EVALUATION OF MODERN *AMAN* RICE VARIETIES IN RELATION TO GROWTH AND YIELD ATTRIBUTES

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Dedicated To:

My Beloved Parents

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CERTIFICATE

This is to certify that thesis entitled, *"***EVALUATION OF MODERN *AMAN* RICE VARIETIES IN RELATION TO GROWTH AND YIELD ATTRIBUTES**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of ***MASTER OF SCIENCE IN*** Agricultural Botany**,** research work carried out by **MD. GULJAR RAHMAN,** Registration Reg. No. 10-04115 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

....

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ABSTRACT

The experiment was carried out in rice (*Oryza sativa* L.) at Sher-e-Bangla Agricultural University (SAU) research farm, during July 2016 to November 2016 to evaluate the growth and yield performance of BRRI hybrid dhan 4 and five inbred (BRRI dhan 32, BRRI dhan 39, BRRI dhan 41, BRRI dhan 51 and BRRI dhan 66) rice varieties of *Aman* season. The experiment was arranged in randomized complete block design with four replications. Different physiological attributes like growth rate at different stage, morphological change, yield determining attributes and yield performance were studied of those test varieties. BRRI hybrid dhan 4 was showed better performance over the other selected inbred rice varieties in different growth parameters like tillers hill^{-1}, leaves hill^{-1}, TDM hill^{-1}, leaf area hill^{-1}, LAI, CGR and RGR. Again in case of yield related characters like effective tillers hill, panicle length, 1000-grain weight, Biological Yield (BY), Harvest Index (HI) were also higher in BRRI hybrid dhan 4. BRRI dhan 51 and BRRI dhan 66 occupied second and third position respectively compared to other three varieties based on growth and yield performance. BRRI dhan 66 had higher CGR (17.76 g m^{-2} d^{-1}) and BRRI dhan 51 had higher RGR (1.86 mg g^{-1} d^{-1}) than the other test varieties. The higher amount of dry matter accumulation at vegetative and reproductive stage was found in BRRI hybrid dhan 4 (84.65g) and second highest in BRRI dhan 66 (84.50 g). Total dry matter accumulations at vegetative and reproductive stages have positive relation with high grain yield. BRRI hybrid dhan 4 provided the highest grain yield (6.25t ha^{-1}) closely followed by BRRI dhan 51 (6.08 t ha^{-1}) and then BRRI dhan 41 (5.05 t ha^{-1}). BRRI hybrid dhan 4 had the maximum tillers hill^{-1} (18.30), panicle length (29.33 cm), grains panicle^{-1} (145.00), 1000-grain weight (30.83g), harvest index (41.89%). So that BRRI hybrid dhan 4 had produced around 20% higher yields over the inbred varieties BRRI dhan 32 and BRRI dhan 41.

CONTENTS

CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATED TERMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.	=	And others
e.g.	=	for example
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization
i.e.	=	that is
LSD	=	Least Significant Difference
m^2	=	Meter square
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
°C	=	Degree Celsius
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
Zn	=	Zinc
Mg	=	Microgram
TSP	=	Triple Super Phosphate
MP	=	Muriate of Potash

CHAPTER I

Introduction

Rice (*Oryza sativa* L.) is the staple food for nearly half of the world's population and in Bangladesh where it constitutes a major part of human diet. Present population status of Bangladesh is 160.18 million (BBS, 2017). Rice is the single most important crop in Bangladesh occupying over 60% of total cultivated area (BBS, 2017). The total area of rice cultivation 10.85 million hectares and production of rice in Bangladesh is 39.69 million tons, respectively (BBS, 2017). Although the production of rice in Bangladesh increased 4 times higher than the several past decades, the demand for rice is still on the increase because of ever increasing population. Again to fulfill the challenges of SDG, we need more sustainable production in this sector. But the nation is being lost 0.7% of cropping land and added about 2.3 million people every year (Kibria, 2011). The country produces 1.2 million tons food deficits every year (Julfiquar, 2009). We need to produce more food for this increasing population with reduction of cropland day by day with less land, less water, less worker and less pesticides. To produce 50 million ton of rice by 2030, the yield should be increased to 6.00 t ha^{-1} compared to

4.25 t ha^{-1} at present (Hossain, 2015). In last 25 years there is a great revolution has happened in agriculture sector mainly in rice production by discovering high yielding rice varieties. In this case hybrid rice varieties have played a great role. Hybrid rice offers to break the yield ceiling of conventional semi-dwarf rice varieties. Hybrid rice has 15-30% higher yield potential over elite inbred rice varieties (IRRI, 2000; Ao *et al*., 2008). IRRI has been introduce hybrid rice cultivation in Bangladesh and commercial seed companies of India and China during last ten years and has already gained positive experience in *Aman* season.

However, the main factors of higher yield in hybrids are greater biomass accumulation before heading and higher shoot reserve translocation (Jeng *et al*., 2006; Yang *et al.*, 2008). Again, many scientists informed that hybrid rice had higher productivity after heading but the more dry matter in vegetative organ at heading contributes little to the grain due to poor transportation and remobilization of stored assimilates (Wu *et al*., 2008). The pre-requisites for higher yield in hybrid rice are slow senescence and more strong photosynthetic capability of flag leaf, higher lay at grain filling period and higher post heading-CGR (Wu *et al*., 2008; Tang *et al*., 2010). Hybrid rice had higher productivity after heading but translocation of assimilates was inefficient. Otherwise there are many problems we are facing in hybrid rice production. So, the available information on source activities, shoot reserve remobilization and its influence on the yield formation of hybrid rice varieties. So for this purpose, for obtaining desirable (sustainable) grain yield we need clear information on the morphological-physiological parameters and yield attributes of hybrid rice varieties comparing with the inbred varieties following the manipulation of agronomic cultural management practices. Under these circumstances, the present research program has been designed to determine or investigate the physiological attributes and yield performance of hybrid and selected inbred rice varieties in *Aman* season to generate afore-said information.

The hybrid rice variety BRRI hybrid dhan 4 has got popularity in Bangladesh and inbred BRRI dhan 32, BRRI dhan 39, BRRI dhan 41, BRRI dhan 51 and BRRI dhan 66 varieties are also popular. But research works on these modern varieties in term of morpho-physiological characteristics and yield performance are limited. So the present research work has been undertaken in order to fulfilling the following objectives.

- To study the leaf characters, dry matter accumulation, CGR and RGR among the test rice varieties in *Aman* season.
- To investigate the yield variation and their causes among the selected modern rice varieties.

CHAPTER II

REVIEW OF LITERATURE

Morphological and physiological characters of the different rice varieties and their yield performance are differing from one another. This difference among the varieties depends on some elements. Variety of rice, environment, agronomic practices and hazardous factors play the main role in rice cultivation. Among all these factor for rice production, difference in rice variety from each other until now considerable matter. In case of rice production using different rice varieties like of local, high yielding and hybrid play a vital role in their adoption with the environment and they greatly affect the return of rice cultivation. Research information on the morpho-physiological characteristics and yield of inbred rice varieties in *Aman* season is available in Bangladesh. But on hybrid varieties is very limited. However, some of the recent and past information on varietal performance of rice have been reviewed under the following headings.

