. (2014); Hossain *et al*. (2014a and b); Shiyam *et al.* (2014); Sarker *et al.* (2013); Baset Mia and Shamsuddin (2011); Jeng *et al*. (2009); Bakul *et al.* (2009) and many other scientists. They also found variation in panicle length due to the variation in genetic make-up of the varieties of rice.

Effect of aerobic condition

Significant difference in panicle length was recorded due to aerobic condition (Table 17). Results showed that the longest panicle length (25.60 cm) was found in treatment $T_3$and the shortest result (24.15cm) was found in T_1 that is similar to T_2 (24.96cm).

Interaction effect of variety and aerobic condition

Length of panicle was significantly influenced by the interaction of variety and aerobic condition (Table 18). As shown in the table, the highest panicle length (26.73 cm) was found in $V_4T_3$and the shortest panicle length (24.00 cm) was found in V_3T_1, V_3T_2 and V_4T_1. The variation in panicle length due to interaction of variety and integrated nitrogen management was also reported by Parvin (2012).

4.18 Panicle weight

Effect of variety

Panicle weight was significantly influenced by different hybrid rice variety (Table 16). V_4 produced highest panicle weight (17.91g) and the V_1 produced the lowest panicle weight (12.20 g).

Effect of aerobic condition

The effect of aerobic condition on panicle weight of different hybrid rice variety is presented in Table 17. A significant difference in panicle weight was detected among the three treatments.

The highest panicle weight (16.13g) produced from T_3 and T_1 produced the lowest panicle weight (14.39g) that is similar to T_2 (14.40g).

Interaction effect of variety and aerobic condition

The interaction effect of variety and aerobic condition was found significant (Table 18). The panicle weight varied from 10.37 to 20.63g. The highest panicle weight (20.63g) was obtained from V_4T_3. The lowest panicle weight (10.37g) was obtained from V_1T_1.

Table 18. Interaction effect of variety and aerobic condition on chlorophyll content, stem weight, no. of panicle, panicle height, panicle length and panicle weight of hybrid rice

Interaction	Stem weight (g)	Chlorophyll Content (mgg^{-1})	No. of panicle	Panicle height (cm)	Panicle length (cm)	Panicle weight (g)
V_1T_1	47.20 g	39.57 j	6.00 g	87.97 d	24.23 fg	10.37 i
V_1T_2	48.80 e	50.27 de	10.50 b	90.00 c	26.17 b	14.83 e
V_1T_3	44.33 h	46.47 h	8.50 d	88.67 cd	24.83 de	12.53 g
V_2T_1	49.33 e	50.73 cd	7.83 ef	97.33 bc	24.33 efg	11.43 h
V_2T_2	40.43 j	47.30 g	7.33 e	88.83 cd	25.00 cd	18.17 c
V_2T_2	39.33 k	51.20 bc	6.50 gh	94.50 b	25.00 cd	17.33 d
V_3T_1	47.10 g	43.40 i	7.50 ef	96.83 bc	24.00 g	12.13 g
V_3T_2	55.60 c	46.30 h	7.67 ef	94.00 b	24.00 g	14.10 f
V_3T_3	42.77 i	50.93 bcd	6.33 gh	90.50 c	25.50 c	15.10 e
V_4T_1	57.70 b	49.17 f	6.83 gh	102.33 a	24.00 g	14.83 e
V_4T_2	47.97 f	51.63 b	7.50 ef	101.33 a	24.67 def	18.87 b
V_4T_3	61.10 a	61.00 a	11.17 a	103.00 a	26.73 a	20.63 a
V_5T_1	53.87 d	37.90 k	9.33 c	96.57 bc	24.17 fg	18.43 bc
V_5T_2	39.43 k	46.87 gh	8.17 cd	98.00 bc	25.43 c	14.67 e
V_5T_3	35.87 l	49.77 ef	8.67 d	94.37 b	25.47 c	11.13 h
LSD $_{(0.05)}$	0.6939	0.7472	0.2381	1.70 9	0.4935	0.4433
CV%	3.39	3.59	6.91	4.18	4.59	6.86

Means with the same letter are not significantly different. CV= Coefficient of variation

4.19 1000-grain weight

Effect of variety

1000 grain weight was significantly influenced by variety (Table 19). V_4 produce the highest 1000-grain weight (26.14 g) and V_1 produce lowest 1000-grain weight (22.12 g). The results are in agreement with the findings of Chowdhury *et al.* (2005) and Rahman *et al*. (2002) who observed varied 1000 grains weight among different varieties of rice.

Effect of aerobic condition

The results showed 1000-grain weight had significant due to aerobic condition (Table 20). It was revealed that T_3 produced the highest 1000-grain weight (26.38g) and T_1 produced lowest 1000-grain weight (22.78g).

Interaction effect of variety and aerobic condition

1000-grain weight was significantly affected by variety and aerobic condition. In variety and aerobic condition interaction the highest 1000-grain weight (26.23g) was obtained from V_4T_3 and lowest 1000-grain weight (20.16 g) was obtained from V_1T_1 (Table 21).

Table 19. Effects of different variety on 1000-grain weight, grain yield and straw yield of hybrid rice

Variety	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
V_1	22.12 c	4.52 d	4..53 d
V_2	24.11 b	4.79 c	4.87 c
V_3	23.16 b	5.01 b	5.11 b
V_4	24.26 b	5.05 c	5.24 b
V_5	26.14 a	5.20 a	5.40 a
LSD (0.05)	0.1823	0.7134	0.1921
CV%	8.43	9.11	7.54

Means with the same letter are not significantly different. CV= Coefficient of variation; V_1= BRRI Dhan -29, V_2= Hybrid-3, V_3=Moina, V_4=Nobin and V_5=Hira-2

4.20 Grain yield

Effect of variety

Grain yield had significant effect on grain yield. Table 19 indicated that the highest grain yield (5.20 t ha^{-1}) was obtained from $V_5$and the lowest grain yield (4.52 t ha^{-1}) obtained from V_1. The results are in agreement with the findings of Islam *et al.* (2009), Bisne *et al.* (2006), Siddiquee *et al.* (2002) and Chowdhury *et al*. (2005) whose stated that grain yield differed significantly among the varieties.

Effect of aerobic condition

Grain yield was significantly influenced by the variety (Table 20). The highest grain yield (5.38 t ha^{-1}) was produced by T_3 and the lowest grain yield (4.91 t ha^{-1}) was obtained from T_1. Grain yield, however decreased significantly when water was reduced to field capacity condition and this was in agreement with previous findings (Beyrouty *et al.* 1994; Grigg *et al*. 2000).

