PHYSIOLOGICAL BEHAVIOUR AND YIELD PERFORMANCE OF HYBRID RICE VARIETIES IN AEROBIC AND ANAEROBIC CONDITIONS

A THESIS

BY

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CERTIFICATE

This is to certify that the thesis entitled **"PHYSIOLOGICAL BEHAVIOUR AND YIELD PERFORMANCE OF HYBRID RICE VARIETIES IN AEROBIC AND ANAEROBIC CONDITIONS"** submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE** in **AGRICULTURAL BOTANY**, embodies the result of a piece of bona fide research work carried out by **MD. SHORIFUL ISLAM**, Registration No. **10-04030** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: 14.08.2016
Dhaka, Bangladesh

Prof. Dr. Md. Moinul Haque
Supervisor

Dedicated to
My
Beloved Parents

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PHYSIOLOGICAL BEHAVIOUR AND YIELD PERFORMANCE OF HYBRID RICE VARIETIES IN AEROBIC AND ANAEROBIC CONDITIONS

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ABSTRACT

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka from November, 2015 to May, 2016 to study the physiological behaviour and yield performance of hybrid rice varieties in aerobic and anaerobic conditions. The experiment was comprised of two factors- 1)System of cultivation: three (3) *viz*. Low land transplant (anaerobic) condition, Raised upland (aerobic) condition, and Raised transplant (aerobic) condition, and (2) Variety: five (5) *viz.* BRRI hybrid dhan3, Bolaka, Moina, Gold and BRRIdhan45. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Significant variation was observed on growth, yield and yield contributing parameters. All the studied hybrid varieties showed superiority in respect of physiological characters, yield and yield attributes in anaerobic condition over aerobic condition. BRRI hybrid dhan3 accumulated the highest amount of chlorophyll (2.47 mg g^{-1}) in its flag leaves at anaerobic condition which was at par with Bolaka and BRRI dhan45 contained the minimum chlorophyll (1.83 mg g^{-1}) at raised transplant condition. BRRI hybrid dhan3 showed the highest leaf area index (4.25),while the minimum leaf area index was found in BRRIdhan45 (3.56). The highest (34.97%) shoot reserve translocation was exhibited by BRRI hybrid3 and closely followed by Gold at low land transplant condition. The minimum shoot reserve translocation was recorded from BRRIdhan45(7.78%) at raised transplant condition. The highest grain dry matter accumulated from current photosynthesis (85.87 %) was achieved from BRRI hybrid3at low land transplant condition andthe lowest was recorded from BRRI dhan45 (70.67%) at raised transplant condition.BRRI hybrid dhan3 provided the highest grain yield (8.05t ha^{-1}) at low land transplant condition due to its higher filled grains $panicle^{-1}$ and 1000 grain weight, and the lowest (4.28tha^{-1}) was obtained from BRRIdhan45 atraised transplant condition.

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LIST OF ABBREVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
BCR	=	Benefit Cost Ratio
cm	=	Centimeter
^{0}C	=	Degree Centigrade
DAS	=	Days after sowing
et al.	=	and others
Kg	=	Kilogram
Kg/ha	=	Kilogram/hectare
g	=	gram (s)
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
m	=	Meter
P^{H}	=	Hydrogen ion conc.
RCBD	=	Randomized Complete Block Design
TSP	=	Triple Super Phosphate
t/ha	=	ton/hectare
%	=	Percent

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Rice is the second most widely grown cereal and primary source of food for more than half of the world population, and about 90% of the world rice is grown in Asia which is carrying about 60% of the world population (Haque *et al.,* 2015). In Asia, Bangladesh is one of the top most rice producing countries covering an area of about 7.85 million hectares of arable land, of which 70% is occupied for rice production (BBS, 2011). Rice is not only the foremost staple food but it also provides nearly 48% of the rural employment, about two-third of the total calories supply and about one-half of the protein intake of an average person in the country (Julfiquar *et al.,* 2009). In fact, rice production is highly concerned with life style of the people of Bangladesh.

Yearly increment of rice production in Bangladesh needs to be sustained to feed her ever increasing population. But there is a little scope to increase rice area (Sarker *et al.,* 2008) rather agricultural land is declining @ 0.7% per annum (BBS, 2011).Despite the steady and significant progress made in rice production over the past 25 years, the recent yield level of modern rice varieties has been reached to a plateau **(**Bhuiyan, 2002**)**. For breaking the yield ceiling of conventional varieties, hybrid rice is a viable option and appropriate strategy and also it is readily available (Kumar *et al.,* 1998; Longping, 2004). FAO has considered hybrid rice technology as the key approach for increasing global rice production (Virmani, 2005).

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).

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 rainfed or irrigation practice) to a level when the plant really deserves it to maintain its sound physiological system.

One third of the World's developed freshwater is used to irrigate rice (Bouman, 2009) with this figure being half of all freshwater supplies for Asia. Continuous flooding is no more needed to have a good yield of rice. Rice requires soil moisture content of 70% throughout the season (Reddy, 2013). So, Aerobic system of rice cultivation does not reduce yield. More so, this practice is facilitated to irrigate equal area of extra land (BRRI, 2013). In Asia, Irrigated agriculture accounts for 90% of the total fresh water of which more than 50% is used for irrigated rice. But scarcity of water is getting a problem everywhere in the irrigated ecosystem. Currently, aerobic system of rice cultivation has been advocated towards saving irrigation water for *Boro* rice (Satter, 2009).

In Bangladesh, hybrid rice has been introduced through IRRI, BRRI and commercial seed companies of India and China during last 10 years and has already gained positive experience in *Boro* season and cultivated extensively (Masum, 2009). *Boro* rice is mainly cultivated by puddled transplanting with flood irrigation. More than 80% of irrigation water comes from underground water source. The withdrawal of huge irrigation water causes lowering of ground water table and consequently causing serious environmental problems. The efficiency of deep tube well goes down too at the same time. Huge amount of electricity or diesel is required to operate these irrigation equipments. The scarcity of electricity or diesel in the country is increasing. The price of fuel as well as cost of crop production is also increasing. More so, many of the waterways of the international rivers were diverged by the neighboring countries. Therefore, water saving *Boro* rice production system is required under this water scarce to ensure food security.

The conventional (submerged) irrigated system requires 3500-5000 L of water for 1 kg of rice grain production (Bouman, 2009 and Reddy, 2013). The dwindling of fresh water resources in coming years forced the farmers to grow rice in aerobic situation water limiting situation. As fresh water for irrigation is getting increasing scarce, system of aerobic rice cultivation is being expanded as an appropriate technology into regions with more intensive cropping in the year to come. Rice growing countries like India, China and Vietnam has already given their attention on system of aerobic rice cultivation including hybrid rice in it. The System of Rice Intensification (SRI) has been promoted for more than a decade as a set of agronomic management practices for rice cultivation that enhances yield (Kabir and Uphoff, 2007).

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 has been designed and under taken to evaluate the physiological behaviour and yield performance of some hybrid rice varieties in aerobic and anaerobic conditions.

OBJECTIVES

1. To assess the growth behavior and yield of hybrid rice varieties under aerobic condition.
2. To characterize the role of stem reserve translocation and current photosynthate in the yield formation of hybrid and inbred rice varieties under aerobic and anaerobic conditions.
3. To identify suitable hybrid rice variety(s) for aerobic condition.

Chapter II

Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

Rice is widely adaptable crop in different environmental condition.The growth and development of rice may be affected due to varietal performance and systems of cultivation. Yield potentiality also depends on physiological parameters like leaf area index, dry matter accumulation, translocation of assimilate etc. The available literatures under the heads of the objectives of the study were reviewed in the following paragraphs.

2.1 Effect of varieties andsystems of cultivation on yield and yield contributing characters rice

The successful production of any crop depends on manipulation of basic ingredients of crop culture. The variety of crop is one of the important basic ingredients. Some of the works related to different rice varieties with different systems of cultivations are cited below.

Yuni Widyastuti *et al*. (2015) established since early 1990's at the Indonesia Center for Rice Research (ICRR). Twenty-four experimental hybrid rice varieties which have been developed were tested in lowland rice fields in Sukamandi (West Java) and Batang (Central Java) during the dry season and the rainy season of 2012. Randomized complete block design (RCBD) with three replications was used in each location. The results showed that grains yields were affected by locations, seasons, and genotypes. The genotypes x locations x seasons interaction effect was significant; therefore, the best hybrid was different for each location and season. A7/PK36 hybrid has the best performance in Batang during the dry season, while A7/PK40 and A7/PK32 are the best hybrids in the rainy season. In Sukamandi, nine hybrids were identified as better yielder than that of the check cultivar in the dry season, but not so in the rainy season.

Using the correlation and path analysis, we found that the number of panicles per hill and the number of filled grains per panicle could be used as selection criteria for yield in hybrid rice.

Bikash *et al.* (92002) and Sarker *et al.* (2013)conducted to study morphological, yield and yield contributing characters of four *Boro* rice varieties of which three were local viz., Bashful, Poshursail and Gosi; while another one was a high yielding variety (HYV) BRRI dhan28. The BRRI dhan8 were significantly superior among the cultivars studied. The BRRI dhan28 was shorter in plant height, having more tillering capacity, higher leaf number which in turn showed superior growth character and yielded more than those of the local cultivars. The HYV BRRI dhan28 produced higher number of grains panicle^{-1} and bolder grains resulted in higher grain yield over the local cultivars. Further, BRRI dhan28 had erect leaves and more total dry mass than those of local varieties. The BRRI dhan28 produced higher grain yield (7.41 t ha^{-1}) and Bashful, Poshurshail and Gosi yielded ha^{-1}, respectively. Among the local rice cultivars, Gosi showed the higher yielding ability than Bashful and Poshursail.

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.

Inefficient photosynthetic activities of flag leaf and poor shoot reserve translocation to grain resulted poor grain filling percentage in the test hybrids. Consequently the studied hybrids showed significantly lower grain yield (*ca*. 36.7%) as compared to inbred BRRI dhan48, irrespective of planting date in *Aus* season.

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 paniclesm^{-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.

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.

The main objective of the experiments was to compare the growth and yield behavior of hybrid and inbred rice varieties under controlled condition. In 2001, BRRI dhan3l had about 10-15% higher plant height, very similar tillers/plant, 15-25% higher leaf area at all days after transplanting (DAT) compared to Sonarbangla-1. Sonarbangla-1 had about 40% higher dry matter production at 25 DAT but had very similar dry matter production at 50 and 75 DAT, 4-11% higher rooting depth at all DATs, about 22% higher root dry weight at 25 DAT, but 5-10% lower root dry weight at 50 and 75 DAT compared to BRRI dhan31. The photosynthetic rate was higher (20 μ mol m^{-2} sec^{-1}) in BRRI dhan3l at 35 DAT (maximum tillering stage) but at 65 DAT, Sonarbangla-l had higher photosynthetic rate of 19.5 μ mol m^{-2} sec^{-1}. BRRI dhan3l had higher panicles $plant^{-1}$ than Sonarbangla-1, but Sonarbangla-1 had higher number of grains $panicle^{-1}$, 1000-grain weight and grain yield than BRRI dhan31. In 2002, BRRI dhan31 had the highest plant height at 25 DAT, but at 75 DAT, BRRI hybrid dhanl had the highest plant height. Sonarbangla-1 had the largest leaf area at 25 and 50 DAT followed by BRRI dhan31, but at 75 DAT, BRRI dhan31 had the largest leaf area. The highest shoot dry matter was observed in BRRI dhan31 followed by Sonarbangla-1 at all DATs. Sonarbangla-1 had the highest rooting depth and root dry weight at all DATs. BRRI dhan31 gave the highest number of panicles $plant^{-1}$ followed by Sonarbangla-1, BRRI hybrid dhan-l had the highest grains $panicle^{-1}$ followed by BRRI dhan31 and Sonarbangla-1 had the highest 1000-grain weight followed by BRRI dhan31. The highest amount of grains $plant^{-1}$ (34.6 g) was obtained from BRRI dhan31.