2.1 Growth parameters

2.1.1 Plant height

Plant height has been regarded as an important regulator of emission of physiological characters and yield potential in rice (*Oryza sativa* L.). In this study, we investigated responses of rice plant to differential variation in *Aman* season. The average plant height of BRRI dhan 32, BRRI dhan 39, BRRI dhan 41, BRRI dhan 51 and BRRI dhan 66 were 95 cm, 100 cm, 95 cm, 105 cm and 110 cm reported by BRRI (2016). As a sun light habitat dependent had negative regulation of heading date, the degree of phenotype effect of plant height on heading date and yield traits are quantitatively related to the transcript level and is also influenced by both environmental conditions and genetic back grounds (Xue *et al.,* 2008). Plant height varied from variety to variety (Song *et al.*, 2004). There is a significant difference in plant height among the local, high yielding and hybrid rice varieties.

2.1.2 Tillering pattern

The tillering capacity of the rice plant differs with variety and environment. The formation of tillers per hill varies from variety to variety. There are many factors influencing in tiller formation, nitrogen level play a vital role.

Higher panicle numbers per m^2 of direct-seeded rice are due to maximum tiller number per m^2 but not to higher panicle-bearing tiller rate. Tillage is considered to be the oldest and the most effective farm activity for developing a desired soil structure. Tillage improves the physical conditions of soil and favors the rooting characteristics of plants, leading to tiller for maturation (Nuruzzaman *et al.*, 2000).

2.1.3 Plant spacing

Plant spacing has an important role on growth and yield of rice. The proper growth of plant with their aerial growth can be ensured through optimum plant density and more solar radiation and soil nutrients utilize by the underground parts (Miah *et al.,* 1990). Closer spacing hampers intercultural operations. Also in a densely populated crop, the inter-plant competition is very high for nutrients, air and light, which usually results in mutual shading, lodging and thus favors more straw yield than grain yield. On the other hand, under wider plant spacing desired hill $unit^{-1}$ area cannot be obtained which ultimately reduces yield $unit^{-1}$ area. The maximum benefit can be derived from a rice field, if the crop is properly spaced between rows and within rows. Alam (2006) stated that optimum spacing gave a maximum number of total tillers m^{-2}, maximum number of fertile tillers m^{-2} which was dependent on temperature, moisture and other soil factors.

2.1.4 Leaves $hill^{-1}$

The formation of leaves per hill mainly depends on the spacing and growing pattern of rice. In this experiment we use one seedling per hill with the spacing 30 cm x 25 cm.

Ashraf (1999) reported that the use of more seedlings $hill^{-1}$ not only adds to cost but is also a mere wastage of natural resources. Based on research findings, we conclude that use of 1 seedling $hill^{-1}$ is most appropriate for timely sowing otherwise 4 seedlings $hill^{-1}$ should be used to compensate for the yield gap in late transplanted rice.

2.1.4 Leaf area $hill^{-1}$

In rice, the major determinants of yield are, the optimum leaf areas for seedlings, optimum leaf shapes to maximize photosynthetic efficiency, deep, well-developed root systems, leaf area index (LAI) at flowering and crop growth rate (CGR) during panicle initiation have been identified (Sun *et al.*,1999).

2.1.5 Leaf area index (CGR)

Leaf area index (LAI) is a dimension less quantity that characterizes plant canopies. It is defined as the one-sided green leaf area per unit ground surface area.

LAI = (leaf area / ground area) in broadleaf canopies

Leaf area index is the efficiency of photosynthetic process and on the extent of photosynthetic surface (Lockhart and Wiseman, 1988). LAI increased significantly by the interaction between transplanting dates and number of seedlings hill^{-1}. The transplanting, spacing and number of seedlings hill^{-1} had little effect on LAI (Zhong *et al.,* 2002). Such variations in results might be due to change in environmental conditions and or genetic make-up of the germplasm.

LAI can be determined directly by taking representative sample of foliage from a unit plot area, measuring the leaf area per sample and dividing it by the plot land surface area.

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

The increasing number of total biomass helps to increase yield performance of the crop because this increasing biomass allocated into the grain that increase the amount of yield (Evans and Fischer, 1999). The length of foliar function is influenced by many factors which are helped to transferring too much of dry matter or too fast into panicle gives rise to premature leaf senescence, which adversely affects grain yield that stated by Zhou *et al.*(2017).

2.1.7 Crop growth rate (CGR)

Crop growth rate is a measure of the increase in size, mass or number of crops over a period of time. The increase can be plotted as a logarithmic or exponential curve in many cases. The absolute growth rate is the slope of the curve. Relative growth rate is the slope of a curve that represents logarithmic growth over a period of time.

The genotypic difference in grain yield was most closely related to that in crop growth rate (CGR) during the late reproductive period (10-15) days before full heading). Rice genotypes having higher CGR during this period produced a greater number of spikelets per unit land area. The higher CGR also led to larger accumulation of non-structural carbohydrate (NSC) in the culms and leaf sheaths during the period that was positively correlated with the rapid translocation of NSC to panicle in the initial period of grain filling.

2.1.8 Relative growth rate (RGR)

Relative growth rate (RGR) is growth rate relative to size. It is also called the exponential growth rate or the continuous growth rate.
Hoffmann (2002) stated that in plant physiology, RGR is a measure used to quantify the speed of plant growth. It is measured as the mass increase per above ground biomass per day. It is considered to be the most widely used way of estimating plant growth, but has been criticized as calculations typically involve the destructive harvest of plants. Another problem is that RGR nearly always decreases over time as the biomass of a plant increases, but traditionally this has been ignored when modeling plant growth. Relative growth rate (RGR) is a prominent indicator of plant strategy with respect to productivity as related to environmental stress and disturbance regimes. RGR is the (exponential) increase in size relative to the size of the plant present at the start of a given time interval. Expressed in this way, growth rates can be compared among species and individuals that differ widely in size. By separate measurement of leaf, stem and root mass as well as LA, good insight into the components underlying growth variation can be obtained in a relatively simple way.

2.2 Yield attributes

2.2.1 Panicles hill^{-1}

Panicles are the flowers of the rice. They are placed at the end of the tillers. The seeds or grains produced in the fertilization of the rice plant grow in the panicles of the rice crops. Panicles are one of the identifying qualities of a fully developed tiller (Maclean, 2013). The number of panicle bearing tillers per unit area does the main function of yield formation. The more number of productive tillers plant^{-1} the more amount of yield found from the rice field.

Total number of panicles required per unit area can vary, depending on soil type and water regime. For most situations, tillers and panicles are thought of as similar although not all tillers produce panicles. For wet season crops, 300 to 400 panicles per m^2 are desired; in the dry season density increases to 500 to 600 panicles per m^2. In more fertile soils and for irrigated and dry season crops, plant populations should be increased. The number of tillers per plant will vary according to nutrient status, variety and planting rate (higher seeding rates normally give fewer tillers). Transplanted crops generally produce more tillers than direct seeded crops, and dry season crops often produce more tillers than wet season crops.