Interaction effect of variety and aerobic condition

Grain yield was significantly influenced by variety and aerobic condition. In variety and aerobic condition interaction (Table 21) the highest grain yield (5.60 t ha^{-1}) was recorded from V_4T_3 and the lowest grain yield (4.32 t ha^{-1}) was recorded from V_1T_1.

Table 20. Effects of different aerobic condition on 1000-grain weight, grain yield and straw yield of hybrid rice

Treatment	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (tha^{-1})
T1	22.78 c	4.91 c	5.12 c
T2	23.23 b	5.13 b	5.32 b
T3	26.38 a	5.38 a	5.54 a
LSD (0.05)	0.1823	0.7134	0.1921
CV%	8.43	9.11	7.54

Means with the same letter are not significantly different. CV= Coefficient of variation; T_1 =SRI method, T_2 = Raised upland and T_3 = Traditional method

4.21 Straw yield

Effect of variety

Straw yield had significant effect by variety. Table 19 indicated that V_4 produced highest straw yield (5.20 t ha^{-1}) compared to other variety and V_1 produced the lowest straw yield (4.53 t ha^{-1}).

Effect of aerobic condition

Straw yield was significantly influenced by aerobic condition (Table 20). T_3produced highest straw yield (5.54 t ha^{-1}) and T_1 produced highest straw yield (5.12 t ha^{-1}).

Interaction effect of variety and aerobic condition

Straw yield was t significantly influenced by variety and aerobic condition. In variety and aerobic condition highest straw yield (5.73 t ha^{-1}) was obtained from V_4T_3 and lowest straw yield (4.40 t ha^{-1}) was obtained from V_1T_1 (Table 21).

Table 21. Interaction effect of variety and aerobic condition on 1000-grain weight, grain yield and straw yield of hybrid rice

Interaction	1000-grain weight (g)	Grain yield (t ha^{1})	Straw yield (t ha^{-1})
V_1T_1	20.16 e	4.32 e	4.40 e
V_1T_2	21.16 d	4.54 cd	4.61 d
V_1T_3	23.04 cd	4.73 cd	4.83 cd
V_2T_1	23.57 c	4.95 c	5.01 c
V_2T_2	21.16 d	4.49 d	4.63 d
V_2T_2	23.60 c	5.01 b	5.21 b
V_3T_1	25.94 b	5.05 b	5.17 b
V_3T_2	24.34 bc	5.15 ab	5.28 ab
V_3T_3	25.15 b	5.30 ab	5.48 ab
V_4T_1	21.13 bc	4.45 d	4.60 d
V_4T_2	23.23 c	5.12 ab	5.22 b
V_4T_3	27.23 a	5.60 a	5.73 a
V_5T_1	23.14 c	5.23 ab	5.35 ab
V_5T_2	24.33 bc	5.32 ab	5.53 ab
V_5T_3	25.12 b	5.35 ab	5.47 ab
$LSD_{(0.05)}$	0.1792	0.8213	0.9453
CV%	8.43	9.11	7.54

Means with the same letter are not significantly different. CV= Coefficient of variation

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Research farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during December, 2017 to May season of 2018 with rice. The objective was to determine the performance of hybrid and modern inbred rice variety under aerobic condition. The experimental land belongs to Madhupur Tract, AEZ No. 28. There were five varieties (V_1=BRRI dhan 29, V_2=Hybrid-3, V_3=Moina, V_4=Nobin and V_5=Hira-2) and three cultivation method, T_1 =SRI method, T_2 = Raised upland and T_3 = Traditional method.

The experiment was laid out in a Randomized complete block design (RCBD) with 3 replications. The unit plot size will be 4m×2.5m= 10m^2. The total number of unit plots was 45. The spaces between replication and between unit plots were 1 m and 0.5 m, respectively. The treatments were randomly distributed. The Calculated amount of fertilizers was thoroughly mixed with soil during final land preparation. Different intercultural operations such as weeding and irrigation were done to ensure normal growth of the crop. Analysis was done by the MSTAT–C package program whereas means were adjudged by LSD test at 5% level of probability.

The effect of variety was significant, whole characters of the study were influenced significantly whereas almost all the characters were showed best performance under the variety V_4 (Nobin). The highest plant height (36.24, 66.01, 82.94, 96.57 and 112.78 cm), the maximum number of tiller (6.58, 13.78, 15.58, 18.87 and 14.98 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest),the maximum number of effective tillers hill^{-1} (13.56), The highest leaves hill^{-1} (20.34, 44.29, 40.83, 54.84 and 50.28 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest, respectively), the maximum leaf length (38.56, 35.56 and 48.20cm at 60 DAT,75 DAT and 85 DAT), the maximum leaf length (0.88, 1.39 and 1.68cm at 60 DAT,75 DAT and 85 DAT), highest flag leaf length (34.18cm) , highest flag leaf breadth (1.57cm), highest penultimate leaf length (41.68cm), highest dry weight of three leaves (0.63 g), highest penultimate leaf breadth (1.42cm), highest dry weight of leaves (16.48 g), highest dry stem weight (55.59 g), highest chlorophyll content (50.36 mg g^{-1}), highest number of panicle (10.06), highest panicle height (101.22cm), longest panicle length (25.60 cm), highest panicle weight (17.91g), highest 1000-grain weight (26.14 g), highest grain yield (5.20 t ha^{-1}) and highest straw yield (5.40 t ha^{-1})

Was obtained from the variety of Nobin (V_4).The maximum number of non-effective tillers hill^{-1} was produced by V_2 (1.78). The shortest plant (32.54, 56.06, 70.64, 83.30 and 97.43 cm at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest, minimum number of tiller (5.83, 11.61, 14.76, 11.81 and 11.56 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest),the minimum number of effective tillers hill^{-1} (10.44), the lowest number of leaves hill^{-1} (16.11, 38.30, 35.02,36.27 and 41.33 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest, respectively), the minimum leaf length (34.52, 33.61 and 42.16cm at 60 DAT, 75 DAT and 85 DAT), the minimum leaf length (0.75, 1.34 and 1.57cm at 60 DAT, 75 DAT and 85 DAT), the lowest flag leaf length with the value 27.94cm, the lowest flag leaf breadth with the value 1.32cm, the lowest penultimate leaf length (33.30cm), the lowest penultimate leaf breadth (1.17cm),the lowest dry matter of leaves (12.96 g),the lowest dry weight of three leaves (0.54 g), the lowest dry stem weight (43.03 g),the minimum chlorophyll content (44.84 mg g^{-1}) , the lowest number of panicle (6.78),the lowest panicle height (90.43cm),the shortest panicle length (24.15cm), the lowest panicle weight (12.20 g), lowest 1000-grain weight (22.12 g), the lowest grain yield (4.52 t ha^{-1}) and the lowest straw yield (4.53 t ha^{-1})was observed from BR-29.The minimum number of non-effective tillers hill^{-1} (0.78) was obtained from V_4.