Obaidullah *et al.* (2009) conducted a field experiment at Sher-e-Bangla Agricultural University, Dhaka during the period from November 2006 to April 2007 to study the growth and yield of inbred and hybrid rice with clonal tillers different of age. They found highest grain yield (5.10 t ha^{-1}) from the clonal tiller of 25 days old and the lowest grain yield (4.31 t ha^{-1}) from 40 days old clonal tillers. Irrespective of variety 25 to 35 days old clonal tiller showed superior performance. Hybrid variety transplanted with 25 days old clonal tiller gave significantly higher grain yield.

Ashrafuzzaman *et al.* (2008) conducted a field experiment at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka during the period from June 2006 to November 2006 to study the growth and yield of inbred and hybrid rice with tiller separation at different growth periods. The experiment was conducted with two levels of treatments *viz.*a) Variety: BRRI dhan32 and Sonarbangla-1; and b) tiller separation days: 20, 25, 30, 35 and 40 days after mother plant transplantation. Maximum filled grains panicle^{-1} (144.28) was observed from the tiller separation at 20 DAT. Total and effective tillers hill^{-1} was affected by tiller separation beyond 30 DAT. Delayed tiller separation extended the flowering and maturity duration. Therefore, it was concluded that earlier tiller separation (20-30 DAT) resulted higher grain yield in hybrid variety but no such variations was observed in inbred variety.

Nitrogen fertilizer was used as urea form (46.5% N) in two splits; 2/3 were added and mixed in dry soil before flooding irrigation water and the other 1/3 was added at panicle initiation. Three hybrid rice H1 (SK-2034H), H4 (IR96258/Giza181) and H5 (IR70368A/Giza178) were used with three irrigation intervals every 4, 7 and 10 days. Three sowing dates 1st May, 15th May and 30th May with seedling age transplanted at 26 days by 20X20 cm planting spacing. All agricultural practices were applied as recommended for each cultivar. As split, split plot design with four replications was used, three sowing dates were allocated in the main plots, three irrigation intervals were allocated in sub-plots and three rice cultivars were allocated in the sub-sub plots. Main results indicated that maximum tillering, panicle initiation, heading dates, crop growth rates (CGR), Leaf area index, straw yield, harvest index and grain yield (t ha^{-1}) were decreased by increased irrigation intervals up to 10 days. While roots length was increased by increase irrigation intervals up to 10 days. Also sowing dates at 1st May gave the highest value to all studied characters.

While 30th May date of sowing gave the lowest value with all traits under study. Also hybrid rice variety surpassed other varieties for studied characters. The interaction between H_1 hybrid rice varieties with 4 days irrigation interval gave the highest value for leaf area index, Leaf area- ratio and the interaction between May 1^{st} with irrigation interval every 10 days gave the highest value of roots length (Abou-Khalif, 2009).

Ahmed *et al.* (2007) conducted a field experiment at Agronomy field, Sher-e-Bangla Agricultural University, Dhaka during December 2005 to May 2006 to study the influence of cultivation methods on inbred and hybrid rice in *Boro* season. The experiment consisted of two levels of treatment viz. variety and cultivation method and was laid out in a split plot design with four replications. Interaction of variety and cultivation method revealed that nursery seedlings of the inbred variety produced the highest grain yield (8.88t ha^{-1}) and sprouted seeds broadcast of the inbred variety gave the lowest grain yield (6.35 t ha^{-1}).

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.

Xia *et al.* (2007) in experiment found that Shanyou63 variety gave the higher yield (12 t ha^{-1}) compared to Xieyou46 variety (10 t ha^{-1}).

AEF (2006) stated that planting 2 clonal tillers $hill^{-1}$ showed significantly higher grain yield (4.24 t ha^{-1}) compared two other plant densities along with nursery seedlings. The higher yield in clonal tillers compared to nursery seedlings might be due to the higher filled grains per panicle. Clonal tillers gave significantly higher number of filled grains per panicle than nursery seedlings irrespective of variety.

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%.

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.

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}.

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.

Akbar (2004) reported that variety, seedling age and their interaction exerted significant influence on almost all the crop characters. Among the varieties, BRRI dhan41 performed the best in respect of number of bearing tillers hill^{-1}, panicle length, total spikelet's panicle^{-1} and number of grains panicle^{-1}. BRRI dhan41 also produced the maximum grain and straw yields. Sonarbangla-1 ranked first in respect of total tillers hill^{-1} and 1000-grain weight but produced highest number of non-bearing tillers hill^{-1} and sterile spikelet's panicle^{-1}. Grain, straw and biological yields were found highest in the combination of BRRI dhan41 with 15 day-old seedlings. Therefore, BRRI dhan4l may be cultivated using 15 day-old seedlings in *Aman* season following the SRI technique to have better grain and straw yields.

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.

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.

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.

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}).

Siddiquee *et al*. (2002) conducted a study to evaluate the difference between hybrid and inbred rice in respect of their growth duration, yield and quality in *Boro* season, 1999. Among the varieties, Aalok 6201 had the highest grain yield followed by BRRI dhan29 and IR68877H but statistically they were similar. BRRI dhan28 had the lowest grain yield, which was statistically similar to Loknath503. BRRI dhan28 and the tested hybrid rice had lower growth duration than BRRI dhan29. Milling out turn varied from 67 to 70%

among the tested varieties. Loknath 503 had the lowest milling out turn (70%) and, BRRI dhan28 and BRRI dhan29 had the highest milling out turn (70%) for unparboiled but parboiled rice the highest milling out turn(73%) were found in BRRI dhan28 and IR68877H . All tested hybrid rice were medium bold, whereas BRRI dhan29 and BRRI dhan28 were medium slender and long slender, respectively in both parboiled and unparboiled condition.Among the varieties, amylose content (%) was higher in BRRI dhan29 and protein content (%) was higher in IR68877H for both under parboiled and unparboiled condition.

Rahman *et al.* (2002) carried out an experiment with 4 varieties of transplant *Aman* rice *viz.*, BR1l, BR22, BR23 and Tuishimala and 6 structural arrangement of rows *viz.*, 25 cm + 25 cm, 30 cm + 20 cm, 35 cm + 1 5 cm, 40 cm + 10 cm) 45 cm + 05 cm and haphazard planting at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh. Thousand grains weight and grain yield were highest in BR23 and these were lowest in Tulshirnaia.

Obulamma *et al.* (2002) performed an experiment with hybrid rice DRRHI and APHR-2 at Andhra Pradesh, India. The treatments were 4 spacing (15x10, 2U x10, 15x15 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.

Biswas and Salokhe (2002) conducted an experiment in a Bangkok clay soil to investigate the influence of N rate, light intensity, tiller separation, and plant density on the yield and yield attributes of parent and clone plants of transplanted rice. Application of 75 kg N and 120 kg N ha^{-1} resulted in similar yields. The 50% reduction of light intensity reduced grain yield to 43.5% compared with normal light intensity. Separation of more than 4 tillers hill^{-1} had an adverse effect on the mother crop. Nitrogen fertilizer had no influence on grain weight, per cent filled grains, and panicle size of the mother crop, but increased N produced a higher number of tillers. Reduction of light intensity and higher tiller separation adversely affected grain weight and panicle number. Variation of N rate and light intensity of the mother crop had no influence on grain yield, grain weight, and panicle number of clonal tillers transplanted with 75 kg N ha^{-1} and with normal light intensity.

The clonal tillers produced higher yields than the nursery seedlings, and transplanting 2 clonal tillers $hill^{-1}$ resulted in almost the same yield as 3 clonal tillers and 4 clonal tillers $hill^{-1}$.A single clonal tiller had the capacity to produce 4.5 t ha^{-1} grain yields. Yield components of clonal tillers, i. e. panicle number and grain weight, had no influence due to variations of N and light intensity of the mother crop, but higher densities of clonal tillers transplanted per hill gave lower panicle number and grain weight.

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 spikelet's $panicle^{-1}$ and adaptability.

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).

Prasad *et al*. (2001) observed that days to flowering are negatively correlated with plant height. Grain yield is negatively correlated with plant height.

Patnaik *et al*. (1990) found that hybrids with intermediate to tall plant height having non-lodging habit could be developed gave more than 20% grain yield than the standard checks.

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 in harvest index and yield examined using 60 Japanese varieties and 20 high yielding varieties bred in Asian countries. It was reported that harvest index varied form 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}.

The mean value of yield in Japanese group was 22.8 g plant^{-1}, and that in the high yielding group was 34.1 g plant^{-1}. They also reported that a positive correlation was found between harvest index and yield in the high yielding group (Cui *et al.*, 2000).

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

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.

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.

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.

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}.

Xu and Li (1998) observed that the maintainer lines were generally shorter than restorer line. Roy *et al*. (1989) observed that the plants, which needed more days for 50% flowering generally, gave more 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 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}).

Associations of various yield components in rice (Padmavathi *et al.,* 1996) indicated that the plants with large panicles tend to have a high number of fertile grains. Similarly, a positive correlation was observed between number of panicle plant^{-1} and panicle length.

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.

The increased grain yield of KRH2 was mainly attributed to the higher number of productive tillers hill^{-1}, panicle length, weight and number filled grains panicle^{-1}.

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}.

Mallick (1994) carried out a pot experiment at the Institute of Postgraduate Studies in Agriculture (IPSA), Salna, Gazipur during the wet season, 1993 to evaluate the varietal differences in panicle characteristics, spikelet ripening, and special distribution of filled and unfilled spikelets within a panicle as influenced by tiller removal and double transplanting. The two varieties-Nizersail and BR 22 representing old and modern rice were taken as variables. Removal of tillers from the mother shoot and double transplanting increased panicle formation by about 10% in both the varieties. Tiller removal increased grain yield panicle^{-1} by 27% in Nizersail and 21% in BR 22. Double transplanting increased the number of spikelet's panicle^{-1} in both the varieties. Tiller removal also increased spikelets but not as much as was in the double transplanted rice.

2.2 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 1 kg of rice which is almost on par with the dry land cereal crops. Therefore rice scientists are working on a new genre of rice cultivars 'aerobic rice' which is expected to be irrigated or rainfed without puddling water in the field. This technology limits the use of water within the field capacity, which will serve as a better option than the current water cultivation technologies. This will also require breeding new rice cultivars. The leading pioneers in breeding these kinds of rice cultivars are China (backed by IRRI), Brazil and India (Predeepa, 2012).

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.

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 (Bouman*et al*. 2002**)**.

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

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

Chapter III

Materials & Methods

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka from October 2015 to May 2016 to study the physiological behavior and yield performance of hybrid rice varieties in aerobic and anaerobic conditions. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analysis.

3.1 Experimental site

The study was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28.The location of the site is $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude with an elevation of 8.2 meter from sea level (Appendix I).

3.2 Climate and weather

The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Idris *et al*., 1979).Details of the meteorological data of air temperature, relative humidity and rainfall during the period of the experiment were collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, presented in Appendix II.

3.3 Soil

The soil belongs to “The Modhupur Tract”, AEZ – 28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details were presented in Appendix III.

3.4 Plant material

In this research work, five samples of hybrid rice varieties were used as plant materials. The rice varieties used in the experiments were BRRI hybrid-3, Bolaka, Moina, Gold and BRRI dhan45 (check). The seeds were collected from the Bangladesh Rice Research Institute (BRRI) at Joydebpur.

3.5 Experimental details

3.5.1 Treatments

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: System of cultivation

i. T_1= Low land transplant condition
ii. T_2= Raised upland condition
iii. T_3= Raised transplant condition

T_1 plot was quite low than T_2 and T_3.Treated plot to be considered as low land condition as the plot was submerged during irrigation.T_2 and T_3 could be designated as aerobic as they were not submerged.T_2 and T_3 plots were prepared as wet seedbed. 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 lowland treatment were kept ponded up to the hard dough stage of the crop. In contrast, the Raised upland and Raised transplant plots were kept unsubmerged throughout growing season. These 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.