2.2.2 Non- effective tillers hill^{-1}

The non- effective tillers hill^{-1} had negative effect on the crop production. In this case variety is a great factor (Chakma., 2006). He also found that BINA dhan5 had the highest non-bearing tillers m^{-2} (8.61) while the lowest was observed in BINA dhan6 (6.83).

2.2.3 Panicles

A panicle is a much-branched inflorescence. Some authors distinguish it from a compound spike by requiring that the flowers (and fruit) be pedicel late. The branches of a panicle are often racemes. A panicle may have determinate or in determinate growth.

Generally hybrids give higher values for panicle length compared to cultivars that reported by Ghosh (2001). Panicle m^2 was significantly and negatively correlated with panicle weight and sterility percentage, while the association of panicle length with panicle weight and 1000-grain weight was found positive and highly significant stated by Chandra and Das (2000).

2.2.4 Grains panicle^{-1}

The panicle length, number of filled grains panical^{-1} and 1000-seed weight had contributed for increased grain yield that reported by Mishra and Pandey (1998).
Grain number for per panicle is the most important components for rice yield. Spikelets on the primary and secondary branches determine the grain number per-panicle in rice. In this study, we identified a natural mutant, *gnp4*, lack of lateral spikelet on the secondary branches in the field condition that reported by Zhan-Ying (2016).

The characterizing of panicle structure of IL SIL040 further revealed that during the domestication from common wild allele to cultivated rice one at *gpa7*, not only the number of branches and grains per panicle increased significantly, more importantly, but also the ratio of secondary branches per panicle to total branches per panicle and the ratio of grains on secondary branches per panicle to total grains per panicle increased significantly. All these results reinforced the idea that *gpa7* might play an important role in the regulation of grain number per panicle and the ratio of secondary branches per panicle during the domestication of rice panicle.

2.2.5 1000-grain weight

Islam *et al*. (2013) stated that significant variation in 1000-grain weight due to the variation in genetic makeup of the variety. The higher number of tillers reduces the number, size and weight of grain stated by Lockhart and Wiseman (1988).

2.2.6 Crop duration

Using a crop calendar allows better planning of all farm activities and the cost of production. A cropping calendar is a schedule of the rice growing season from the fallow period and land preparation, to crop establishment and maintenance, to harvest and storage.

Determine the time the variety takes from planting to harvest. The length of time from establishment to harvest is known for each variety. It may vary a little depending on the growing conditions especially water availability and solar radiation. Normally short duration varieties take 100-120 days, medium duration 120-140 days and long duration 160 days plus. The main causes of this variability are varying temperature and day length. Breeding for stable crop duration in such environments might make a major contribution to rice production. A previous study established genetic differences in phonological responses to temperature and photoperiod, based on a field study with sequential planting dates in Senegal.

Growth analyses were performed at key growth stages and yield components were determined at physiological maturity. Regression analysis of yield versus year of release indicated an annual gain in rice yield of 75 to 81 kg ha^{-1}, equivalent to 1% per year. The highest yields obtained with the most recently released cultivars was 9 to 10 Mg ha^{-1}, which is equivalent to reported yields of IR8 and other early IRRI cultivars obtained in the late 1960s to early 1970s at these same sites. Therefore, the 1% annual increase in yield may not represent genetic gain in yield potential. The increasing trend in yield of cultivars released before 1980 was mainly due to the improvement in harvest index (HI).

2.2.7 Grain yield

IR8, the first high-yielding modern rice cultivar, was released by IRRI in 1966. This event marked the start of the -green revolution‖ in Asia. IR8 is a semi dwarf with profuse tillers, stiff culms, erect leaves, light insensitivity, high N responsiveness, and high harvest index compared with traditional cultivars (Chandler, 1969).

During the past 30 years, rice breeding efforts have been directed towards incorporation of disease and insect resistance, earlier maturity and improving grain quality (Khush, 1990).

Rice is highly sensitive to temperature stress (cold and heat), particularly during the reproductive and grain-filling stages. Physiological and biotechnological tools, along with integrated management and adaptation options as well as conventional breeding, can help to develop new rice genotypes possessing better grain yield under thermal stress during reproductive and grain-filling phases.

2.2.8 Straw yield

Straw yield was significantly affected due to varieties that stated by Rejaul (2005). It was observed that highest straw yield found in BRRI dhan29 that 5.64 t ha^{-1}.

There is a general tendency that varieties with less vegetative growth are apt to be small ingrain weight. Therefore, it is necessary to break this correlation in order to develop a plant type with large grain weight and less vegetative growth that is high grain / straw ratio. The correlation between yield and straw weight was high when the solar radiation was limited at the vegetative growth stage, whereas correlation between yield and grain/straw ratio was high when solar radiation was limited at the ripening stage. The higher the light transmission rate at the ripening stage was the higher the yield and grain / straw ratio. The smaller the leaf area at the heading stage, and the better the plant structure in receiving sun light at the heading and ripening stages reported by Murata *et al.*, (1961).

2.2.9 Harvest index (HI)

The term harvest index is used in agriculture to quantify the yield of a crops pecies versus the total amount of biomass that has been produced. Physiological process leading to a high net accumulation of photosynthesis and its partitioning into plant called high yielding. The HI is the grain yield over total above-ground biomass. The grain yield and water productivity would be improved by either an increase in transpiration efficiency or an increase in HI (Yang *et al.*, 2010).

High-yielding rice had more harvest index (51%) than the high-yielding rice that reported by Jian-Chang *et al*. (2006). That grain yield exhibited a very strong positive correlation with harvest index stated by Shriame and Muley (2003). HI has been shown to be a variable factor in crop production. Variations in harvest index within a crop are mainly attributed to differences in crop management (Yang *et al*., 2000).

CHAPTER III

MATERIALS AND METHODS

Different materials used and methodologies that are followed in the experiment, their details were showed up in this chapter. A brief description of experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and analysis, etc were discussed in this chapter.

3.1 Description of the experimental site

The experiment was carried out at the Sher-e-Bangla Agricultural University (SAU) research farm, Sher-e-Bangla Nagar, Dhaka-1207. This Agro-ecological zone under the Madhupur Tract, AEZ-28 (23^0 $41'$ N latitude and 90^0 $22'$) at an elevation of 8 m above the sea level (Appendix-I)

3.1.1 Experimental field preparation

The experiment field was ploughed and cross ploughed three times, using power tiller followed by laddering. The land was made free from weeds and crop residues by using *khurpi* and hand hoe. Puddling was also done in the field by using stagnant water. The unit plot was leveled before transplanting. The experimental area was laid out according to the design of the experiment.

3.1.2 Climate

The experimental site geographically located under the Madhupur AEZ where the climactic condition subtropical in nature, characterized by three distinct seasons, from March to April the pre-monsoon period (*kharip-1*) or hot season and from May to October the monsoon period (*kharip*-2) and from August to middle of the march which count as winter (*Robi*) season. Details of this experiment like the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the study period were collected from the Weather Station of Bangladesh, Sher-e-Bangla Nagar, Dhaka-1207. The Climatic data is presented in Appendix -II.