In case the effect of aerobic condition was significant, whole characters of the study were influenced significantly whereas almost all the characters were showed best performance under the T_3. The highest number of tiller (6.65, 13.68, 15.98, 15.51 and 14.20 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest), the maximum (13.27) number of effective tillers hill^{-1}, highest number of leaves hill^{-1} (21.13, 45.62, 41.15, 46.20 and 49.26 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest, respectively), highest number of leaves hill^{-1} (21.13, 45.62, 41.15, 46.20 and 49.26 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest, respectively), the highest leaf length (38.50, 35.70 cm and 46.03 at 60 DAT, 75 DAT and 85 DAT), The highest leaf breadth (0.82, 1.35 and 1.64cm at 60 DAT, 75 DAT and 85 DAT), highest flag leaf length (33.24cm) , highest flag leaf breadth (1.45cm) , highest penultimate leaf length (38.55cm), highest penultimate leaf breadth (1.44cm), highest dry weight of leaves (15.77g), highest dry weight of three leaves (0.63g), highest dry stem weight (51.04g), highest chlorophyll content (50.62 mg g^{-1}), highest number of panicle (8.40),highest panicle height (96.21cm), highest panicle weight (16.13g), highest 1000- grain weight (26.38g) ,highest grain yield (5.38 t ha^{-1}) and highest straw yield (5.54 t ha^{-1}) was obtained from T_3. The highest plant height obtained from was recorded

35.44, 61.70, 76.51, 88.31 and 105.27cm at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest, respectively. The maximum (1.60) number of effective tillers hill^{-1} was obtained from T_1.The lowest plant height (33.35, 56.43, 73.17, 86.43 and 102.37cm at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest) ,lowest number of tillers (5.25, 11.67, 14.16, 12.72 and 12.93 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest), lowest number (11.73) of effective tillers hill^{-1}, the lowest number (1.07) of effective tillers hill^{-1}, the lowest number of leaves (15.65, 40.01, 35.43, 39.20 and 39.93 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest, respectively), the lowest leaf length (35.40, 33.70 and 42.98cm at 60 DAT, 75 DAT and 85 DAT), the lowest leaf breadth (0.77, 1.34 and 1.56 at 60 DAT, 75 DAT and 85 DAT), the lowest flag leaf length with the value 30.89cm, the lowest flag leaf length with the value 1.35cm, the penultimate penalty leaf length (36.49cm), the lowest penultimate leaf breadth (1.10cm), showed the lowest dry weight of leaves (13.30g), the lowest dry weight of three leaves (0.59g), the lowest dry stem weight (44.68g), the lowest chlorophyll content (44.14 mg g^{-1}), the lowest number of panicle (7.20), the lowest panicle height (93.61cm), the lowest panicle weight (14.39g), lowest 1000-grain weight (22.78g), the lowest grain yield (4.91 t ha^{-1}) and the lowest straw yield (5.12t ha^{-1}).

There was significant effect of variety and aerobic condition. Effect of interaction was also significantly influenced the whole characters of the study where almost all the characters were highly influenced by the V_4T_3 compared other treatments of the study. The highest plant height 37.97, 70.17, 51, 87.40, 101.23 and 115.67 cm at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest, respectively, the highest number of tillers 7.67, 17.57, 17.07, 19.97 and 18.33 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest, respectively, maximum number of effective tillers hill^{-1} (16.67), the highest number of leaves hill^{-1} (23.00, 47.67, 53.07, 60.30 and 62.00 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest), the highest leaf length (42.33, 37.67 and 54.13cm at 60 DAT, 75 DAT and 85 DAT), the highest flag leaf length (39.80cm), the highest flag leaf breadth (1.80cm), the highest penultimate leaf length (44.00cm), the highest penultimate leaf breadth (1.82cm), the highest dry weight of leaves (20.50g), the highest dry weight of three leaves (0.80g), the highest dry stem weight (61.10g), the highest chlorophyll content (61.00 mg g^{-1}), the highest number of panicle (11.17), the highest panicle height (103.00cm), the highest panicle length (26.73 cm), the highest panicle weight (20.63g), highest 1000-grain weight (26.23g), highest grain yield (5.60 t ha^{-1}) and highest straw yield (5.73 t ha^{-1}) were obtained from V_4T_3. The highest number of non-effective tiller obtained from V_2T_2 (2.67). The highest leaf length of rice plants that received from V_3T_3 (0.94, 1.39 and 1.72 cm at 60 DAT, 75 DAT and 85 DAT).The lowest plant height (31.67, 53.43, 70.10, 75.80 and 92.00 cm at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest), the lowest number of tiller (4.50, 10.73,12.73, 10.30 and 10.67 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest),the lowest number of non-effective tillers (0.00), the lowest number of leaves hill^{-1} (13.13, 34.43, 32.47, 31.00 and 36.33 at 45 DAT, 60 DAT, 75 DAT, 85DAT and at harvest), the lowest leaf length (32.83, 32.33 and 39.60cm at 60 DAT, 75 DAT and 85 DAT), the lowest leaf length (0.72, 1.30 and 1.47 at 60 DAT, 75 DAT and 85 DAT), the lowest flag leaf length (26.70cm), the lowest flag leaf breadth(1.12cm), the lowest penultimate leaf length (29.90cm), the lowest penultimate leaf breadth (1.04cm), the lowest dry weight of leaves (9.07g), the lowest dry weight of leaves (0.46g), the lowest dry stem weight (39.33g), the lowest chlorophyll content (37.90 mg g^{-1}), the lowest number of panicle (6.00) ,the lowest panicle height (87.97cm),the lowest panicle weight (10.37g), lowest 1000-grain weight (22.78g), the lowest grain yield (4.32 t ha^{-1}) and lowest straw yield (4.40 t ha^{-1}) were obtained from V_1T_1. The shortest panicle length (24.00 cm) was found in V_3T_1.

Above observation of the present study, it may be concluded that the V_4 (Nobin) and T_3 (traditional) treatment as singly or their interaction were more successful for produce highest results.

Recommendation

1. Hybrid rice variety, Nobin should be cultivated in traditional system for getting higher grain yield.

2. Such type of study is needed in different Agro-Ecological Zones (AEZ) of Bangladesh for testing the regional compliance and other quality attributes.

CHAPTER VI

REFERENCES

Abou-Khalif, A.A.B. 2009. Evaluation of some hybrid rice varieties in under different sowing times. *Afr. J. Plant Sci.*, 3 (4): pp. 053-058.