Factor B: Variety

Varieties	Developed by	Imported by
V_1=BRRI hybrid3	BRRI	-
V_2=Bolaka	ACI Seed Company Ltd	-
V_3=Moina	China	Lal Teer Seed Company Ltd.
V_4= Gold	Chain	Lal Teer Seed Company Ltd.
V_5= BRRI dhan45	BRRI	-

3.5.2 Experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the variety. There were 45 plots of size 2.5 m × 4 m in each of 3 replications.

The treatments of the experiment were assigned at random into each replication following the experimental design. Seedlings were sown in the seed bed.When age of seedling was 21 daysthen up rooted and transplanted maintaining line to line distance 25 cm and hill to hill distance 15 cm. Two seedlings hill^{-1} were used during transplanting.

3.6 Growing of crops

3.6.1 Raising seedlings

3.6.1.1 Seed sprouting

Healthy seeds were selected by specific gravity method and then immersed in water bucket for 24 hours and then it was kept tightly in gunny bags. The seeds started sprouting after 48 hours.

3.6.1.2Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m wide adding nutrients as per the requirements of soil. Seed were sown in the seed bed @ 70 g m^{-2} on 5 December, 2015.

3.6.2 Preparation of the main field

The plot selected for the experiment was opened in 20 December 2015 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed, and finally obtained a desirable tilth of soil for transplanting of seedlings.

3.6.3 Fertilizers and manure application

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}

Whole amount of cow-dung, TSP, MP, Gypsum and Zinc and one third of urea were applied at the time of final land preparation at broadcasting method. Half of the rest two third of urea was applied at 20 DAT and the rest amount of urea was applied at 45 DAT.

3.6.4 Uprooting seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on December 26, 2015 without causing much mechanical injury to the roots.

3.6.5 Transplanting of seedlings in the field

The seedlings were transplanted in the main field on December 27, 2015 and the rice seedlings were transplanted in lines each having a line to line distance of 20 cm and plant to plant distance was 15 cm for all test varieties in the well prepared plot.

3.6.6 Cultural operations

The details of different cultural operations performed during the course of experimentation are given below:

3.6.6.1 Irrigation and drainage

Three water regimes namely, low land transplant, raised upland, raised transplant were used as main plot treatment.

3.6.6.2 Gap filling

Gap filling was done for all of the plots at 7-10 days after transplanting (DAT) by planting same aged seedlings.

3.6.6.3 Weeding

First weeding was done from each plot at 15 DAT and second weeding was done from each plot at 40 DAT. Mainly hand weeding was done from each plot.

3.6.6.4 Plant protection

Furadan 57 EC was applied at the time of final land preparation and Dimecron 50 EC was applied at 30 DAT.

3.7 Harvesting, threshing and cleaning

The rice plant was harvested depending upon the maturity of grains and harvesting was done manually from each plot. Maturity of crop was determined when 80-90% of the grains become golden yellow in color.Ten pre-selected hills per plot from which different data were collected and 3 m^2 areas from middle portion of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor. Enough care was taken for harvesting, threshing and also cleaning of riceseed.

Fresh weight of grain and straw were recorded plot wise. Finally the weight was adjusted to a moisture content of 14%. The straw was sun dried and the yields of grain and straw $plot^{-1}$ were recorded and converted to t ha^{-1}.

3.8 Data recording

3.8.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 75 DAT (days after transplanting) and at harvest. Data were recorded as the average of same 10 hills selected at random from the outer side rows (started after 2 rows from outside) of each plot. The height was measured from the ground level to the tip of the plant.

3.8.2 Leaves hill^{-1}

The number of leaves hill^{-1} was recorded at 75 DAT (days after transplanting) and at harvest by counting total leaves as the average of same 5 hills pre selected at random from the inner rows of each plot.

3.8.3 Leaf area index

Leaf area index (LAI) was estimated manually at the time of 75, 90 DAT and at harvest. Data were collected as the average of 5 plants selected. From meddle of each row. Final data were calculated multiplying by a correction factor 0.75

3.8.4 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.

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

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

Where,

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

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

W = Fresh weight in gram of the tissues extracted.

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

3.8.5 Tillers hill^{-1}

The number of tillers hill^{-1} was recorded at 75 DAT (days after transplanting) and at harvest by counting total tillers as the average of same 5 hills pre-selected at random from the inner rows of each plot.

3.8.6 Dry matter hill^{-1}

Total dry matter hill^{-1} was recorded at the time of 75 DAT (days after transplanting) and at harvest by drying plant sample. Data were recorded as the average of 3 sample hill plot^{-1} selected at random from the outer rows of each plot leaving the boarder line and expressed in gram.

3.8.7 Shoot dry matter accumulation and its remobilization to grain

Plants were sampled from each plot at flowering and maturity stages.The harvesting plant was separated into leaf blade (leaf),culm, sheath (stem) and panicles.Dry matter of each component was determined after drying at 72^{0}C for 72 hours.The shoot (stem + leaf) translocation was calculated by net loss in dry weight of vegetative organs between flowering and maturity stages (Bonnett and Incoll, 1992).

$$\text{Shoot reserve translocation (\%)} = \frac{A - M}{A} \times 100$$

Where, A = Total shoot dry matter at pre-anthesis, gm^{-2}

M = Total shoot dry matter at maturity, gm^{-2}

3.8.8 Grain dry matter from current photosynthate

Percentage of grain dry matter from current photosynthate (GDMCPn %) was calculated by using this equation (Haque *et al.* 2015) –

$$\text{(GDMCPn \%)} = \frac{\text{Yield sink - (panicle dry weight + remobilization)}}{\text{Grain weight}} \quad (\text{g cm}^{-2})$$

3.8.9 Grains panicle^{-1}

The total number of grains was collected from the randomly selected 10 panicles in each plot and then average number of grains panicle^{-1} was calculated.

3.8.10 Weight of 1000 grains

One thousand grains were counted randomly from the total cleaned harvested grains of each individual plot and then weighed with an electric balance in grams and recorded.

3.8.11 Grain yield

The central 6 lines from each plot were harvested, threshed, dried, weighed and finally converted to t ha^{-1} basis.

3.8.12Biological yield

The dry weight of straw of central 6 lines were harvested, threshed, dried and weighed and finally converted to t ha^{-1} basis.

3.8.13 Harvest index (%)

Harvest index was calculated dividing the grain yield by the total biological yield (grain and straw)of the same area and multiplying by 100.

3.9 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatment means were estimated by the Duncan’s Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter IV

Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

The experiment was conducted to study the physiological behaviour and yield performance of hybrid rice varieties in aerobic and anaerobic conditions. The analysis of variance (ANOVA) of the data on growth behaviour, yield and yield contributing parameters are presented in Appendix III-VIII. The findings have been presented and discussed by using tables, graphs and possible interpretations given under following headings:

4.1 Plant height

Cultivation system affected the plant height of rice significantly at 75DAT and at harvest (Table 1). The tallest plant (69.28 and 102.70 cm at 75DAT and at harvest, respectively) was recorded with T_1 (Low land transplant condition) treatment. In contrast, the shortest plant (63.22 cm) was recorded from T_3 (Raised transplant condition), which was statistically similar with T_2 treatment (Raised upland condition) at 75DAT and at harvest.The height of rice plant is directly related to the depth of water and generally increases with increasing water depth (Datta, 1981). Khaliq and Cheema, (2005) also observed tallest plant in the wager logged condition and shortest plant height in alternate wet and dry condition. With advancing plant age, water requirement increased and reducing water to field capacity condition significantly reduced plant height especially at maturity as well as tiller production during later growth stages. Beyrouty *et al*. (1994) also observed reduction in plant height but not tiller production when flood was delayed.

Table 1: Effect of cultivation systems of rice on the Plant height and leaves hill^{-1}

Treatment	Plant height (cm)		leaves hill^{-1}	
	75 DAS	at harvest	75 DAS	at harvest
T_1	69.28 a	102.7 a	71.27 a	75.05 a
T_2	64.38 b	98.97 b	55.13 b	46.8 b
T_3	63.22 b	98.77 b	48.67 b	45.07 b
LSD $_{(0.05)}$	4.738	2.813	10.16	6.029
CV (%)	7.29	6.59	7.63	10.35

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

T_1= Low land transplant condition, T_2= Raised upland condition, T_3= Raised transplant condition

Significant influence was remarked in terms of plant height with different varieties of transplanted rice (Table 2). Results showed that at 75 DATand at harvest showed the highest plant height (66.90 and 105.70 cm,at 75 DAT and at harvest, respectively) was found in variety of BRRI hybrid-3 (V_1), which was closely followed by V_4 (gold variety) treatment. The competition in accordance with plant height among the test varieties, the shortest plant was observed with BRRI dhan45 (64.85 and 96.12 cm at 75 DAT and at harvest, respectively) which were statistically similar with Bolaka and Moina at75 DAT. The results corroborate with the findings of Islam*et al*. (2009), Bisne*et al.* (2006), Mishra and Pandey (1998), BINA (1993) and Hossain and Alam (1991)who observed various plant height due to different varieties.

Table 2: Effect of rice varieties on the plant heights and leaves hill^{-1}

	Plant height (cm)		leaves hill^{-1}	
Treatment	75 DAS	at harvest	75 DAS	at harvest
V_1	66.90 a	105.70 a	61.67 a	59.89 a
V_2	64.97 b	97.44 ab	56.78 b	52.33 bc
V_3	64.91 b	102.30 ab	61.22 a	59.41 a
V_4	66.49 ab	99.28 ab	56.00 b	57.67 ab
V_5	64.85 b	96.12 b	56.11 b	50.56 c
LSD $_{(0.05)}$	1.62	8.37	3.49	6.78
CV (%)	7.29	6.59	7.63	10.35

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

V_1=BRRI hybrid-3, V_2=Bolaka, V_3=Moina, V_4= Gold, V_5= BRRI dhan45

The combined effect of cultivation system and variety had significant effect on plant height at 75 DAT and at harvest (Table 3). The tallest plant (71.77 and 110.50 cm at 75 DAT and at harvest) was obtained in T_1V_1 (Low land transplant condition with BRRI hybrid-3) treatment combination, whereas the shortest plant (61.14 and 91.17 cm at 75 DAT and at harvest) was observed in T_3V_5(Raised transplant condition with BRRI dhan45) treatment combination.

Table 3: Combined effect of cultivation systems and varieties on the plant height and leaves hill^{-1} of rice in *Boro* season

Treatment	Plant height (cm)				leaves hill^{-1}			
	75 DAS		at harvest		75 DAS		at harvest	
T_1V_1	71.70	a	110.50	a	79.00	a	90.67	a
T_1V_2	70.47	ab	99.57	abc	68.67	abc	73.67	c
T_1V_3	68.12	abc	101.90	abc	76.00	ab	67.33	d
T_1V_4	71.63	a	101.90	abc	64.67	abcde	56.67	e
T_1V_5	64.47	bc	99.67	abc	68.00	abcd	86.90	b
T_2V_1	62.72	c	106.00	ab	55.67	cde	53.67	e
T_2V_2	63.30	c	93.83	bc	48.00	de	42.33	i
T_2V_3	63.99	bc	102.00	abc	55.00	cde	46.33	fgh
T_2V_4	64.67	bc	98.70	abc	49.00	cde	48.00	f
T_2V_5	67.21	abc	104.70	ab	45.33	e	43.67	ghi
T_3V_1	63.70	bc	99.10	abc	59.33	bcde	45.67	fgh
T_3V_2	63.07	c	98.93	abc	58.00	bcde	46.67	fgh
T_3V_3	63.86	bc	97.53	abc	49.00	cde	43.33	hi
T_3V_4	64.33	bc	97.27	bc	54.33	cde	47.00	fg
T_3V_5	61.14	c	91.17	c	45.33	e	47.67	f
LSD $_{(0.05)}$	6.01		11.05		17.21		3.05	
CV (%)	7.29		6.59		7.63		10.35	

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

T_1= Low land transplant condition, T_2= Raised upland condition, T_3= Raised transplant condition
V_1=BRRI hybrid-3, V_2=Bolaka, V_3=Moina, V_4= Gold, V_5= BRRI dhan45

4.2 Leaves hill^{-1}

Significant variation was observed in case of leaves hill^{-1}as influenced by cultivation system of *Boro* rice at different growth stages (Table 1). Results showed that at all growth stage the highest leaves hill^{-1}was recorded by T_1 (71.27 and 75.05 at 75 DAT and at harvest, respectively). The results obtained from T_3 showed the lowest leaves hill^{-1}(48.67 and 45.07 at 75 DAT and at harvest, respectively) which was statistically similar with T_2 at 75 DAT and at harvest.