3.1.3 Soil

The soil of the experimental field belongs to Joydebpur series. It is Shallow Red-Brown Terrace type soil with silty clay in surface and silt clay loam in sub-surface region. The evaluation was performed at Soil Resources and Development Institute (SRDI), Dhaka. The physical and chemical properties of the soil are showed in Appendix-III.

3.2 Experimental treatments and source of plant materials

Six rice varieties were used as treatments for this study *viz*:

BRRI hybrid dhan 4: It is the first hybrid rice variety innovated by BRRI for *Aman* season. The breeding line of this variety is BR28H. The best performance of this variety found in flood free area. Plant height of this variety nears 112 cm. Crop duration nearly118 days. Grain is medium in size, white color. It's yield 6-6.5 t ha^{-1}.

BRRI dhan 32: This high yielding variety is very much suitable for *Aman* season which grain is medium fine and tasty. Plant height nears 115-120 cm. But strength of the variety is not so good. So that it become fallen down in case of heavy rain and air blowing. Growth duration is 130 days. The average yields of BRRI dhan 32 more or less 5 t ha^{-1}.

BRRI dhan 39: It is one of the best short duration rice varieties of *Aman* season in

Bangladesh. It's grain is medium fine and tasty. The straight of the plant stem is good and it's not easily fallen down. Flag leaf of this variety is thick and straight. Growth duration is 115-120 days. Grain yield was recorded the highest 4-4.5 t ha^{-1} and highest number of grains $panicle^{-1}$.

BRRI dhan 41: BRRI dhan 41 very much popular in southern part of our country. It is a salt tolerant and photo sensitive rice variety. Plant height is near 115 cm. Stem erect and thick so that it's not easily fallen down. Growth duration of this variety is 145 days. Grain yield was recorded the highest 4.5 t ha^{-1} and highest number of grains $panicle^{-1}$.

BRRI dhan 51: It is one of the best short duration floods tolerant rice varieties of *Aman* season in Bangladesh. Grain is medium fine and tasty. The straight of the plant stem is good and it's not easily fallen down. Flag leaf of this variety is thick and straight. Growth duration is 135-140 days. Plant height around 90 cm. Grain yield was recorded the highest 4-4.5 t ha^{-1} and highest number of grains $panicle^{-1}$.

BRRI dhan 66: This high yielding variety is a popular drought tolerant variety for *Aman* season. It's grain fine and tasty. Grain color is slightly red. Growth duration is 110-115 days which is 3-4 days more than BRRI dhan56. Average yield for BRRI dhan 66 is around 4.5-5 t ha^{-1}.

All those hybrid and inbred varieties Seeds were collected from the respective seed companies and BRRI, Gazipur

3.3 Preparation of experimental field

The land was processed by dint of power tiller by three successive ploughing and then cross ploughing and after that laddering was done. The experimental field was puddled by standing water. Weeds and crop residues of previous crop were removed from the field. The experimental area was laid out according to the design of the experiment. The unit plot was leveled before transplanting.

3.4 Fertilizer management

After prepared of the experimental field different type fertilizers were used. At the time of first ploughing, cow-dung was applied at the rate of 10 t ha^{-1}. Urea, triple super phosphate (TSP), Muriate of Potash (MP), Gypsum and Zinc Sulphate fertilizers were used 120, 80, 80, 20 and 5 kg ha^{-1} for supplying N, P_2O_5, K_2O, S and Zn in the experimental area.

3.5 Experimental treatments

In this experiment five inbred and one hybrid rice varieties were used as different treatment *viz*:

V_1 = BRRI dhan 32

V_2 = BRRI dhan 39

V_3 = BRRI dhan 41

V_4 = BRRI dhan 51

V_5 = BRRI dhan 66

V_6 =BRRI hybrid dhan 4

3.6 Experimental design and layout

Randomized complete block design with four replications was followed for the arrangement of unit plots. The unit plot size was 4 m x 2.5 m. The spacing between block was 1 m and between plots 1 m. The unit plot to unit plot distance 0.5m. The layout of the experiment has been shown in Appendix-IV.

3.7 Raising of seedlings

In August 23, 2016 seedbeds were prepared and seedlings of different varieties were raised in the separate seedbed by following general methods. Before placing in the seedbed, seeds were soaked in water for 24 hours and incubated for a period until radicals came out. Broadcasting method used to sow the sprouted seeds in beds. No fertilizer was applied in seedbed. Irrigation was applied as per requirement. Due care was taken to protect the seedbed from damages by birds and pests.

3.8 Uprooting of seedlings

Before uprooting the seedlings, seedbeds were made wet by application of water both in the morning and evening on the previous day. The seedlings were uprooted carefully with minimum mechanical injury in the roots and keep them under shade and soft mud.

3.9 Transplanting of seedlings

On 20 September of 2016, 28 days old seedlings of all studied hybrid rice and check variety were transplanted in the experimental field keeping row to row distance 25 cm and plant to plant distance 20 cm.

3.10 Intercultural operations

Gap filling was done up to 7 days after transplanting for maintaining a required plant population. Weeding was done manually as per requirement. Irrigation also done properly as per required to maintain a constant level of standing water up to 5-10 cm in the field. Almost throughout the growing season necessary steps were taken.

3.11 Growth parameters

3.11.1 Sampling for growth analysis

For growth analysis sampling six hills plot^{-1} were selected at 50 DAT (vegetative stage) and uprooted carefully for maximum retention of roots. The sampled plants roots were washed carefully. Then the plants were taken to the laboratory for data collection. Same procedure was followed at 70 and 90 DAT (reproductive stage) too.

3.11.2 Data collection

Data were recorded on the following crop characters:

3.11.2.1 Plant height

At 10 days interval starting from 28 days after transplantation and continued up to harvest plant height was measured from randomly preselected ten hills plot^{-1}. By measuring the distance from the soil surface to the tip of the leaf before heading and to the tip of panicle after heading plant height was measured.

3.11.2.2 Tillers hill^{-1}

At 10 days interval starting from 20 day after transplantation and up to harvest number of tillers hill^{-1} were counted from preselected ten hills plot^{-1} and then the mean value was calculated as their number hill^{-1}. The tillers having three or more leaves were considered for counting.

3.11.2.3 Leaves hill^{-1}

Leaves hill^{-1} in each plot was counted at different growth stage *viz*. 50 (vegetative stage), 70 and 90 DAT (reproductive stage) and at harvesting.

3.11.2.4 Leaf area hill^{-1}

The sampled plants were divided in leaf, stem and roots for measuring leaf area hill^{-1}. An electronic area meter (LI 3000, USA) was used for calculating leaf area and then their corresponding dry weight was recorded after drying at 72 ± 2^0 C for 24 hours. Sub-sampling was done when the sample volume was excess and difficult to handle. Finally, leaf area was calculated hill^{-1}.