Abou-Khalifa, A. A. B. (2009). Evaluation of some rice varieties under different nitrogen levels. Seedling. 1:12

AIS (Agricultural Information Service). (2016). Krishi Diary 2016, Agril Inform. Ser. Khamarbari, Farmgate, Dhaka-1215, Bangladesh.

Ali, A., Khalifa, A., Elkhoby, W. and Okasha, E.M. (2014). Effect of sowing dates and seed rates on some rice cultivars. *African J. of Agri. Res.* 9(2): 196–201.

Amin, R.M., Hamid, A., Choudhury,U.R., Raquibullah, M.S. and Asaduzzaman M. 2006. Nitrogen fertilizer effect on tillering, dry matter production and yield of traditional varieties of Rice. *Intl. J. Sustain. Crop Prod.*, 1(1): 17-20.

Anonymous. (1988). Land resources appraisal of Bangladesh for agricultural development. Report No. 2. Agro-ecological regions of Bangladesh, UNDP and FAO. pp. 472–496.

Anwar, M. P. and Begum, M. 2004. Tolerance of hybrid rice variety Sonarbangla-1 to tiller separation. *Bangladesh J. Crop Sci*., 13-15: 39-44.

Ashrafuzzaman, M., M.R. Islam, M.R. Ismail, S.M. Shahidullah and M.M. Hanafi. (2009). Evaluation of six aromatic rice varieties for yield and yield contributing characters. *Intl. J. Agri. Biol.*, 11: 616–620.

Babiker FSH 1986: The effect of zinc sulphate levels on rice growth and productivity. *Alexandria J. Agril. Res*., 31 (2): 480-481.

Bakul, M.R.A., Akter, M.S., Islam, M.N., Chowdhury, M.M.A.A. and Amin, M.H.A. (2009). Water stress effect on morphological characters and yield attributes in some mutants T-*Aman* rice lines. *Bangladesh Res. Pub. J.*, 3(2): 934–944.

Baset Mia, M.A. and Shamsuddin, Z.H. (2011). Physio-morphological appraisal of aromatic fine rice (*Oryza sativa* L.) in relation to yield potential. *Intl. J. Botany*., 7(3): 223–229.

BBS (Bangladesh Bureau of Statistics) 2013: Yearbook of Agricultural Statistics of Bangladesh. Ministry of Planning. Govt. of the People’s Republic of Bangladesh, Dhaka. p. 136–140.

BBS (Bangladesh Bureau of Statistics) 2013: Yearbook of Agricultural Statistics of Bangladesh. Ministry of Planning. Govt. of the People’s Republic of Bangladesh, Dhaka. p. 136–140.

BBS (Bangladesh Bureau of Statistics). (2010). Agriculture crop cutting. Estimation of *Boro* rice 2009-2010. Govt. of the People's Republic of Bangladesh, Dhaka, p. 38.

BBS (Bangladesh Bureau of Statistics). (2014). Statistical Yearbook of Bangladesh. Statistics Division, Ministry of Planning, Govt. of the People’s Republic of Bangladesh.

BER 2013: Bangladesh Economic Review, Ministry of Finance, Government of the People's Republic of Bangladesh, Dhaka.

Beyrouty, C. A.Grigg, B. C., Nornan, R. J., and Wells, B. R. 1994. Nutrient uptake by rice in response to water management. *J. Plant Nutr*., 17: 39-55.

Bhowmick, N. and Nayak, R.L. 2000. Response of hybrid rice (Oryza sativa L.) varieties to nitrogen, phosphorus and potassium fertilizers during dry (Boro) season in West Bengal. *Indian J. Agron*., 45 (2): 323-326.

Bhuiyan SI, Karim ANMR 1999: "Rice production in Bangladesh: an overview." In: Increasing rice production in Bangladesh. Challenges and Strategies. IRRI. BRRI. pp. 1-11.

BINA (Bangladesh Institute of Nuclear Agriculture) 1993: Annual Report for 1992- 93. Bangladesh Inst. Nuc. Agric., Mymensingh. P. 143- 147.

Bisne, R., Motiramani, N.K. and Sarawgi, A.K. 2006. Identification of high yielding hybrids in rice. *Bangladesh J. Agril. Res.,* 31(1): 171-174.

Bokyeong, K., Kiyoung, K., Myungkyu, O., Jaekil, Jaekwon, K. and Heekyoung, K. 2003. Effects of nitrogen level and seedling number on panicle structure in japonica rice. *Korean J. Crop Sci.,* 48 (2): 120-126.

Bouman, B.A.M., Yang Xiaoguang, Wang Huaqi, Wang Zhimin, Zhao Junfang, and Chen Bin 2005. Performance of aerobic rice varieties under irrigated conditions in North China. *Field Crops Res.,* 103(3):170-177

Bouman, B.A.M., Yang Xiaoguang, Wang Huaqi, Wang Zhiming, Zhao Junfang, Wang Changgui and Cheng Bin. 2002.Aerobic Rice (Han Dao): A new way of growing rice in water-short areas.12th ISCO Conference, Beijing: 176-181.

BRRI (2017). Bangladesh Rice Research Institute "Rice in Bangladesh", Bangladesh Rice Res. Inst.

BRRI (Bangladesh Rice Research Institute) 1994: Annual Report for 1993. Bangladesh Rice Res. Inst., Joydebpur, Gazipur. pp. 8-9.

BRRI (Bangladesh Rice Research Institute) 1997: Annual Report for 1996. Bangladesh Rice Res. Inst., Joydebpur, Gazipur.pp.3-18.

BRRI (Bangladesh Rice Research Institute) 2000: Annual Report for 1999.. Bangladesh Rice Res. Inst., Joydebpur, Gazipur. pp. 3-38.

BRRI (Bangladesh Rice Research Institute) 2013: Annual Report for 2013. Bangladesh Rice Res. Inst., Joydebpur, Gazipur.pp.28-35.

BRRI (Bangladesh Rice Research Institute). (2012). Annual Report for 2011. Bangladesh Rice Res. Inst. Joydebpur, Gazipur, Bangladesh, pp. 9-13

BRRI (Bangladesh Rice Research Institute). (2013). Modern Rice Cultivation, 17 th Edition.

BRRI (Bangladesh Rice Research Institute). 1994. Annual report for 1993. Bangladesh Rice Res. Inst., Jodebpur, Gazipur. pp. 8-9.

BRRI (Bangladesh Rice Research Institute). 1995. Annual report for 1994.Bangladesh Rice Res. Inst., Joydebpur, Gazipur. p. 138.

Chen, B.M., Wang, Z.H., Li, S.X., Wang, G.X. and Song, H.X. (2008). Effects of nitrate supply on plant growth, nitrate accumulation, metabolic nitrate concentration and nitrate reductase activity in three leafy vegetables. *Plant Sci.,* 167: 635–643.