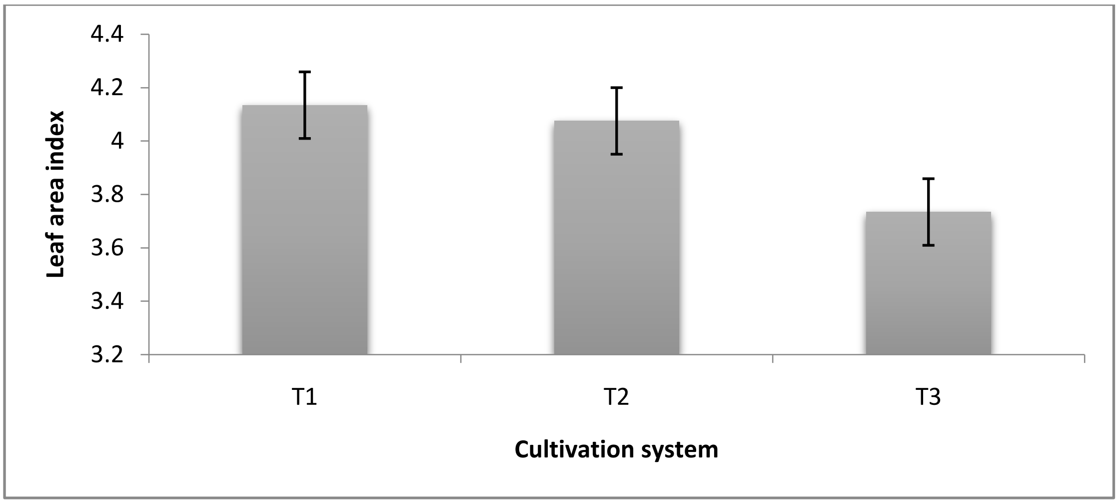
Significant variation was marked in terms of leaves hill^{-1} at different growth stages of rice among the test varieties (Table 2).

Results showed that the highest leaves hill^{-1} (61.67 and 59.89 at 75 DAT and at harvest, respectively) was produced from V_1 treatment which was statistically similar with V_3treatment at 75 DATandat harvest. The lowest leaves hill^{-1} (56.11 and 50.56 at 75 DAT and at harvest, respectively) was obtained from V_5 treatment. 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 tillering capacity of the variety, the spacing used and the fertility level.

Interaction effect of cultivation system and variety had significant influence on leaves hill^{-1} at different growth stages of the five varieties of *Boro* rice (Table 3). Results indicated that the highest number of leaves hill^{-1} (79.00 and 90.67 at 75 DAT and at harvest, respectively) was with V_1T_1 which was closely followed by V_3T_1 at 75 DAT and by V_4T_1at harvest. The results recorded from V_5T_3 showed the lowest leaves hill^{-1}(45.33 and 17.67 at 75 DAT and at harvest, respectively. The results obtained from all other treatments showed significantly different results compared to the highest and the lowest result of leaves hill^{-1}.

4.3 Leaf area index

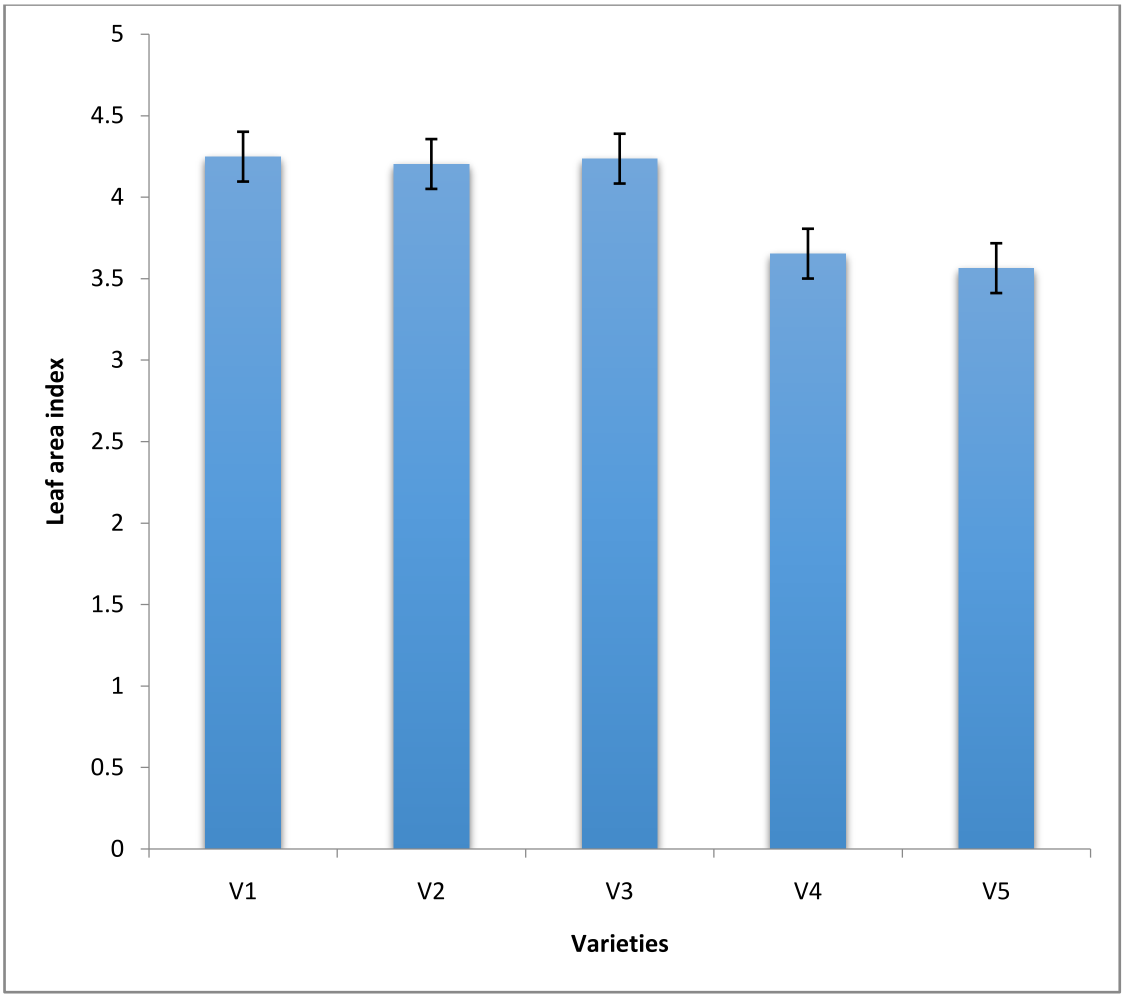
Significantly varied result was observed in case of leaf area index as influenced by cultivation system of *Boro* rice at different growth stages (Fig. 1). Result showed that the highest leaf area index was recorded by T_1 (4.13), which was statistically similar with T_2. The results obtained from T_3 showed the lowest leaf area index (3.73).



T_1= Low land transplant condition, T_2= Raised upland condition, T_3= Raised transplant condition
Vertical bar represents *LSD* value

Fig. 1 Effect of cultivation systems on leaf area index of rice

The production of leaf area was significantly influenced by the tested different varieties (Fig. 2). Rice variety of BRRI hybrid-3 showed the highest leaf area index (4.25), which was statistically similar with V_2 and V_3 treatments. The minimum leaf area index was found in V_5 (3.56) treatment, which was statistically identical with V_4.



V_1=BRRI hybrid-3, V_2=Bolaka, V_3=Moina, V_4= Gold, V_5= BRRI dhan45

Vertical bar represents *LSD* value

Fig. 2 Effect of varieties on leaf area indexof rice

Interaction effect of cultivation system and variety significantly influenced the leaf area index at different growth stages (Table 4). Results indicated that the highest leaf area index (4.68) was with V_1T_1 which was closely followed by V_2T_1. The results recorded from V_5T_3 showed the lowest leaf area index (3.40).

Table 4: Combined effect of cultivation systems and varieties on the leaf area index and spade value of rice in *Boro* season

Treatment	Leaf area index		Chlorophyll content	
T_1V_1	4.68	a	49.03	a
T_1V_2	4.38	abc	45.10	abc
T_1V_3	4.25	abcd	44.00	abcd
T_1V_4	3.96	bcde	46.23	abc
T_1V_5	3.48	e	41.07	cde
T_2V_1	4.65	a	49.00	a
T_2V_2	3.48	e	43.87	abcd
T_2V_3	3.80	cde	46.80	abc
T_2V_4	3.64	de	47.13	abc
T_2V_5	3.81	cde	41.43	bcde
T_3V_1	4.43	ab	38.90	de
T_3V_2	4.45	ab	47.37	ab
T_3V_3	3.93	bcde	46.77	abc
T_3V_4	3.36	e	45.60	abc
T_3V_5	3.40	e	36.57	e
LSD (0.05)	0.55		5.29	
CV (%)	5.68		7.80	

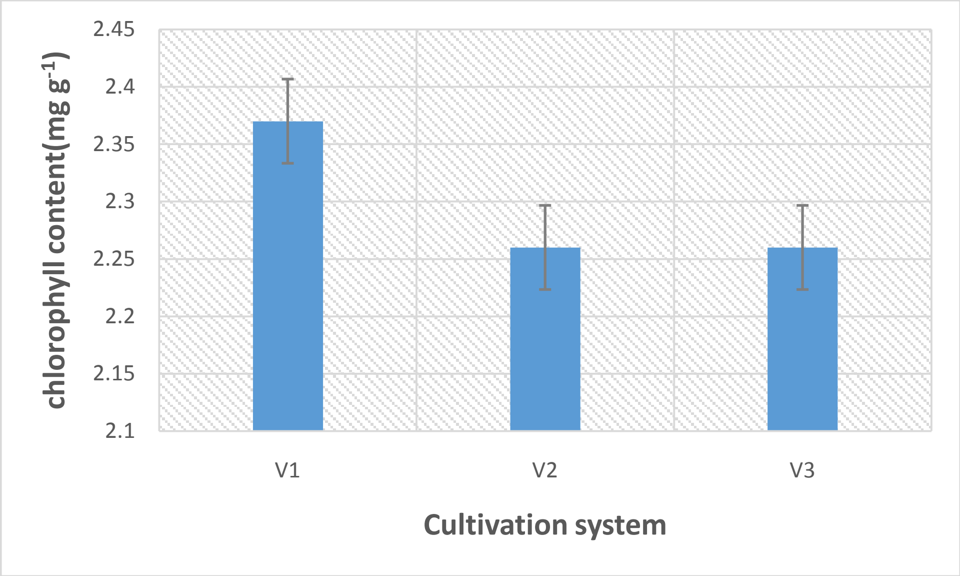
Values with common letter (s) within a column do not differ significantly at 5% level of probability

T_1= Low land transplant condition,T_2= Raised upland condition, T_3= Raised transplant condition