3.11.2.5 Leaf area index

LAI is the ratio of leaf to its ground area. It was determined by the following formula from the sampled plants as follows

$$LAI = \frac{LA}{A}$$

Where,

LA = Leaf area (cm^2)

A =Unit land area (cm^2)

3.11.2.6 Total dry matter hill^{-1}

Total dry weight was measured at uprooting the plant with root from 2nd line were of weight was attained from which the weight of 10 days interval up to harvest by Sub-samples of 5 hills plot^{-1} oven dried until a constant level.

3.11.2.7 Crop growth rate

Increase of plant material per unit of time per unit of land area called crop growth rate.

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

Where,

W_1= Total plant dry matter at time T_1 (g)

W_2 = Total plant dry matter at time T_2 (g)

A = Ground area (m^2)

3.11.2.8 Relative growth rate

Increase of plant material per unit of material present per unit of time

$$\mathbf{RGR} = \frac{Log\ W1 - Log\ W2}{T2-T1} \ \mathrm{mg}\ \mathbf{g^{-1} d^{-1}}$$

Where,

W_1 = Total plant dry matter at time T1(g)

W_2 = Total plant dry matter at time T2(g)

Log = Natural logarithm

3.12 Yield parameters

3.12.1 Harvesting and processing

Hybrid and inbred rice test varieties were harvested on different days depending on their maturity. When 80-90 % of the grains become golden in color then harvesting was done. Sampled plants were cut at the ground level and were separately bundled and properly tagged for recording of necessary data. Harvesting one sq. meter was prefixed at the corner of each plot to determine the Grain yield. After harvesting crops were become threshed and cleaned. After proper drying in the sun (14% moisture) the grain weight was recorded.

3.12.2 Data on yield

Data were recorded on the following yield parameters:

3.12.2.1 Effective tillers hill^{-1}

The effective tillers from ten hills were counted and mean value was calculated as hill^{-1} basis. The panicle which had at least one grain was considered as effective tillers.

3.12.2.2 Non-effective tillers hill^{-1}

At final harvesting from each plot Non-effective tillers hill^{-1} from the sampled plants was calculated.

3.12.2.3 Panicle length

Panicle length was measured from basal node of the rachis to apex of each panicle. An average of five panicles was taken for each observation of Panicle length measurement.

3.12.2.4 Filled and unfilled grains panicle^{-1}

Total number of grains present in each panicle was counted and presence of any food material in the spikelet was considered as filled grain. Spikelet lacking any food material inside was considered as unfilled grains and such spikelet present on the each panicle were counted.

3.12.2.5 1000-grains weight

From every sample one thousand cleaned dried seeds were counted randomly and a digital electric balance used for weighting at the stage when the grain retained 12% moisture and the mean weight were expressed in gram.

3.12.2.6 Crop duration

For measuring crop duration, it was counted from seeding to harvesting days.

3.12.2.7 Grain yield

To calculate grain yield m^{-2} from each plot central 6 m^2 undisturbed area used for this purpose and then it was expressed as t ha^{-1} on 12% moisture basis. A digital moisture tester was used to measure the grain moisture content.

3.12.2.8 Straw yield

To calculate straw yield m^{-2} from each plot, straw yield was taken from the central 5 m^2 undisturbed area. After threshing, the sub-sample was firstly sun dried for two days, then placed to oven for a constant weight and finally converted to t ha^{-1}.

3.12.2.9 Biological yield

The biological yield refers to the total dry matter accumulation of a plant system. This Improve harvest index represents increased physiological capacity to mobilize photosynthetic and translocation them into organs having economic yield.

The biological yield was calculated with following formula-

Biological yield (BY) = Grain yield + straw yield.

3.12.2.10 Harvest index

Harvest index expresses the relationship between grain yield and biological yield. It was calculated by using the following formula-

$$HI=\frac{Grain\ Yield}{Biological\ Yield}\times 100$$

3.13 Statistical analysis

Different parameters were used to collect data for statistically analysis. The Statistix 10.0 computer package program was used to obtain the level of significance. The randomized complete block design was used for analyzing of variance. The mean differences among the treatments were compared by least significant difference (LSD) test at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was performed to study about the different traits of the rice plants and its contribution to the yield of hybrid and inbred rice varieties in *Aman* season. The results of the study have been presented and discusses with the help of table and graphs and possible interpretations were given under the following headings-

4.1 Growth parameters

4.1.1 Plant height

Plant height at different days after transplanting (DAT) exhibited remarkable variation among the test rice varieties (Table 1). Plant height increased progressively with the advancement of time. At 50 DAT, the tallest plant was obtained from BRRI hybrid dhan 4 (64.60 cm) followed by BRRI dhan 51 (62.26 cm) and the shortest height was recorded in BRRI dhan 66 (55.52 cm) showed in Table 1. At reproductive phase (70 and 90 DAT), the highest plant height was achieved from BRRI hybrid dhan 4 (94.15 cm and 103.90 cm respectively) and the shortest was recorded in BRRI dhan 32 (82.50 cm and 94.17 cm respectively).

At final harvest, BRRI hybrid dhan 4 had highest height (110.91 cm) followed by BRRI dhan 51 (108.26 cm) and the shortest was in BRRI dhan 41 (96.62 cm) proceeded by BRRI dhan 32 (96.32 cm) with same statistical rank. Rest of the varieties showed in-between status. Shalauddin (2012), Om *et al*. (1998) and Kabir *et al.*, (2004) also found difference in plant height due to varietal differences. Result focused that BRRI hybrid dhan 4 was the tallest and BRRI dhan 39 the shortest plant.

Table 1. Plant height at different days after transplanting and at harvest of selected rice varieties in *Aman* season

Rice variety	Plant height (cm)			
	50 DAT	**70 DAT**	**90 DAT**	**At harvest**
BRRI dhan 32	58.62bc	82.50d	94.17b	96.91bc
BRRI dhan 39	59.58abc	87.50c	95.23b	96.62c
BRRI dhan 41	59.94abc	82.77d	95.87b	98.11bc
BRRI dhan 51	62.26ab	91.17ab	97.90b	108.26a
BRRI dhan 66	55.52c	88.17bc	96.01b	100.57b
BRRI hybrid dhan 4	64.60a	94.15a	103.90a	110.01a
$LSD_{(0.05)}$	5.60	3.55	5.44	3.73
CV%	5.13	2.23	3.08	2.02

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) difference significantly at 0.05 level of probability

4.1.2 Tillers hi1l^{-1}

The significant variation in total number of tillers hill^{-1} showed among the hybrid and inbred rice varieties at DAT (Table 2). Number of tillers hill^{-1} increased with the advancement of vegetative growth. But at reproductive stages, number of total tillers hill^{-1} decreased in all the studied rice varieties. At 50 DAT, the highest number of tillers hill^{-1} was produced by BRRI hybrid dhan 4 (16.60) that was significantly different from the rest. The lowest number of tillers hill^{-1} was found in BRRI dhan 32 (11.34). At 70 and 90 DAT, maximum number of tillers hill^{-1} was achieved from BRRI hybrid dhan 4 (16.78 and 17.90). Yield also decreased considerably with the decrease of tillers hill^{-1}. In this experiment we also found same type of result.