Chen-Liang, Y., Laignelet, B. and Marie, R. 2000.Variation of technological quality in rice according to genotype and environment. *J. Agron.*, 3(2): 179-183.

Chowdhury MJU, Sarker AU, Sarkar MSR, Kashem MA 1993: Effect of variety and number of seedlings hill-1 on the yield and its components on late transplanted aman rice. *Bangladesh J. Agril. Sci*., 20(2): 311-316.

Chowdhury, U.M.J., Sacker, U.A., Sarkar, R.M.A. and Kashem, A.M. 2005. Effect of variety and number of seedlings hill's on the yield and its components on late transplanted Aman rice. *Bangladesh J. Agril. Sci.*, 20(2): 311-316.

Devaraju, K.M., Gowda, H. and Raju, B.M. 1998. Nitrogen response of Karnataka Rice Hybrid 2. *Intl. Rice Res. Notes*, 23(2): 43.

Dongarwar, U.R., Patankar, M.N and Pawar, W. S. 2003. Response of hybrid rice to different fertility levels. *J. Soils and Crops.* 13 (1): 120-122.

Futsuhara, J. and Kikuchi, Y. 1984. Grain quality evaluation and improvement at IRRI. In: proc. The workshop on chemical aspect of rice grain quality, IRRI, Philippines.

Gomez KA, Gomez AA 1984: Statistical Procedures for Agricultural Research. 2nd Edn. John Willey and Sons, New York. pp. 97–411.

Grigg, B. C., Beyroty, C. A., Nornan, R. J., Gbur, E. F.., Hamson, M. G. and Wells, B. R. 2000. Rice responses to changes in flood water and N turing in Southern USA. *Field Crop Res*., 66: 73-79.

Haque, M. M. and Biswas, J. K. (2011). Annual Research Review. Plant Physiology Division. Bangladesh Rice Research Institute, Joydebpur, Gazipur, Bangladesh.

Haque, M. M., Pramanik, H. R. and Biswas, J. K. 2013. Physiological behavior and yield performances of hybrid rice at different planting dates in Aus Season. *Bangladesh Rice J*. 17(1&2): 7-14.

Hasan MS, Hossain SMA, Salim M, Anwar MP, Azad AKM 2002: Response of hybrid and inbred rice varieties to the application methods of urea super granules and prilled urea. *Pakistan J. Biol. Sci.,* 5(7): 746-748.

Hasan SM 2007: Effect of level of urea super granules on the performance of T. aman rice. M. Sc. Ag. Thesis in Agronomy, BAU, Mymensingh.

Hasan SM 2007: Effect of level of urea super granules on the performance of T. aman rice. M. Sc. Ag. Thesis in Agronomy, BAU, Mymensingh.

HIES 2010: Household Income and Expenditure Survey, Bangladesh Bureau of Statistics, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka.

Hossain MS 2007: Grain yield and protein content of transplant *Aman* rice as influenced by variety and rate of nitrogen. M. Sc. (Ag.) Thesis in Agronomy, BAU, Mymensingh, pp. 51-55.

Hossain MS, Mamun AA, Basak R, Newaj MN, Anam MK 2003: Effect of cultivar and spacing on weed infestations and performance of transplant aman rice in Bangladesh. *Pakistan J. Agron*., 2(3):169-178.

Hossain, M.F., Bhuiya, M.S.U. and Ahmed, M. (2005). Morphological and agronomic attributes of some local and modern aromatic rice varieties of Bangladesh. *Asian J. Plant Sci.,* 4(6): 664–666.

Hossain, M.M., Sultana, F. and Rahman, A.H.M.A. (2014a). A comparative screening of hybrid, modern varieties and local rice cultivar for brown leaf spot disease susceptibility and yield performance. Archives of Phyto-pathology and Plant Protection, 47(7): 795–802.

Hossain, M.T., Ahmed, K.U., Haque, M.M., Islam, M.M., Bari, A.S.M.F. and Mahmud, J.A. (2014b). Performance of hybrid rice (*Oryza sativa* l.) varieties at different transplanting dates in Aus season. *Applied Sci. Report*, 1(1): 1-4.

IRRI (International Rice Research Institute) 2015: http://www.irri.org.

IRRI (International Rice Research Institute) 1989: Principles and Practices of Rice Cultivation. John Wiley and Sons. Inc., New York. p. 327.

Islam, M.S.H., Bhuiya, M.S.U., Gomosta, A.R., Sarkar, A.R. and Hussain, M.M. 2009. Evaluation of growth and yield of selected hybrid and inbred rice varieties grown in net-house during transplanted Aman season. *Bangladesh J. Agric. Res.*, 34: 1.

Islam, M.S.H., Bhuiya, M.S.U., Gomosta, A.R., Sarkar, A.R. and Hussain, M.M. 2009. Evaluation of growth and yield of selected hybrid and inbred rice varieties grown in net-house during transplanted Aman season. *Bangladesh J. Agric. Res.*, 34: 1.

Islam, N., Kabir, M.Y., Adhikary, S.K. and Jahan, M.S. (2013). Yield performance of six local aromatic rice cultivars. *J. Agric. Veterinary Sci.*, 6(3): 58–62.

Jeng, T.L., Tseng, T.H., Wang, C.S., Chen, C.L. and Sung, J.M. (2009). Yield and grain uniformity in contrasting rice genotypes suitable for different growth environments. *Field Crops Res.*, 99: 59–66.

Julfiquar AW, Haque MM, Enamul Haque AKGM, Rashid MA 1998: Current status of hybrid rice research and future programme in Bangladesh. A country report presented in the workshop on Use and Development of Hybrid Rice in Bangladesh held at BARC May 18-19, 1998.

Julfiquar, W.A., Haque, M.M., Haque, E.K.G.M.A. and Rashid, A.M. (2009). Current status of Hybrid Rice Research and Future Program in Bangladesh. Proc. Workshop on use and development of hybrid rice in Bangladesh, held at BARC, 18-19, May, 2009.

Julfiquar,W.A., Haque, M.M., Haque, E.K.G.M.A.and Rashid, A.M. 1998. Current status of hybrid rice research and future program in Bangladesh. Proc. Workshop on use and development of hybrid rice in Bangladesh, held at BARC, 22-23, April, 1998.

Kamal AMA, Islam MR, Chowdhury MLD 1999: Growth performance, protein content and nutrient uptake by modern varieties of rice under irrigated condition in Bangladesh. *Thai. J. Agric. Sci.*, 32(1): 105-110.

Koffi Djaman, Boubie V Bado, Valere C Mel 2016: Effect of nitrogen fertilizer on yield and nitrogen use efficiency of four aromatic rice varieties. *Emirates J. Food Agric*., 28(2): 126-135.