V_1=BRRI hybrid-3, V_2=Bolaka, V_3=Moina, V_4= Gold, V_5= BRRI dhan45

4.4 Chlorophyll content

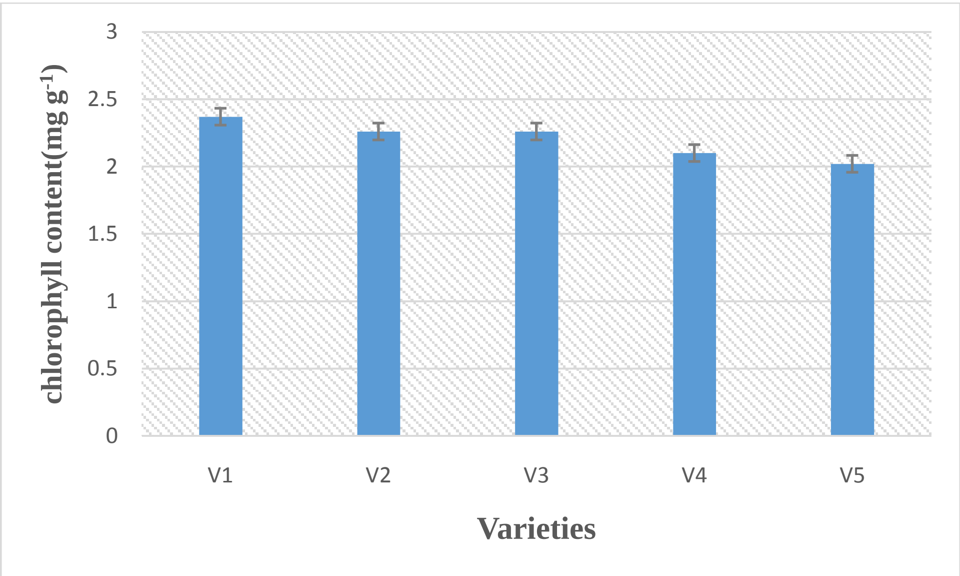
Significantly varied result was observed in case of chlorophyll contentas influenced by cultivation system of *Boro* rice at different growth stages (Fig. 3). Results showed that the highest chlorophyll contentwas recorded by T_1 (2.31 mg g^{-1}). The results obtained from T_3 showed the lowest chlorophyll content(2.16 mg g^{-1}).



T_1= Low land transplant condition, T_2= Raised upland condition, T_3= Raised transplant condition
Vertical bar represents *LSD* value

Fig. 3 Effect of cultivation system on chlorophyll content of rice varieties

The production of chlorophyll contentwas significantly influenced by the tested different varieties (Fig. 4). Rice variety of BRRI hybrid-3 showed the highest chlorophyll content(2.37 mg g^{-1}). The minimum chlorophyll contentwas found in V_5 (2.02 mg g^{-1}) treatment.



V_1=BRRI hybrid-3, V_2=Bolaka, V_3=Moina, V_4= Gold, V_5= BRRI dhan45
Vertical bar represents *LSD* value

Fig. 4Effect of variety on chlorophyll contentof rice

Interaction effect of cultivation system and variety significantly influenced the chlorophyll contentat different growth stages (Table 4).

Results indicated that the highest chlorophyll content(2.47 mg g^{-1}) was with V_1T_1 which statistically similar V_2T_1. The results recorded from V_5T_3 showed the lowest chlorophyll content (1.83 mg g^{-1}).

4.5 Tillers hill^{-1}

Significantly varied result was observed in case of tillers hill^{-1}as influenced by cultivation systems *Boro* rice at different growth stages (Table 5). Results showed that at all growth stage the highest tillers hill^{-1} was recorded by T_1 (18.67 and 32.20 at 75 DAT and at harvest respectively). The results obtained from T_3 showed the lowest tillers hill^{-1} (11.07 and 11.53 75 DAT and at harvest, respectively) which was statistically similar with T_2 at 75 DAT. Rice growth low land transplant condition give higher tillers hill^{-1} than raised upland condition, comparable with raised transplant condition. This finding is in agreement with Anwar *et al.* 2010. Toung and Bouman (2001) also found the highest tillers hill^{-1} in the saturated condition.

Table 5: Effect of cultivation systems on the tillers hill^{-1}and dry matter hill^{-1}of rice varieties

Treatment	Tillers hill^{-1}		Dry matter hill^{-1}		
	75 DAT	at harvest	vegetative stage (g)	flowering stage (g)	at harvest (g)
T_1	18.67 a	32.20 a	27.99 a	46.27 a	68.87 a
T_2	12.47 b	16.60 b	17.79 ab	49.00 a	60.40 b
T_3	11.07 b	11.53 c	15.50 b	33.87 b	45.73 c
LSD $_{(0.05)}$	1.50	4.32	11.79	8.58	7.57
CV (%)	9.33	8.72	6.43	9.93	10.33

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

T_1= Low land transplant condition, T_2= Raised upland condition, T_3= Raised transplant condition

The production of tillers hill^{-1} was significantly influenced by the tested different varieties (Table 6). Rice variety of BRRI hybrid-3 showed the highest tillers hill^{-1} (15.89 and 22.89 at 75 DAT and at harvest, respectively), which was statistically similar with V_4 treatment at harvest.

The minimum tillers hill^{-1}at 75 DAT and at harvestwas found in V_5(13.01 and 17.33, respectively) treatment, which was statistically identical with V_3 treatment at 75DAT.

Islam*et al*. (2009), Bisne*et al.* (2006), Chowdhury*et al*. (2005), Akbar (2004) andBhowmick and Nayak (2000) reported similar trend of tillering habitswithdifferentvarietiesofrice.

Table 6: Effect of varieties on tillers hill^{-1}and dry matter hill^{-1}

Treatment	Tillershill^{-1}				Dry matter hill^{-1}					
	75 DAS		at harvest		vegetative stage (g)		flowering stage (g)		at harvest (g)	
V_1	15.89	a	22.89	a	23.15	a	48.44	a	63.89	a
V_2	13.44	ab	19.78	ab	20.96	ab	39.56	ab	58.78	bc
V_3	13.11	b	19.67	ab	19.48	bc	45.56	ab	61.56	ab
V_4	14.78	ab	21.89	a	21.35	ab	43.78	ab	54.22	cd
V_5	13.01	b	17.33	b	17.21	c	37.89	b	53.22	d
LSD $_{(0.05)}$	2.46		4.25		2.55		9.06		4.89	
CV (%)	9.33		8.72		6.43		9.93		10.33	

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

V_1=BRRI hybrid-3, V_2=Bolaka, V_3=Moina, V_4= Gold, V_5= BRRI dhan45

Interaction effect of cultivation system and variety significantly influenced the number of tillers hill^{-1} at different growth stages (Table 7). Results indicated that the highest number of tillers hill^{-1} (21.33 and 37.00 at 75 DAT and at harvest, respectively) was with V_1T_1 which was closely followed by V_3T_1 at 3 75 DAT. The results recorded from V_5T_3 showed the lowest number of tillers hill^{-1}(9.67 and 8.33 at 75 DAT and at harvest, respectively). The results obtained from all other treatments showed significantly different results compared to the highest and the lowest result of number of tillers hill^{-1}.

Table 7: Combined effect of cultivation systems and varieties ontillers hill^{-1}and dry matter hill^{-1} of rice in *Boro* season

Treatment	Tillers hill^{-1}				Dry matter hill^{-1}					
	75 DAS		at harvest		vegetative stage (g)		flowering stage (g)		at harvest (g)	
T_1V_1	21.33	a	37.00	a	33.86	a	63.00	a	80.00	a
T_1V_2	19.00	abc	20.00	a-e	32.04	a	43.67	abc	71.33	abc
T_1V_3	20.67	ab	14.67	de	24.94	b	40.00	abc	65.67	abc
T_1V_4	15.67	b-e	13.33	de	32.12	a	48.00	abc	77.67	a
T_1V_5	16.67	a-d	19.00	b-e	17.00	cd	52.33	abc	49.67	cd
T_2V_1	11.33	def	10.67	e	14.26	d	43.33	abc	40.67	d
T_2V_2	12.67	def	9.33	e	14.22	d	30.67	c	51.67	bcd
T_2V_3	10.00	f	10.67	e	18.22	cd	35.00	bc	49.00	cd
T_2V_4	10.67	ef	17.33	cde	17.86	cd	34.33	bc	42.00	d
T_2V_5	10.67	ef	16.00	cde	16.76	cd	41.00	abc	58.33	a-d
T_3V_1	14.00	c-f	32.33	abc	21.32	bc	38.00	abc	72.67	ab
T_3V_2	13.67	def	30.00	a-d	16.62	cd	44.33	abc	73.00	ab
T_3V_3	12.00	def	26.67	a-e	15.28	cd	56.33	ab	49.67	cd
T_3V_4	13.00	def	35.00	ab	17.86	cd	47.33	abc	55.00	bcd
T_3V_5	9.67	f	8.33	e	14.06	d	28.33	c	38.67	d
LSD (0.05)	4.78		15.28		5.61		21.55		19.84	
CV (%)	9.33		8.72		6.43		9.93		10.33	

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

T_1= Low land transplant condition, T_2= Raised upland condition, T_3= Raised transplant condition

V_1=BRRI hybrid-3, V_2=Bolaka, V_3=Moina, V_4= Gold, V_5= BRRI dhan45

4.6 Dry matter hill^{-1}

Significantly varied results were observed in terms of dry weight hill^{-1} as influenced by different cultivation system *Boro* rice at different growth stages (Table 5). Results showed that at all growth stage the highest dry weight hill^{-1} was recorded by T_1 (27.99, 46.27 and 68.87 g at vegetative, flowering and harvest, respectively). The results obtained from T_3showed the lowest dry weight hill^{-1} (15.50, 33.87 and 45.73 g at vegetative, flowering and harvest, respectively). The results obtained from all other treatments showed significantly different results compared to the highest and the lowest result of dry weight hill^{-1}.

The dry matter weight was significantly varied due to varietal differences. The dry matter weight of the varieties was not similar at the beginning of growth stage and was also varied with the advancement of harvest(Table 6). At vegetative stage the highest dry matter (23.15 g) was observed in V_1 treatment. The second highest dry matter (21.35 g) was observed in V_4 treatment. The highest dry matter (48.44 g) at flowering stage was obtained from V_1. The V_1treatment also showed highest dry matter (63.89 g) at harvest. At vegetative stage the lowest dry matter were produced from V_5treatment (17.21 g). Atflowering stage the lowest dry matter hill^{-1} (37.89 g) was obtained from V_5. The lowest dry matter was produced from V_5 treatment (53.22g) at harvest. Lower dry matter hill^{-1} was also achieved from BRRI dhan45at the time of harvest which showed lower varietal performance afterward.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.

Interaction effect of cultivation system and variety had significant influence on dry weight hill^{-1} at different growth stages (Table 7). Results indicated that the highest dry weight hill^{-1} (33.86, 63.00 and 80.00 gat vegetative, flowering and harvest, respectively) was with T_1V_1which was statistically similar with T_1V_4 and T_1V_2at vegetative stageand at harvest.

The results recorded from T_3V_5 showed the lowest dry weight hill^{-1}(14.06, 28.33 and 38.67 g at vegetative, flowering and harvest, respectively). The results obtained from all other treatments at different growth stages showed significantly different compared to the highest and the lowest values of dry weight hill^{-1}.

4.7 Shoot dry matter accumulation and its remobilization to grain

Significantly varied results were observed in terms of shoot dry matter accumulation as influenced by different cultivation system in *Boro* rice at flowering and maturity stages (Table 8). Results showed that the highest shoot dry matter accumulation was recorded by T_3 (42.43 at flowering).

At maturity stage, the highest shoot dry matter accumulation was recorded by T_3 (33.47g). The reserve translocation was the highest (25.39%) from T_1 treatment. The results obtained from T_2 showed the lowest shoot dry matter accumulation (27.47 and 24.23 g at flowering and maturity stage, respectively). The reserve translocation was the lowest (11.77%) in T_2 treatment.