Mondal *et al*. (2005) found significant difference in number of tillers hill^{-1} in 17 rice varieties. Marambe (2005) observed that the tillers number varied from 14 to 18 per plant with 6-9 panicles. Kabir *et al.* (2004) and Shalauddin (2012) reported that significant variation observed among the rice cultivars.

Table 2. Tillers hill^{-1} at different days after transplanting (DAT) in selected rice varieties of *Aman* season.

Rice variety	Tillers hill^{-1} at			
	50 DAT	70 DAT	90 DAT	At final
BRRI dhan 32	11.34e	13.78b	12.27c	13.81c
BRRI dhan 39	12.57de	13.48b	11.87c	13.30 bc
BRRI dhan 41	13.14cd	14.01b	14.20bc	13.87 bc
BRRI dhan 51	15.63ab	14.94ab	15.52ab	15.24abc
BRRI dhan 66	14.48bc	14.91ab	14.90b	15.57ab
BRRI hybrid dhan 4	16.60a	16.78a	17.90a	15.93a
$LSD_{(0.05)}$	1.34	2.14	2.50	1.96
CV (%)	5.30	8.06	9.50	7.37

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

4.1.3 Stem dry matter hill^{-1}

In the selected rice varieties we found significant variation in stem dry matter hill^{-1} at different DAT observation (Table 3). In first 70 DAT, we found stem dry matter hill^{-1} was increased rapidly followed by a declined. At 50 DAT, the highest number of stem dry matter was observed in BRRI hybrid dhan 4 (55.09 g) and second highest in BRRI dhan 51 (51.63 g).Then the stem dry matter accumulation became decreased due to staring reproductive phase. At 70 DAT, the maximum stem dry matter hill^{-1} observed in BRRI hybrid dhan 4 (50.62 g) followed by BRRI dhan 51 (46.62 g). At 90 DAT, the maximum number of Stem dry matter hill^{-1} (44.25 g) was recorded from BRRI hybrid dhan 4. In 50 and 70 DAT, BRRI dhan 32 and BRRI dhan 41 produced the lowest amount stem dry matter. However, BRRI hybrid dhan 4 produced the highest amount of stem dry matter hill^{-1} and BRRI dhan 32 produced the lowest amount of stem dry matter hill^{-1}.

Table 3. Stem dry matter hill^{-1} at different days after transplanting (DAT) in selected rice varieties in Aman season

Rice variety	Stem dry matter hill^{-1} (g) at		
	50 DAT	**70 DAT**	**90 DAT**
BRRI dhan 32	47.87bc	42.80c	36.50d
BRRI dhan 39	46.21c	41.35bc	35.01cd
BRRI dhan 41	47.35bc	42.56bc	36.77bcd
BRRI dhan 51	51.63ab	46.62ab	40.42ab
BRRI dhan 66	48.69bd	43.35bc	37.143bc
BRRI hybrid dhan 4	55.09a	50.62a	44.25a
$LSD_{(0.05)}$	4.78	3.43	4.78
CV (%)	5.31	3.03	3.32

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

4.1.4 Leaf area hill^{-1}

Leaf area (LA) in the test rice varieties varied considerably during the different DAT (Table 4). LA increased up to heading and thereafter declined. The rate of leaf area development hill^{-1} varied significantly among the rice varieties. In 50 and 70 DAT, the highest leaf area hill^{-1} was produced by BRRI hybrid dhan 4 (1309 cm^2 and 2091 cm^2). The lowest leaf was recorded in BRRI dhan 32 and BRRI dhan 41. Variation in leaf area might occur due to the variation in number of leaves (Sarkar, 2014).

4.1.5 Leaf area index (LAI)

Leaf area index (LAI) significantly differed in the studied rice varieties from 50 DAT to 90 DAT (Table 4). At 50 DAT, the maximum LAI was observed in BRRI hybrid dhan 4 (3.62) closely followed by BRRI dhan 51 (3.46). At 50 and 70 DAT, BRRI dhan 32 showed the lowest LAI (2.51 and 1.83 respectively). Rest of the varieties showed intermediate LAI values. On the other hand, at 90 DAT the hybrid variety BRRI hybrid dhan 4 showed the highest value (4.81). Mondal *et al.* (2007) who stated that the variation in LAI could be attributed due to the changes in number of leaves and the rate of leaf expansion and abscission. The high yielding varieties possessed higher LAT values throughout the whole growth period which led to the higher biomass production and yield (Ready *et al.,* 1995).

Table 4. Leaf area hill^{-1} and Leaf area index (LAI) at different days after transplanting (DAT) in hybrid and inbred rice varieties

Rice Variety	Leave area hill^{-1} (cm^2)			Leave area index (LAI)		
	50 DAT	70 DAT	90 DAT	50 DAT	70 DAT	90 DAT
BRRI dhan 32	734e	1433d	1421e	2.51d	1.83e	3.81d
BRRI dhan 39	1086c	1666c	1610cd	3.17c	2.31cd	4.96a
BRRI dhan 41	886d	1533d	1517de	2.68cd	2.03de	4.04cd
BRRI dhan 51	1223b	1813b	1804b	3.46b	2.79b	4.66ab
BRRI dhan 66	1003d	1715c	1672c	3.01cd	2.41c	4.32bc
BRRI hybrid dhan 4	1309a	2091a	1976a	3.62a	3.16a	4.81a
LSD(0.05)	0.59	0.61	1.29	1.29	2.81	0.43
CV%	7.98	5.10	6.17	6.17	9.11	11.30

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

4.1.6 Root dry matter hill^{-1}

At different growth stages in case root dry matter production, there was a significant variation observed among tested rice varieties (Table 5). At vegetative stages (50 DAT) maximum root dry matter was observed in BRRI hybrid dhan 4 and the lowest was found in BRRI dhan 41. At reproductive stage (70 and 90 DAT) the maximum root dry matter was found in BRRI hybrid dhan 4and the lowest was found among the different tested inbred varieties. Mostly lowest amount of root dry matter accumulation found in BRRI dhan 41. From this Result we found that root dry matter was gradually increased with time.

4.1.7 Stem dry matter hill^{-1}

At different DAT there was significant difference observed in stem dry matter among the hybrid and inbred rice varieties (Table 5). At 50 DAT maximum stem dry matter was recorded in BRRI hybrid dhan 4 and the minimum was obtained from BRRI dhan 41. At 70 and 90 DAT, we found the same rapid accumulation result as we found in 50 DAT. Result showed that stem dry matter was gradually increased with time.

4.1.8 Leaf dry matter hill^{-1}

Among the rice varieties Leaf dry matter accumulation significantly varied at different DAT (Table 5). At 50 DAT, the maximum leaf dry matter was recorded in BRRI hybrid dhan 39 (5.40 g), followed by BRRI dhan 66 (5.34 g) and the minimum was collected by BRRI dhan 41 (13.34 g). At 70 and 90 DAT the highest leaf dry matter was found in BRRI hybrid dhan 4 (16.56 g and 16.40 g) and the minimum was received in the BRRI dhan 41 (13.56 g and 13.34 g). It means that leaf dry matter was gradually increased with time.