Luh, B. S. 1991. Rice Production. Vol. 1. Second Edn. AVI Publication Company, Inc. USA.

Mahamud, J.A., Haque, M.M. and Hasanuzzaman, M. (2013). Growth, dry matter production and yield performance of transplanted *Aman* rice varieties influenced by seedling densities per hill. *Intl. J. Sust.. Agric.*, 5(1): 16–24.

Main, M. A., Biswas, P. K. and Ali, M. H. 2007. Influence of planting material and planting methods on yield and yield attributes of inbred and hybrid rice. *J. Sher-e-Bangla Agri. Univ.*, 1(1): 72-79.

Mannan MA, MSU Bhuiya, HMA Hossain, MIM Akhand 2010: Optimization of nitrogen rate for aromatic Basmati rice (*Oryza* sativa L.). *Bangladesh J. Agril. Res*., 35(1): 157-165.

Mishra, P.K. and Pandey, R. 1998. Physico-chemical properties of starch and protein and their relation to grain quality and nutritional value of rice. Rice Breed. Pub. IRRI, Los Banos, Phillippines. pp.389-405.

Molla, M. A. H. 2001. Influence of seedling age and number of seedling on yield attribute and yield of hybrid rice in the wet season. *Intl. Rice Res. Notes*. 26(2): 73-74.

Munoz, D., Gutierrez, P. and Carredor, E. 1996. Current status of research and development of hybrid rice technology in Colombia. In. Abst., Proc. 3r Intl. Symp. on Hybrid Rice. November 14-16. Directorate Rice Res., Hyderabad, India. p. 25.

Murthy, K.N.K., Shankaranarayana, V., Murali, K., Jayakumar, B.V., 2004. Effect of different dates of planting on spikelet sterility in rice genotypes (*Oryza sativa* L.). *Res. Crops*. 5(2/3): 143-147.

Myung, K. 2005. Yearly variation of genetic parameters for panicle characters of Japonica rice (*Oryza sativa* L.). *Japanese J. Crop Sci*., 69(3): 357-358.

Obulamma, U., Reddeppa, R. and Reddy, R. 2002. Effect of spacing and seedling number on growth and yield of hybrid rice. *J. Res. Angrau,*. 30(1): 76-78.

Oko, A.O., Ubi, B.E. and Efisue, A.A. (2012). A Comparative Study on Local and Newly Introduced Rice Varieties in Ebonyi State of Nigeria based on Selected Agronomic Characteristics. *Intl. J. Agri*. *Forestry*. 2(1): 11–17 (doi: 10.5923/j.ijaf.20120201.03.).

Om, H., Katyal, S.K., Dhiman, S.D. and Sheoran, O. P. 1999. Physiological parameters and grain yield as influenced by time of transplanting and rice (*Oryza sativa* L.) hybrids. *Indian J. Agron*., 44 (4): 696-700.

Panwar, C.S., Vishwakarma, S.K. and Verma, N. (2012). Comparative performance of different rice varieties in relation to growth and yield. *Bioinfolet.* 9(4A): 631–632.

Parvin S 2012: Improving yield of T. Aman rice (cv. BRRI dhan52) through integrated use of nitrogen. MS Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh. p. 23-33.

Patjoshi, A. K. and Lenka, D. 1998. Determination of water management practices and effective rainfall in direct seeded medium land rice under varying water table situations. *Oryza*, 35 (2): 145-147.

Patnaik, M.M., Bautista, G.M., Lugay, J.C. and Reyes A.C. 1990.Studies on the physiochemical properties of rice. *J. Agric. Food Technol*., 19: 1006-1011.

Peng, S., Ang, J. U. Y., Carcia, F. V. and Laza, R. C. 2006. Physiology based crop management for yield maximization of hybrid rice. In: Advances in hybrid rice technology. Proc. 3 Intl. Symp. on Hybrid rice. IRRI, Los Banos, Philippines. Pp.-12-14.

Predeepa, J. R. 2012. Aerobic rice- the next generation innovation in rice cultivation technology. *Intl. J. Farm Sci*., 2(2): 54-58.

Rahman A, Yasin M, Akram M, Awan ZI 2002: Response of rice to Zinc application and different N-sources in calcareous soil. *Sci. Vision*, 8(1):20-25

Rahman MM 2006: Effect of cultivar, depth of transplanting and depth of placement of urea super granules on growth and yield of *Boro* rice. MS (Ag.) Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh. 94 p.

Rahman, M.A., Hossain, S.M.A., Sarkar, N.A.R., Hossain, M.S. and Islam, M.S. 2002. Effect of variety and structural arrangement of rows on the yield and yield components of transplant *Aman* rice. *Bangladesh .J. Agril. Sci.*, 29(2): 303-307.

Reddy, M. D. 2013. Report, The sustainable water resource management project in India (India–USA Joint Project), Oryza Exclusive, Oryza.com.

Russel DF 1986: MSTAT-C package program. Crop and Soil Science Department, Michigan State University, USA

Sarkar SK, MAR Sarkar, N Islam, SK Paul 2014: Yield and quality of aromatic fine rice as affected by variety and nutrient management. *J. Bangladesh Agril. Univ*., 12(2): 279–284.

Sarker, B.C., Zahan, M., Majumder, U.K., Islam, M.A. and Roy, B. (2013). Growth and yield potential of some local and high yielding *Boro* rice cultivars. *J. Agrofor. Envment.*, 7(1): 107-110.

Sattar M. A. and Bhuiyan, S. I. 1994. Performance of direct- seeded and transplanted rice under different water management practices. *Bangladesh Rice J*., 3 (1&2): 1-5.

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

Shiyam, J.O., Binang, W.B. and Ittah, M.A. (2014). Evaluation of growth and yield attributes of some lowland chinese hybrid rice (*Oryza sativa* L.) varieties in the Coastal Humid Forest Zone of Nigeria. *J. Agric. Vetry. Sci.*, 7(2): 70–73.

Siddiquee, M.A., Biswas, S.K., Kabir, K. A., Mahbub, A.A., Dipti, S.S., Ferdous, N., Biswas, J.K. and Banu, B. 2002. A Comparative study between hybrid and inbred rice in relation to their yield and quality. *Pakistan J. Biol. Sci*., 5: 550-552.

Son, Y., Park, T.S., Kim, Y.S., Lee, W. H.and Kim, C.S. 1998. Effects plant density on the yield and yield components of low-tillering large panicle type rice. *RDA J. Crop Sci.*, 40: 2.

Sritharan, N. and Vijayalakshmi, C. (2012). Physiological basis of rice genotypes under aerobic condition. Plant Archives. 12(1): 209–214.