Table 8: Effect of cultivation systems on shoot dry matter accumulation, its translocation to the grain and grain dry matter accumulation from current photosynthesis in rice

Treatment	Shoot dry mater at flowering stage (g)	Shoot dry mater at maturity stage (g)	Changes in shoot dry mater (g)	Shoot reserve translocation (%)	Grain dry matter from current photosynthesis (%)
T_1	39.93 a	29.79 b	10.13 ab	25.39 a	82.19 a
T_2	27.47 b	24.23 c	3.23 b	11.77 b	79.32 ab
T_3	42.33 a	33.47 a	8.87 a	20.97 a	78.08 b
LSD $_{(0.05)}$	11.76	3.88	8.28	6.11	3.63
CV (%)	5.89	5.56	7.89	28.56	7.33

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

T_1= Low land transplant condition, T_2= Raised upland condition, T_3= Raised transplant condition

The shoot dry matter accumulationwas significantly varied due to varietal differences (Table 9). The highest shoot dry matter accumulation(41.44 g) at flowering stage was obtained from V_1.

The V_4 treatment showed highest shoot dry matter accumulation (27.44 g) at maturity. The highest change in shoot dry matter (14.11 g) was obtained from V_1treatment. The reserve translocation was the highest (34.06%) from V_1 treatment. On the other hand, the lowest shoot dry matter accumulation (32.44 g at flowering) obtained from V_5 treatment. At maturity stage the lowest shoot dry matter accumulation (27.33 g) obtained from V_1 treatment.

The lowest change in shoot dry matter (2.47 g) was obtained from V_5 treatment. The reserve translocation was the lowest (7.63%) from V_5 treatment.

Table 9: Effect of rice varieties on shoot dry matter accumulation, its translocation to the grain and grain dry matter accumulation from current photosynthesis

Treatment	Shoot dry mater at flowering stage (g)	Shoot dry mater at maturity stage (g)	Changes in shoot dry mater (g)	Shoot reserve translocation (%)	Grain dry matter from current photosynthesis (%)
V_1	41.44 a	27.33	14.11 a	34.06 a	81.62 a
V_2	34.00 ab	28.46	5.53 cd	16.29 c	80.30 ab
V_3	36.78 ab	28.56	8.21 bc	22.34 bc	80.03 ab
V_4	38.22 ab	27.44	10.78 ab	28.22 ab	79.37 ab
V_5	32.44 b	29.96	2.47 d	7.63 d	77.98 b
LSD $_{(0.05)}$	7.59	ns	5.34	7.34	2.35
CV (%)	5.89	5.56	7.89	28.56	7.33

Values with common letter (s) within a column do not differ significantly at 5% level of probability,ns=non-significant.

V_1=BRRI hybrid-3, V_2=Bolaka, V_3=Moina, V_4= Gold, V_5= BRRI dhan45

Interaction effect of cultivation system and variety was significantly influenced by shoot dry matter accumulation at flowering and maturity stage (Table 10). Results indicated that the highest shoot dry matter accumulation(56.00 g at flowering) was obtained with T_1V_1 treatment. At maturity stage, the highest shoot dry matter accumulation(36.43 g) was recorded from T_3V_4 treatment. The highest change in shoot dry matter (19.58 g) was found in T_1V_1 treatment.

The reserve translocation was the highest (34.97%) in T_1V_1 treatment which was statistically similar with T_1V_4 andT_3V_3. The results from T_3V_5 showed the lowest shoot dry matter accumulation(22.67 g at flowering).

The results recorded from T_3V_5 showed the lowest shoot dry matter accumulation(21.00 g at maturity). The reserve translocation was the lowest (7.78%) from T_3V_5 treatment.

Table 10: Combined effect of cultivation systems and rice varieties on shoot drymatter accumulation, its translocation to the grain and grain dry matteraccumulation from current photosynthesis in *Boro* season

Treatment	Shoot dry mater at flowering stage (g)		Shoot dry matter at maturity stage (g)		Changes in shoot dry matter (g)		Shoot reserve translocation (%)		Grain dry matter from current photosynthesis (%)	
T_1V_1	56.00	a	36.41	bc	19.58	a	34.97	a	85.87	a
T_1V_2	38.33	cde	33.41	b	4.91	bcd	12.81	bcd	82.85	abc
T_1V_3	33.00	efg	25.92	c	7.07	a-d	21.44	bc	80.78	c
T_1V_4	41.00	cde	27.74	cd	13.25	a-d	32.32	a	81.59	bc
T_1V_5	45.33	bc	32.45	bc	12.87	abc	28.61	ab	74.49	d
T_2V_1	36.33	def	28.25	bc	7.73	a-d	21.23	bc	75.51	d
T_2V_2	26.33	gh	24.33	bc	2.00	cd	8.12	d	77.22	d
T_2V_3	28.00	fgh	24.67	bc	3.33	cd	12.22	bcd	77.47	d
T_2V_4	27.33	gh	19.43	d	7.89	a-d	28.90	ab	81.87	bc
T_2V_5	33.00	efg	24.15	cd	8.85	a-d	26.83	ab	84.51	ab
T_3V_1	32.67	efg	23.67	bc	9.00	bcd	23.33	b	81.00	c
T_3V_2	37.33	cde	26.89	cd	10.43	a-d	27.95	ab	80.84	c
T_3V_3	49.33	ab	33.96	c	15.36	ab	31.35	a	81.83	bc
T_3V_4	42.00	bcd	36.43	a	5.67	cd	21.79	bc	81.40	bc
T_3V_5	22.67	h	21.00	cd	1.67	d	7.78	d	70.67	e
LSD $_{(0.05)}$	7.59		6.20		17.30		10.16		2.93	
CV (%)	5.89		5.56		7.89		28.56		7.33	

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

T_1= Low land transplant condition, T_2= Raised upland condition, T_3= Raised transplant condition
V_1=BRRI hybrid-3, V_2=Bolaka, V_3=Moina, V_4= Gold, V_5= BRRI dhan45

4.8 Grain dry matter from current photosynthesis

Cultivation system had significant effect on grain dry matter accumulation from current photosynthesis (Table 8). Results showed that the highest grain dry matter from current photosynthesis recorded by T_1 (82.19%) where the lowest (78.08%) was obtained from T_3.

Performance of test varieties under the present study showed a significant difference in respect of grain dry matter from current photosynthesis (Table 9). The highest grain dry matter from current photosynthesis (81.62) was observed in variety of BRRI hybrid-3 (V_1) which was significantly different from all other test varieties. BRRI dhan45 produced the lowest grain dry matter from current photosynthesis (77.98%).

Interaction effect of cultivation systems and varieties had significant influence on grain dry matter from current photosynthesis (Table 10). Results indicated that the highest grain dry matter from current photosynthesis(85.87%) was with T_1V_1 treatments. On the other hand the lowest grain dry matter from current photosynthesis was recorded from V_5T_3 (70.67%).

4.9 Filled grains panicle^{-1}

Cultivation system had significant effect on filled grains panicle^{-1} (Table 11). Results showed that the highest filled grains panicle^{-1}was recorded by T_1 (159.8) where the lowest (152.9) was obtained from T_3.The results obtained from T_2 showed medium result compared to the highest and the lowest grains panicle^{-1}. The result under the present study was similar with the findings of Bouman *et al.* (2005).

Table 11:Effect of cultivation systems on yield contributing characters of rice

Treatment	Filled grain panicle^{-1}	Unfilled grain panicle^{-1}	Thousand grain weight (g)
T_1	159.80 a	17.67 c	29.29
T_2	154.90 b	25.60 b	28.88
T_3	152.90 c	38.07 a	27.62
LSD (0.05)	3.73	6.47	ns
CV (%)	8.87	7.04	4.97

Values with common letter (s) within a column do not differ significantly at 5% level of probability, ns=non-significant.

T_1= Low land transplant condition, T_2= Raised upland condition, T_3= Raised transplant condition

Performance of test varieties under the present study showed a significant difference in respect of grains panicle^{-1} (Table 12). The highest filled grains panicle^{-1} (163.4) was observed in variety of BRRI hybrid-3 (V_1) which was significantly different from all other test varieties.

Moina andgold also showed better performance but significantly different from BRRI hybrid-3. BRRI dhan45 produced the lowest filled grains panicle^{-1} (149.30) which was significantly with V_2 treatment.The results obtained by Chowdhury*et al*. (2005), Murthy *et al.* (2004), Bhowmick and Nayak (2000) and Patel (2000) was in agreement with findings of present study.

Table 12: Effect of varieties on yield contributing characters of rice

Treatment	Filled grain panicle^{-1}	Unfilled grain panicle^{-1}	Thousand grain weight (g)
V_1	163.40 a	24.22 c	29.18
V_2	149.60 b	26.44 abc	28.40
V_3	158.00 ab	25.78 bc	28.29
V_4	158.90 ab	28.78 ab	29.04
V_5	149.30 b	30.33 a	28.06
LSD (0.05)	12.28	4.17	ns
CV (%)	8.87	7.04	4.97

Values with common letter (s) within a column do not differ significantly at 5% level of probability,ns=non-significant.

V_1=BRRI hybrid-3, V_2=Bolaka, V_3=Moina, V_4= Gold, V_5= BRRI dhan45

Interaction effect of cultivation system and variety had significant influence on number of filled grains panicle^{-1} rice (Table 13). Results indicated that the highest number of grains panicle^{-1} (175.30) was with T_1V_1 treatments,which was significantly similar with T_2V_2 treatment combinations. The results from V_2T_1, V_4T_3, and V_3T_3 gave comparatively higher number of grains panicle^{-1} but significantly different from V_1T_1. On the other hand the lowest result was recorded from V_5T_3 (141.7), which were also significantly similar with T_2V_3 treatment combinations.

The results obtained from all other treatments combinations was significantly different compared to the highest and the lowest number of grains panicle^{-1}.

Table 13: Combined effect of cultivation systems and varieties on yield contributing characters of rice in *Boro* season

Treatment	Filled grain panicle^{-1}		Unfilled grain panicle^{-1}		Thousand grain weight (g)	
T_1V_1	175.30	a	13.67	b	29.97	a
T_1V_2	168.30	ab	35.33	ab	29.47	a
T_1V_3	145.70	ef	32.33	ab	29.37	a
T_1V_4	159.70	bcd	14.00	b	29.10	ab
T_1V_5	150.00	def	27.67	ab	28.53	abc
T_2V_1	151.70	cdef	14.00	b	29.13	ab
T_2V_2	171.30	a	15.33	b	29.27	a
T_2V_3	143.70	f	30.33	ab	29.70	a
T_2V_4	155.30	cde	14.33	b	27.60	bcd
T_2V_5	154.30	cde	31.00	ab	28.70	abc
T_3V_1	147.00	ef	28.67	ab	28.90	ab
T_3V_2	150.70	def	28.67	ab	28.82	abc
T_3V_3	161.30	bc	47.67	a	26.93	d
T_3V_4	161.70	bc	24.33	ab	27.30	cd
T_3V_5	141.70	f	49.33	a	26.13	d
LSD (0.05)	9.06		24.41		1.38	
CV (%)	8.87		7.04		4.97	

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

T_1= Low land transplant condition, T_2= Raised upland condition, T_3= Raised transplant condition

V_1=BRRI hybrid-3, V_2=Bolaka, V_3=Moina, V_4= Gold, V_5= BRRI dhan45

4.10 Unfilled grains panicle^{-1}

Cultivation system had significant effect on unfilled grains panicle^{-1} (Table 11). Results showed that the highest unfilled grains panicle^{-1}was recorded by T_3 (38.07) where the lowest (17.67) was obtained from T_1.
The results obtained from T_2 showed medium result compared to the highest and the lowest grains panicle^{-1}.