4.1.9 Total dry matter hill^{-1}

Total dry matter (TDM) accumulation showed significant variation among hybrid and inbred rice varieties (Table 5). As the age of the rice plant increased the accumulation of dry matter increased. In first 50 DAT we found that dry matter accumulation in plant was low and after that it was increased so fast. At 90 DAT, BRRI hybrid dhan 4 (84.65 g) provided the highest dry matter hill^{-1} followed by BRRI dhan 51 (84.50 g) while BRRI dhan 41 produced the lowest amount of TDM (68.45 g). The increase of TDM was dependent on the leaf area production as reported by Chandra and Das (2010). This result was also supported by the result of Sarkar (2014) who reported that TDM increased with increasing plant age up to physiological maturity and high yielding rice always maintained higher TDM hill^{-1}.

Table 5. Dry matter accumulation of selected rice varieties at different days after transplanting in *Aman* season

Rice variety	Root dry matter hill^{-1}(g)			Stem dry matter hill^{-1}(g)			Leaf dry matter hill^{-1}(g)			Total dry matter hill^{-1}(g)		
	50DAT	70DAT	90DAT	50DAT	70DAT	90DAT	50DAT	70DAT	90DAT	50DAT	70DAT	90DAT
BRRI dhan 32	4.40c	4.46c	12.34bc	10.34a	24.45c	42.45b	3.34b	13.34b	13.54b	21.45c	45.1b	70.34cd
BRRI dhan 39	5.34b	6.45a	12.13c	15.13a	35.56a	52.45a	5.40a	15.83a	14.43b	25.34b	5.45a	74.45c
BRRI dhan 41	3.56d	3.56c	12.23c	9.45b	21.34c	41.34b	4.99b	11.56c	13.34b	19.45c	46.4b	68.45de
BRRI dhan 51	6.32a	4.34b	14.34ab	10.34b	27.44b	45.56b	4.23ab	13.56a	15.56ab	24.44b	57.56a	84.50a
BRRI dhan 66	4.56c	6.23a	13.56b	15.34a	33.54a	51.34a	5.34a	15.34a	15.54ab	26.54ab	44.0b	79.45ab
BRRIhy.dhan 4	6.34a	6.43a	15.42a	14.45a	33.34a	52.06a	5.23a	16.56a	16.40a	27.83a	58.50a	84.65a
$LSD_{(0.05)}$	0.59	0.61	1.29	2.81	4.31	5.21	1.31	1.23	1.54	2.31	2.11	4.58
CV(%)	7.98	5.10	6.17	9.11	11. 30	7.91	12.80	3.83	7.23	8.32	6.2	7.057

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

4.1.10 Crop growth rate

At vegetative stage, (50-70 DAT), the BRRI dhan 66 exhibited the highest CGR (17.76 g m^{-2} d^{-1}) followed by BRRI dhan 51 (16.58 g m^{-2} d^{-1}) while the minimum CGR found in BRRI dhan 32 (11.825 g m^{-2} $d^{-1)}$ and BRRI dhan 41 (26.23 g m^{-2} d^{-1}). At reproductive stage (70-90DAT), the highest CGR was recorded in BRRI dhan 66 (17.57 g m^{-2} d^{-1}) closely followed by BRRI dhan 51 (13.47 g m^{-2} d^{-1}). The minimum CGR at 70-90 DAT was observed in BRRI dhan 39 (09.00 g m^{-2} d^{-1}) and at par with BRRI dhan 41 (11.05 g m^{-2} d^{-1}). CGR declined at near maturity might be due to the decrease in LAI at the later stage. So, we found that CGR increased along with increases in LAT. This result is in consonance with the results of Yang *et al*. (2010). At vegetative stage (50-70 DAT), the CGR was observed to be maximum that indicated that plants allocated more it's dry matter for growth of leaf area. These results are consistent with the result of Miah *et al*. (1996) and Piranhas *et al*. (1997) who reported that varietal differences of CGR were significant at different growth stage.

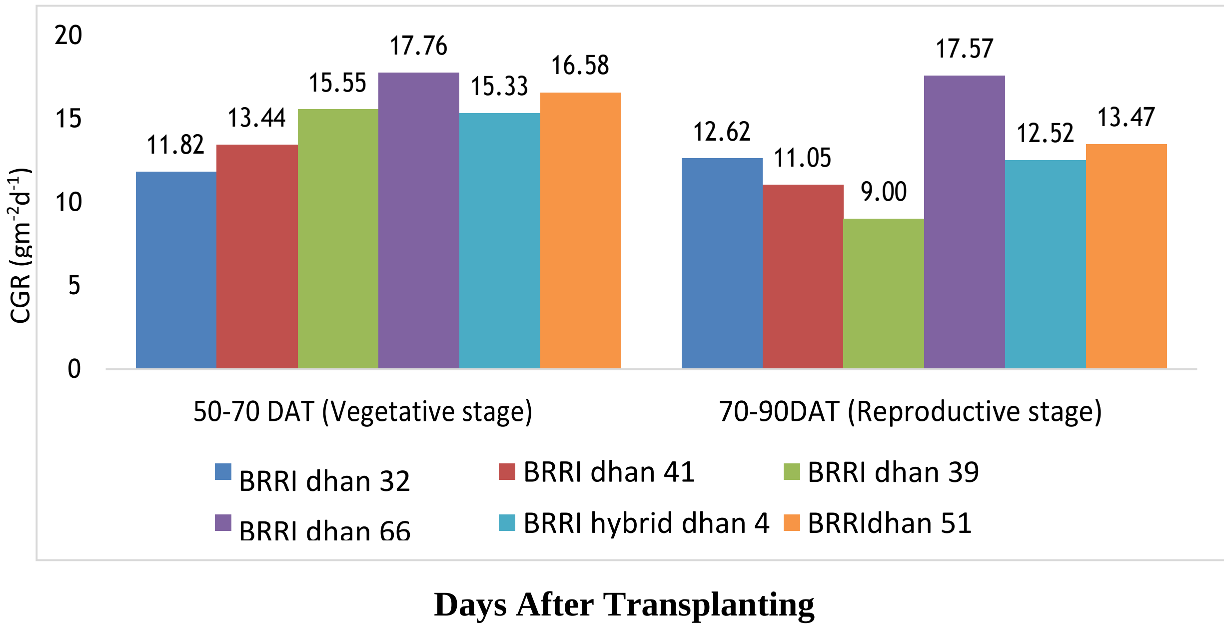
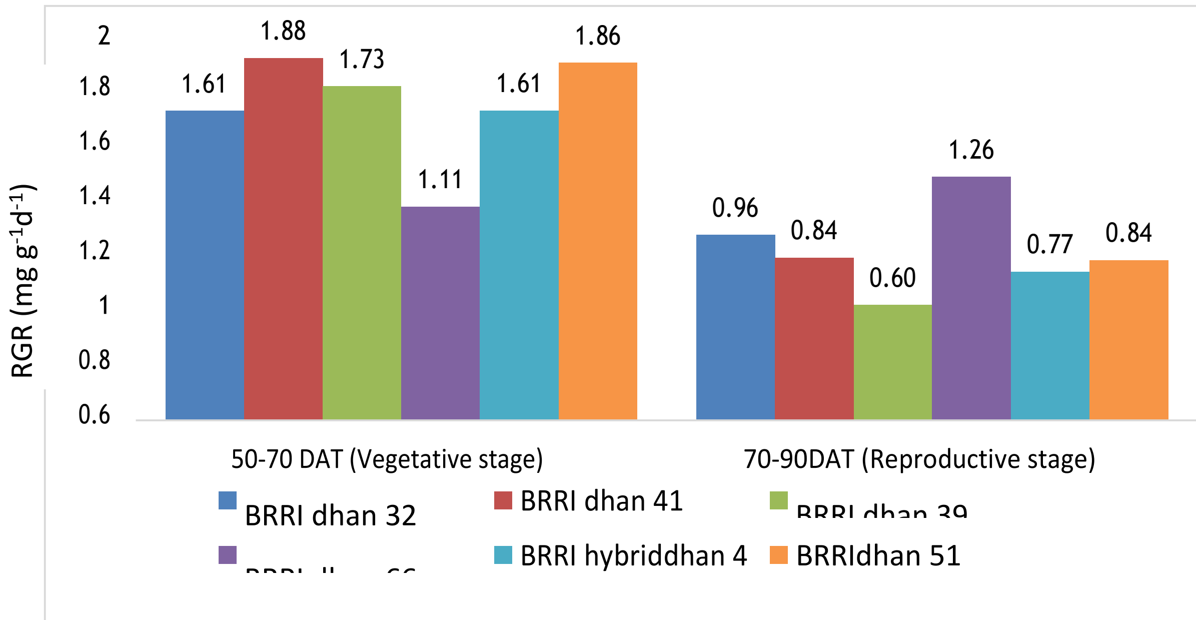