Sumit, C; Pyare, L; Singh, A.P. and Tripathi, M.K. 2004. Agronomic and morpho-physiological analysis of growth and productivity in hybrid rice (*Oryza sativa* L.). *Ann. Biol*. 20(2): 233-238.

Swain, P., Annie, P. and Rao, K. S. 2006. Evaluation of rice (*Oryza sativa*) hybrids in terms of growth and physiological parameters and their relationship with yield under transplanted condition. *Indian J. Agric. Sci.*, 76(8): 496-499.

Tac, T.H., Hirano, M., Iwamoto, S., Kuroda, E. and Murata, T. 1998. Effect of top-dressing and planting density on the number of spikelets and yield of rice cultivated with nitrogen- free basal dressing. *Plant Prod. Sci*., 1(3): 191-198.

Tang, W. B., Zhang, G. L. and Xiao, Y. H. (2010). Physiological and biochemical characteristics in flag leaves of the C Liangyou series of rice hybrid combinations at late growth stages. *Rice Sci.*, 17(4):319-325.

Uddin, M.J., M.M., Hasan, S. Ahmed, and M.M. Hasan (2010). Effect of spacing on morpho-physilogical response of different. *Aman* rice cultivars under coastal high land ecosystem. *Indian J. Agril. Res.*, 44(4): 251–258.

Wang, L.J., Xu, J.Z. and Yi, Z.X. 2006. Effects of seedling quantity and row spacing on the yields and yield components of hybrid and conventional rice in northern China. *Chinese J. Rice Sci.*, 20(6): 631-637.

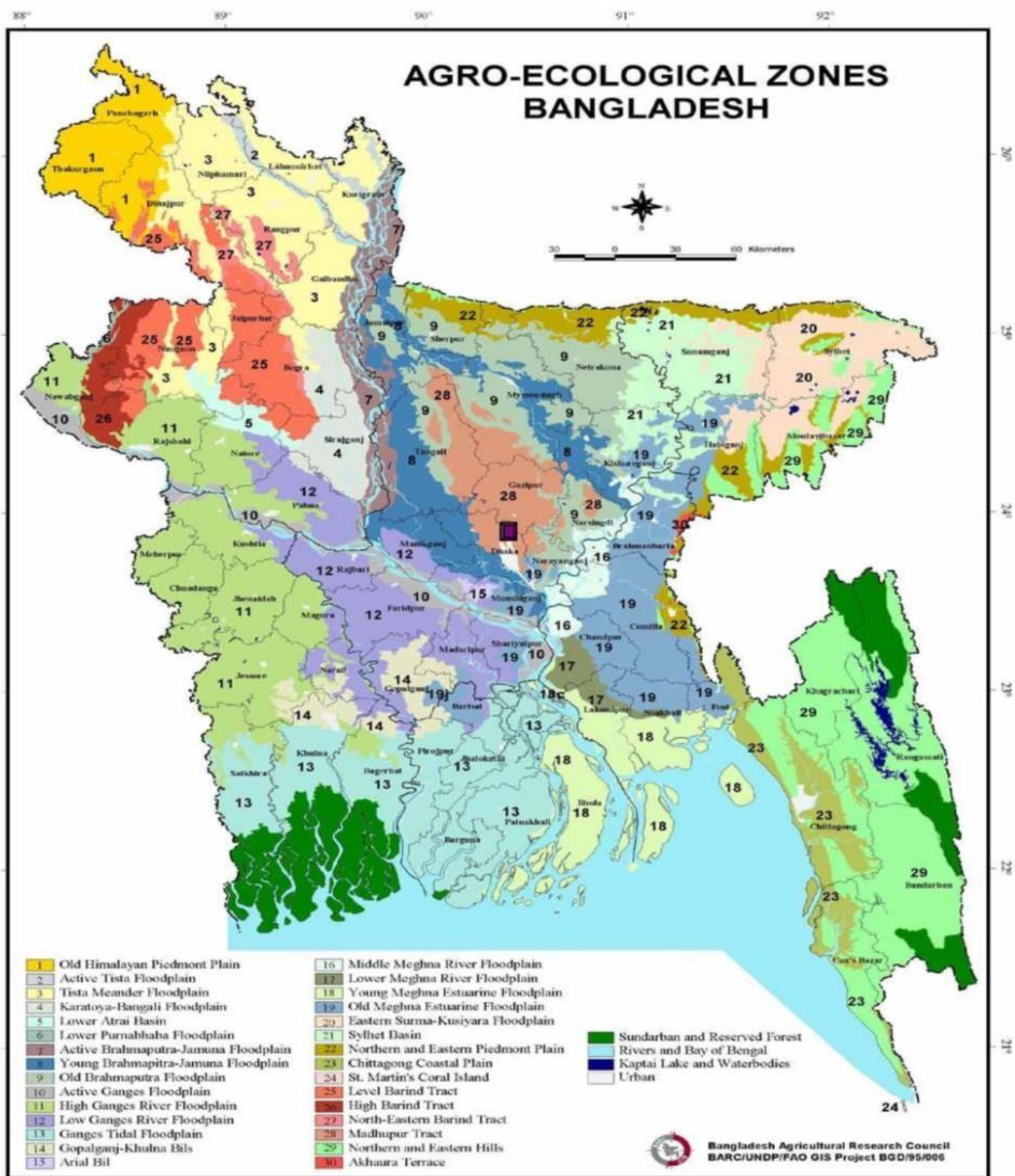
Witham, H., Blaydes, D. F. and Devin, R. M. 1986. Exercises in plant physiology.2nd edition. PWS Publishers, Boston. USA. p. 128-131.

Wong Y, Kuroda E, Hirano M, Murak T, Wang YD 1997: Comparison of growth and yield characteristics and dry matter production. *Japan. J. Crop Sci.*, 66(2): 293-299.

Xu, S and Wang, C. 2001. Study of yield attributes of some restorer and maintainer lines. *Intl. Rice Res. Newsl.*, 26(7): 136-138.

Zhang, X.P., Gu-Qiang-Sheng and Shi-Bin. 2004. Water saving technology for paddy rice irrigation and its popularization in China. *Irrigation-and-Drainage-Systems*. 18 (4): 347-356.