Unfilled grains panicle^{-1} was significantly influenced by test varieties under the present study (Table 12). Results showed that the highest unfilled grains panicle^{-1} (30.33) was observed in BRRI dhan45 which was significantly different from all other test varieties. On the other hand, the lowest unfilled grains panicle^{-1} (24.22) was achieved from BRRI hybrid-3 (V_1) that was followed by V_4treatment. The result obtained by Chowdhury *et al.* (2005) was more or less similar with the present study.

Interaction effect of cultivation system and variety had significant influence on unfilled grains panicle^{-1} rice (Table 13). Results indicated that the highest unfilled grains panicle^{-1} (49.33) was with T_3V_5 treatments,which was significantly similar with T_3V_3 treatment combinations. On the other hand the lowest result was recorded from V_1T_1 (13.67), which were also significantly similar with $T_1V_{4,}$ $T_2V_{1,}$ $T_2V_{2,}$ and T_2V_4 treatment combinations.

4.11 Weight of 1000 grain

Cultivation system had not significant effect on 1000 grain weight rice (Table 11). Results showed that the highest 1000 grain weightwas recorded by T_1 (29.29 g) where the lowest (27.62 g) was obtained from T_3.The results obtained from T_2 showed medium result compared to the highest and the lowest 1000 grain weight.

No significant influence of different varieties was observed on 1000 grainweight (Table 12). It is attained that the highest 1000 grain weight (29.18 g) was in V_1 treatment.

Thelowest 1000 seed weight (28.08g) was observed in BRRI dhan45.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.

Interaction effect of cultivation system and variety had significant influence on 1000 grain weight of rice (Table 13). Results indicated that the highest 1000 grain weight (29.97 g) was with V_1T_1 treatment. On the other hand the lowest result was recorded from V_5T_3 (26.13 g) which was statistically similar with V_3T_3. The results obtained from all other treatments combinations was significantly different compared to the highest and the lowest 1000 grain weight.

Table 14:Effect of cultivation systems on yield and harvest index of hybrid and inbred rice varieties

Treatment	Grain yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
T_1	7.01 a	15.14 a	42.02 a
T_2	5.77 b	12.37 b	42.34 a
T_3	5.45 b	12.25 b	40.59 b
LSD (0.05)	0.51	1.14	0.79
CV (%)	5.83	7.08	8.30

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

T_1= Low land transplant condition, T_2= Raised upland condition, T_3= Raised transplant condition

4.12 Grain yield

Cultivation systems had significant effect on grain yield of rice (Table 14). The highest grain yield was recorded by T_1 (7.01 t ha^{-1}) where the lowest (5.45 tha^{-1}) was obtained from T_3 treatment, which was statistically similar with T_2 treatment.Bouman and Tuong (2010) suggested that there is a reduction in the grain yield in alternate wetting and drying when compared with rice grown with standing water. 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).

Table 15: Effect of varieties on yield and harvest indexof rice

Treatment	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1	6.37 a	14.70 a	40.23 b
V_2	6.20 ab	12.78 b	43.28 a
V_3	6.23 ab	12.61 b	43.73 a
V_4	6.32 a	13.88 a	43.19 a
V_5	5.26 b	12.30 b	37.82 c
LSD (0.05)	1.02	1.03	2.267
CV (%)	5.83	7.08	8.30

Values with common letter (s) within a column do not differ significantly at 5% level of probability
V_1=BRRI hybrid-3, V_2=Bolaka, V_3=Moina, V_4= Gold, V_5= BRRI dhan45

Different varieties significantly produced variable grain yield (Table15). Among the tested five varieties BRRI hybrid-3 (V_1) showed the highest grain yield (6.37 t ha^{-1}) which was statistically similar with V_4 (6.32 t ha^{-1}) that was the second highest grain yield. On the other hand, the lowest grain yield (5.26 t ha^{-1}) was obtained from BRRI dhan45. Variety of BRRI hybrid-3 in the present experiment produced the highest number tillers $hill^{-1}$, dry mater weight, filled grains $panicle^{-1}$ which ultimately gave higher grain yield than BRRI dhan45.

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.

Interaction effect of cultivation system variety and different had significant influence on grain yield (Table 15). The highest grain yield per hectare (8.05 t) was with T_1V_1, which closely followed by V_2T_1. The lowest result was recorded from T_3V_5 (4.28 t) which closely followed by V_1T_3. The results obtained from the rest of the treatment combinations showed intermediate level of grain yield compared to the highest and the lowest grain yield.

4.13 Biological yield

Cultivation system had significantly effect on Biological yield of rice (Table 14). Results showed that the highest Biological yield was recorded by T_1 (15.14 t ha^{-1}) where the lowest (12.25 t ha^{-1}) was obtained from T_3, which was statistically similar with T_2 treatment.

Biological yield differed significantly due to varietal differences (Table15). The treatment V_1 gave the highest Biological yield (14.7 t ha^{-1}) which was statistically similar with V_4 treatment. The lowest Biological yield was found in BRRI dhan45 (12.30 t ha^{-1}) which was statistically similar with V_3 andV_2 treatment. The differences in Biological yield among the varieties may be attributed to the genetic makeup of the varieties. The results uphold with the findings of Chowdhury *et al*. (2005), Akbar (2004), Patel (2000) and Om *et al.* (1999) where they concluded that Biological yield differed significantly among the varieties.

Table 16: Combined effect of cultivation systems and varieties on yield and harvest index of rice in *Boro* season

Treatment	Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_1V_1	8.05 a	18.33 a	41.47 abcd
T_1V_2	7.75 ab	13.63 bcd	46.60 a
T_1V_3	6.70 abcd	14.00 bcd	42.74 abc
T_1V_4	7.08 abc	14.33 bc	43.30 abc
T_1V_5	5.47 bcd	15.40 b	35.98 de
T_2V_1	6.36 abcd	11.40 d	45.70 ab
T_2V_2	4.82 cd	11.94 cd	39.82 bcd
T_2V_3	6.53 abcd	11.83 cd	45.58 ab
T_2V_4	5.60 abcd	12.37 cd	41.39 abcd
T_2V_5	5.56 bcd	14.30 bc	39.22 bcde
T_3V_1	6.03 abcd	11.91 cd	43.43 abc
T_3V_2	4.77 cd	14.38 bc	33.50 e
T_3V_3	5.87 abcd	11.99 cd	42.86 abc
T_3V_4	6.28 abcd	11.63 cd	44.88 ab
T_3V_5	4.28 d	11.37 d	38.27 cde
LSD $_{(0.05)}$	2.12	2.37	5.55
CV (%)	5.83	7.08	8.30

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

T_1= Low land transplant condition, T_2= Raised upland condition, T_3= Raised transplant condition

V_1=BRRI hybrid-3, V_2=Bolaka, V_3=Moina, V_4= Gold, V_5= BRRI dhan45

Interaction effect of cultivation system and variety had significant influence on Biological yield of rice (Table 15). Results indicated that the highest Biological yield (18.33 t ha^{-1}) was with T_1V_1which was closely followed by T_1 V_5. Again, the lowest result was recorded from T_3V_5 (11.37 t ha^{-1}). The results obtained from the rest of the treatment combinations showed intermediate level of Biological yield compared to highest and lowest straw yield.

4.14 Harvest index

Cultivation system had significant effect on harvest index (Table 13). The highest harvest index was recorded by T_2 (42.34), which were statistically similar with T_2 treatment. The lowestharvest index (40.59) was obtained from T_3 treatment.

Different varieties significantly produced variable harvest index (Table14). The V_3 treatment showed the highest harvest index (43.73). On the other hand, the lowest harvest index (37.82) was obtained from BRRI dhan45.

Interaction effect of cultivation systems and different varieties had significant influence on harvest index (Table 15). The highest harvest index (46.60) was obtained from T_1V_2. The lowest harvest index (33.50) was recorded from V_1T_3.

Chapter V

Summary and Conclusion

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted at the Experimental Field of Sher-e-Bangla Agricultural University, Dhaka from November 2015 to May 2016 to study the physiological behavior and yield performance of hybrid rice varieties in aerobic and anaerobic condition. The experiment comprised of two factor viz. (1) Factor A – cultivation system: 3, T_1= Low land transplant condition, T_2= Raised upland condition, T_3= Raised transplant condition and (2) Factor B – Variety: 5, V_1=BRRI hybrid-3, V_2=Bolaka, V_3=Moina, V_4= Gold, V_5= BRRI dhan45. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the variety. There were 45 plots of size 2.5 m × 4 m in each of 3 replications. The treatments of the experiment were assigned at random into each replication following the experimental design. Seedlings were sown in seed bed and age of transplanted seedling was 12 and 35 days. Line to line distance was 25 cm where hill to hill distance was 15 cm. Two seedlings hill^{-1} were used during transplanting.

Significant variation was recorded for data on growth, yield and yield contributing parameters of experimental materials. Data was collected on plant height, leaves hill^{-1}, leaf area index, chlorophyll content, tillers hill^{-1}, dry matter hill^{-1}, shoot dry matter accumulation, filled grains panicle^{-1}, unfilled grains panicle^{-1}, 1000 grain weight, grain yield and biological yield andharvest index.

Cultivation system affected the plant height of rice significantly at 75DAT and at harvest. The tallest plant (69.28 and 102.70 cm at 75DAT and at harvest, respectively) was recorded with T_1 (Low land transplant condition). Significantly different variation was observed in case of number of leaves hill^{-1}and number of tillers hill^{-1}as influenced by cultivation system of *Boro* rice at different growth stages.

The highest number of leaves hill^{-1}was recorded by T_1 (71.27 and 75.05 at 75 DAT and at harvest, respectively). The highest leaf area index was recorded by T_1 (4.13). The highest chlorophyll content was recorded by T_1 (46.2). The highest number of tillers hill^{-1} was recorded by T_1 (18.67 and 32.20 at 75 DAT and at harvest respectively. Significantly varied results were observed in terms of dry weight hill^{-1} as influenced by different cultivation system *Boro* rice at different growth stages. The highest dry weight hill^{-1} was recorded by T_1 (27.99, 46.27 and 68.87 g at vegetative, flowering and harvest, respectively).The highest shoot dry matter accumulation was recorded by T_3 (42.43 at flowering). The highest grain dry matter from current photosynthesis was recorded by T_1 (82.19%).Cultivation system had significant effect on number of filled and unfilled grains panicle^{-1} (Table 7). The highest number of filled grains panicle^{-1}was recorded by T_1 (159.8). The lowest (17.67) was obtained from T_1. Cultivation system had not significant effect on 1000 grain weight rice. The highest 1000 grain weight was recorded by T_1 (29.29 g). The highest grain yield was recorded by T_1 (0.70 kg plot^{-1}). Cultivation system had significant effect on grain yield of rice. The highest grain yield was recorded by T_1 (7.01 t ha^{-1}) where the lowest (5.45 tha^{-1}) was obtained from T_3 treatment. The highest biological yield was recorded by T_1 (15.14 t ha^{-1}).

Significant influence was remarked in terms of plant height with different varieties of transplanted rice. Results showed that at 75 DAT and at harvest showed the highest plant height (66.90 and 105.70 cm, at 75 DAT and at harvest, respectively) was found in variety of BRRI hybrid-3. Significant variation was marked in terms of number of leaves hill^{-1} at different growth stages of rice among the test varieties. Results showed that the highest number of leaves hill^{-1} (61.67 and 59.89 at 75 DAT and at harvest, respectively) was produced from V_1 treatment. Rice variety of BRRI hybrid-3 showed the highest leaf area index (4.25). BRRI hybrid-3 showedthe highest chlorophyll content(2.465 mg g^{-1}) at anaerobic condition which statistically similar V_2T_1

and BRRI dhan45 showed the lowest chlorophyll content (1.83 mg g^{-1}) at Raised transplant condition.