Appendix I: Map showing the experimental sites under study



The experimental site under study

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

Month	Temperature(°C)		Relative humidity (%)		Rainfall (cm)
	Max	Min	Max	Min	
November, 2017	28.00	18.00	75	52.50	00
December, 2018	27.00	18.00	74	53.36	00
January, 2018	22.00	17.05	53	41.58	00
February, 2018	26.77	19.74	58	43.71	25
March, 2018	30.48	20.16	62	50.52	32

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

Appendix III. Morphological, chemical and physical properties of the experimental field

A. Morphological characteristics of experimental plot soil

Constituents	Characteristics
Location	Sher-e-Bangla Agricultural University Farm, Dhaka
Land Type	High land
General type	Deep Red Brown Terrace Soil
Soil series	Tejgaon
AEZ	Madhupur Tract, AEZ No. 28
Topography	Fairly leveled
Soil color	Grey
Drainage system	Well drained
Soil texture	Clay loom
Consistency	Granular

B. Chemical and physical composition of initial soil (0-15 cm)

Characteristics	Value
Textural class	Silty–clay
pH	5.7
Organic Matter (%)	1.79
Total Nitrogen (%)	0.134
Available P µg/g	3.1
Exchangeable K meq/100g	0.30
Available S µg/g	32
Sand (2.00 – 0.5 mm dia)	28.2
Silt (0.5 – 0.002 mm dia)	41.2
Clay (below 0.002 mm dia)	30.6

Appendix IV. Layout of the experimental field

R_1		R_2		R_3
V_5T_3		V_2T_1		V_3T_2
V_4T_3		V_1T_1		V_4T_2
V_3T_3	1m	V_5T_1	1m	V_2T_2
V_2T_3		V_4T_1		V_1T_2
V_1T_3		V_3T_1		V_5T_2
		0.5m		
V_5T_2		V_2T_3		V_3T_1
V_4T_2		V_1T_3		V_4T_1
V_3T_2	1m	V_5T_3	1m	V_2T_1
V_2T_2		V_4T_3		V_1T_1
V_1T_2		V_3T_3		V_5T_1
		0.5m		
V_5T_1		V_2T_2		V_3T_3
V_4T_1		V_1T_2		V_4T_3
V_3T_1	1m	V_5T_2	1m	V_2T_3
V_2T_1		V_4T_2		V_1T_3
V_1T_1		V_3T_2		V_5T_3

Legend:

Total number of plot: 45; Total number of varieties: 5; Total number of Treatment: 3

Length of plot: 4 m; Plot width: 2.5 m; Plot area: 4 m× 2.5m (10 m^2)

Peripheral drain: 1m (each side);

Internal Drain: Replication to Replication: 1 m and Plot to plot: 0.5 m

Appendix V. Analysis of variance (mean square values) of plant height of hybrid rice

Source of variance	DF	Plant Height (cm)				
		At 45 DAT	At 60 DAT	At 75 DAT	At 85 DAT	At harvest
Replication	2	0.831	4.728	3.418	18.478	39.207
Factor A	4	20.899	149.715	209.716	243.376	351.149
Factor B	2	16.918	104.610	46.035	14.580	13.940
AB	8	12.655	19.570	21.279	62.352	26.296
Error	28	2.988	2.907	6.850	8.522	9.831

Appendix VI. Analysis of variance (mean square values) of number of tiller of hybrid rice

Source of variance	DF	Number of Tiller				
		At 45 DAT	At 60 DAT	At 75 DAT	At 85 DAT	At harvest
Replication	2	0.026	1.766	1.075	1.070	1.867
Factor A	4	0.988	0.738	6.872	74.235	14.556
Factor B	2	9.356	12.442	19.073	30.438	6.467
AB	8	2.383	7.047	5.840	7.515	17.272
Error	28	0.259	0.685	1.020	1.073	2.819

Appendix VII. Analysis of variance (mean square values) of effective tiller, non-effective tiller and no. of leaves of hybrid rice

Source of variance	DF	Effective tiller	Non Effective tiller	No. of leaves				
				At 45 DAT	At 60 DAT	At 75 DAT	At 85 DAT	At harvest
Replication	2	1.089	1.756	0.244	0.186	0.524	0.378	15.075
Factor A	4	14.467	1.644	21.016	53.447	53.954	566.706	109.478
Factor B	2	9.089	1.156	113.59	133.299	161.515	190.721	421.685
AB	8	14.617	1.794	20.960	52.202	65.668	79.457	225.043
Error	28	2.208	0.732	1.851	3.450	3.445	2.540	4.345

Appendix VIII. Analysis of variance (mean square values) of no. of leaves, leaf length of hybrid rice

Source of variance	DF	No. of length			Leaf breadth		
		At 60 DAT	At 75 DAT	At 85 DAT	At 60 DAT	At 75 DAT	At 85 DAT
Replication	2	4.353	7.817	3.285	0.001	0.005	0.030
Factor A	4	23.654	5.603	47.244	0.030	0.002	0.017
Factor B	2	36.218	15.800	35.761	0.014	0.000	0.023
AB	8	33.043	4.599	33.581	0.022	0.004	0.013
Error	28	1.854	1.567	0.406	0.002	0.004	0.006

Appendix IX. Analysis of variance (mean square values) of flag leaf length, flag leaf breadth, penultimate leaf length, penultimate leaf breadth, dry wt. of leaves and dry wt. of 3 leaves of hybrid rice

Source of variance	DF	Flag leaf length (cm)	Flag leaf breadth (cm)	Penultimate leaf length (cm)	Penultimate leaf breadth (cm)	Dry wt. of leaves (g)	Dry wt. of three leaves (g)
Replication	2	3.627	0.001	1.060	0.003	0.257	0.001
Factor A	4	58.950	0.087	94.423	0.098	14.351	0.015
Factor B	2	21.228	0.036	18.340	0.455	27.249	0.012
AB	8	44.758	0.103	59.971	0.086	28.208	0.027
Error	28	3.118	0.004	3.246	0.004	0.908	0.001

Appendix X. Analysis of variance (mean square values) of chlorophyll content, stem weight, no. of panicle, panicle height, panicle length and panicle weight of hybrid rice

Source of variance	DF	Chlorophyll content	Stem weight	No. of panicle	Panicle height	Panicle length	Panicle weight
Replication	2	1.969	4.863	0.739	17.244	2.134	3.450
Factor A	4	46.557	239.787	16.964	160.803	1.760	39.244
Factor B	2	184.195	161.674	7.006	26.470	7.968	15.023
AB	8	87.808	120.919	1.110	30.247	0.784	28.508
Error	28	2.994	2.582	0.304	15.656	1.306	1.054

Appendix XI. Analysis of variance (mean square values) of 1000-grain weight, grain yield and straw yield of hybrid rice

Source of variance	Degree of freedom	1000-grain weight (g)	Grain yield (tha^{-1})	Straw yield (tha^{-1})
Replication	2	2.186	11.203	1.831
Factor A	4	0.196	0.092	0.297
Factor B	2	0.002	0.735	0.173
AB	8	0.188	1.813	0.051
Error	2 8	0.628	0.613	0.157