The production of tillers $hill^{-1}$ was significantly influenced by the tested different varieties. Rice variety of BRRI hybrid-3 showed the highest tiller number $hill^{-1}$ (15.89 and 22.89 at 75 DAT and at harvest, respectively). The dry matter weight was significantly varied due to varietal differences. The highest dry matter (23.15, 48.44 and 63.89 g at vegetative, flowering and harvest, respectively) was observed in V_1 treatment. The highest shoot dry matter accumulation (41.44 g) at flowering stage was obtained from V_1. The highest grain dry matter from current photosynthesis (81.62) was observed in variety of BRRI hybrid-3 Performance of test varieties showed a significant difference in respect of grains $panicle^{-1}$. The highest number of filled grains $panicle^{-1}$ (163.4) was observed in variety of BRRI hybrid-3. Number of unfilled grains $panicle^{-1}$ was significantly influenced by test varieties. The lowest number of unfilled grains $panicle^{-1}$ (24.22) was achieved from BRRI hybrid-3. No significant influence of different varieties was observed on 1000 grain weight. It is attained that the highest 1000 grain weight (29.18 g) was in V_1 treatment. Different varieties significantly produced variable grain yield per plot. Among the tested five varieties BRRI hybrid-3 showed the highest grain yield (0.64 kg). Different varieties significantly produced variable grain yield. Among the tested five varieties BRRI hybrid-3 (V_1) showed the highest grain yield (6.37 t ha^{-1}). On the other hand, the lowest grain yield (5.26 t ha^{-1}) was obtained from BRRI dhan45. Biological yield differed significantly due to varietal differences (Table 11). The treatment V_1 gave the highest biological yield (14.7 t ha^{-1}).

The combined effect of cultivation system and variety had significant effect on all parameter. The tallest plant (71.77 and 110.50 cm at 75 DAT and at harvest) was obtained in T_1V_1 (Low land transplant condition with BRRI hybrid-3) treatment combination. The highest number of leaves $hill^{-1}$ (79.00 and 90.67 at 75 DAT and at harvest, respectively) and number of tillers $hill^{-1}$ (21.33 and 37.00 at 75 DAT and at harvest, respectively) was with V_1T_1 treatment. The highest dry weight $hill^{-1}$ (33.86, 63.00 and 80.00 g at vegetative, flowering and harvest, respectively) was with T_1V_1. The highest shoot dry matter accumulation(56.00g at flowering) was with T_1V_1 treatment. The reserve translocation was the highest (34.06%) from T_1V_1 treatment.

The highest grain dry matter from current photosynthesis (85.87) was with T_1V_1 treatments. The highest number of grains $panicle^{-1}$ (175.30) was with T_1V_1 treatments. The highest 1000 grain weight (29.97 g). The highest grain yield per hectare (8.05 t) was with T_1V_1. The lowest result was recorded from T_3V_5 (4.28 t). The highest biological yield (18.33 t ha^{-1}) was with T_1V_1. The highest harvest index (46.60) was obtained from T_1V_2.

From the above summary of the study, it can be concluded that in aerobic condition rice demonstratedlower performance due to low leaf area index,chlorophyll content, tillering, shoot dry matter accumulation and grain dry matter from current photosynthesis. Again, among the different cultivation system, Low land transplant condition showed the best performance where the Raised transplant condition gave the lowest efficiency considering growth, yield and yield contributing characters. As combined effect of the present study Low land transplant condition with BRRI hybrid 3 showed the best performance regarding growth, yield and yield contributing characters of *Boro* rice varieties.

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

1. All the studied rice varieties produced higher yield in anaerobic (Low land transplant) condition.
2. Stem reserve translocation and grain dry matter accumulation from current photosynthate were also higher in most of the test varieties in anaerobic condition.
3. BRRI hybrid dhan3, Moina and Gold demonstrated comparatively better performance among the test varieties at aerobic conditions in *Boro* season.

Recommendation

- Test rice varieties are not suitable for cultivation at aerobic condition in *Boro* season.
- However, it needs more trials under farmer's field conditions at different agro-ecological zones of Bangladesh for the conformation of the results.

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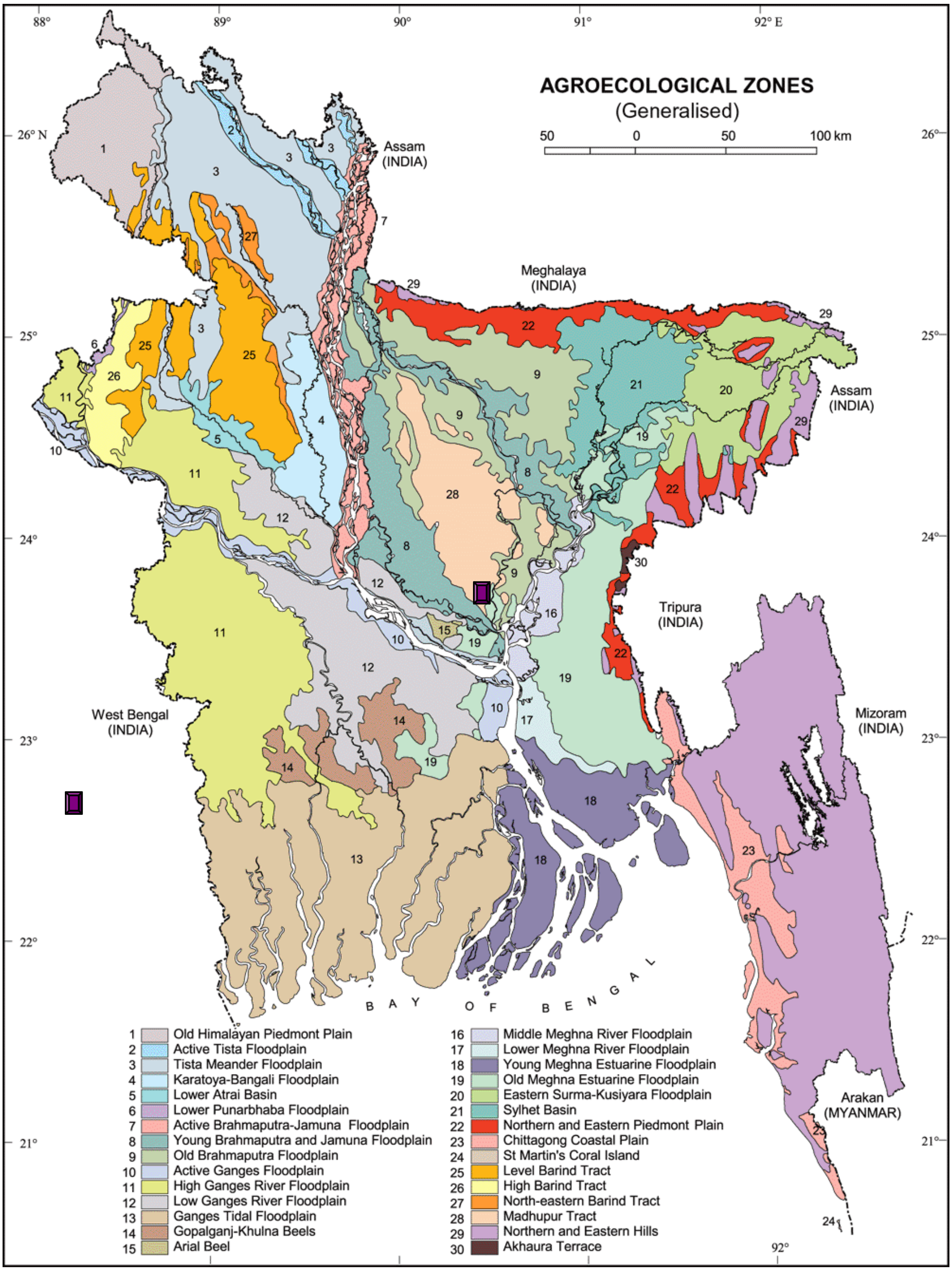
Appendices

APPENDICES

Appendix I: Map showing the experimental sites under study



Appendix II: Characteristics of soil of experimental is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka-1207

B. Morphological characteristics of the experimental field

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

B. Physical and chemical properties of the initial soil

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

Source: Soil Resources Development Institute (SRDI)

Appendix III:Analysis of variance of the data on plant height and leaves hill^{-1} of rice as influenced by cultivation systems and different varieties

Sources of Variation	Degrees of freedom	Mean Square			
		Plant height (cm)		leaves hill^{-1}	
		75 DAS	at harvest	75 DAS	at harvest
Replication	2	168.37	224.07	250.16	1130.2
Factor A	2	155.07	71.485	2032.2	4095.6
Factor B	4	8.819	135.26	72.578	163.39
AxB	8	16.473*	31.254*	68.378*	245.95*
Error	28	22.9	43.641	105.87	288.48

*significant at 5% level of probability

Appendix IV:Analysis of variance of the data on Leaf area index andChlorophyll contentof rice as influenced by cultivation systems and different varieties

Sources of Variation	Degrees of freedom	Mean Square	
		Leaf area index	Chlorophyll content
Replication	2	0.415	1.635
Factor A	2	0.699	35.372
Factor B	4	1.049	63.814
AxB	8	0.425*	29.365*
Error	28	0.382	36.866

*significant at 5% level of probability

Appendix V: Analysis of variance of the data on tillers hill^{-1} andDry matter hill^{-1}of rice as influenced by cultivation systems and different varieties

Sources of Variation	Degrees of freedom	Mean Square				
		Tillers hill^{-1}		Dry matter hill^{-1}		
		75 DAT	at harvest	vegetative stage	flowering stage	at harvest
Replication	2	21.8	1648.8	11.267	477.49	45.267
Factor A	2	245.4	1740.4	663.22	975.62	2054.9
Factor B	4	13.589	32.278	44.536	168.2	190.06
AxB	8	8.372*	37.078*	64.872*	142.73*	420.67*
Error	28	8.181	283.51	11.267	165.97	140.65

*significant at 5% level of probability

Appendix VI: Analysis of variance of the data on Shoot dry mater accumulation andgrain dry matter from current photosynthesis of rice as influenced by cultivation systems and different varieties

Sources of Variation	Degrees of freedom	Mean Square				
		Shoot dry mater at flowering stage (g)	Shoot dry mater at maturity stage (g)	Changes in shoot dry mater (g)	Shoot reserve translocation (%)	Grain dry matter from current photosynthesis (%)
Replication	2	844.02	462.2	60.689	176.75	149.83
Factor A	2	955.49	109.4	568.62	1462.8	66.754
Factor B	4	112.86	56.633	326.92	1274.3	15.986
AxB	8	142.57*	73.733*	104.12*	377.06*	60.846*
Error	28	120.57	103.84	107.52	347.7	3.071

*significant at 5% level of probability

Appendix VII:Analysis of variance of the data on yield contributing characters of rice as influenced by cultivation systems and different varieties

Sources of Variation	Degrees of freedom	Mean Square		
		Filled grain panicle^{-1}	Unfilled grain panicle^{-1}	Thousand seed weight (g)
Replication	2	2402.7	1648.2	0.726
Factor A	2	191.02	1586.3	11.376
Factor B	4	345.64	53.389	2.184
AB	8	329.33*	280.29*	2.476*
Error	28	1162	330.35	2.024

*significant at 5% level of probability

Appendix VIII: Analysis of variance of the data yield and yield of rice as influenced bycultivation systems and different varieties

Sources of Variation	Degrees of freedom	Mean Square		
		Grain yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	5.153	9.241	69.246
Factor A	2	10.21	40.075	13.109
Factor B	4	1.896	9.111	58.565
AB	8	2.447*	5.013*	40.474*
Error	28	1.601	7.805	50.629

*significant at 5% level of probability

AppendixIX: Pictorial view of field experiment

Plate-1: Preparation of the main field

Plate-2: Transplanting of seedlings in the field

Plate-3: Data recording from the field

Plate-4:Plant at ripening stage