Figure 1. Crop growth rate (CGR) at 50-70 DAT) and 70-90 DAT in the selected rice varieties at *Aman* season

4.1.11 Relative growth rate

The studied varieties showed the higher RGR at vegetative stage than the reproductive stage. BRRI dhan 51 produced the highest RGR (1.86 mg g^{-1} d^{-1}) at 50-70 DAT followed by BRRI dhan 39 (1.73 mg $g^{-1}d^{-1}$). Whereas BRRI dhan 66 and BRRI dhan 32 showed the lower RGR (1.113 mg $g^{-1}d^{-1}$ and 1.61 mg $g^{-1}d^{-1}$). At reproductive stage (70-90 DAT) BRRI dhan 66 (1.26 mg $g^{-1}d^{-1}$) present highest RGR and the lowest RGR value was found in BRRI dhan 39 (0.60 mg $g^{-1}d^{-1}$). RGR is decreased in most of the field crops near maturity (Dutta and Mondal, 1998). Almost similar result was also observed by Sallauddin (2012) and in this experiment. The result of the present study are in agreement with the result of Sarkar (2014), who stated that the higher RGR was existed during the vegetative stage and declined rapidly near maturity.



Days After Transplanting

Figure 2. Relative growth rate (RGR) at 50-70 DAT and 70-90 DAT stages of the selected rice varieties in *Aman* season

4.2 Yield attributes

4.2.1 Panicles hill^{-1}

Panicles (effective tillers) hill^{-1} exhibited significant difference among the test rice varieties (Table 6). The highest number of effective tillers hill^{-1} (18.30) was recorded in BRRI hybrid dhan 4 followed by BRRI dhan 51(16.65). Whereas, the lowest number of panicles hill^{-1} was recorded in BRRI dhan 4 (14.17) which was closely followed by BRRI dhan 66 (14.25).

Non- effective tillers hill^{-1}

There was a significant difference noticed among Non- effective tillers hill^{-1} of the studied varieties (Table 6). The highest non-effective tillers hill^{-1} as obtained in BRRI dhan 41 (5.38) followed by BRRI dhan 39 (4.33). On the other hand, the minimum number of non-effective tillers hill^{-1} was recorded from BRRI dhan 66 (1.67). It was statistically identical with BRRI dhan 41 (2.04).

4.2.3 Panicle length

Panicle length exhibited remarkable variation in different test rice varieties (Table 6). The longest panicle was recorded in the hybrid BRRI hybrid dhan 4 (29.33 cm) followed by BRRI dhan 39 (27.66 cm) and then BRRI dhan 66 (24.00 cm). The shortest panicle was found in BRRI dhan 41 (21.56 cm), it was statistically same as BRRI dhan 32 (26.14 cm). This result is consistent with the result of Sarkar (2014) who reported that panicle length was significantly varied among rice varieties and hybrid rice varieties usually have extra-heavy panicle.

4.2.4 Unfilled spikelets panicle^{-1}

Number of unfilled spikelets panicle^{-1} varied significantly among the studied rice varieties (Table 6). BRRI dhan 4 provided the maximum number unfilled spikelet spanicle^{-1} (15.45) followed by BRRI dhan 66 (13.72) while, the lowest by number of unfilled spikelets panicle^{-1} was recorded in BRRI dhan 51 (6.33) followed by BRRI hybrid dhan 4 (9.23). The test rice varieties significantly differed in respect of unfilled spikelets panicle^{-1}. Similar result was also reported by Sarkar (2012) who observed a wide range of variability in unfilled spikelets panicle^{-1} in different rice varieties.

4.2.5 Grains panicle^{-1}

Grains panicle^{-1} was showed considerable different among the test rice varieties (Table 6). BRRI hybrid dhan 4 provided the maximum the number of grains panicle^{-1} (145.00) followed by BRRI dhan 51 (143.7). Whereas, BRRI dhan 41 gave the lowest number of grains panicle^{-1} (137.3).

4.2.6 1000-grain weight

1000-grain weight was significantly differed among the hybrid and inbred rice varieties (Table 6). BRRI hybrid dhan 4 showed the highest 1000-grain weight (30.83 g). Whereas, BRRI dhan 39 showed the lowest l000-grains weight (23.41 g). 1000-grain weight is a varietal characteristic controlled by genetic makeup.

4.2.7 Crop duration

Crop duration varied significantly among the test hybrid and inbred rice varieties (Table 6). Result indicated that all the varieties required shorter days to maturity than BRRI hybrid dhan 4 (125 days). BRRI dhan 66 took the lowest days for maturity (115 days). This result was in consonance with Anonymous (2004) who reported that hybrid rice took more days to maturity than that of local varieties due to delay in tillering, flowering and grain maturity which might be help them accumulated more dry matter.

4.2.8 Biological yield (BY)

Biological yield had remarkable difference among the studied rice varieties (Table 6). The highest biological yield was achieved in BRRI dhan 51 (15.11 t ha^{-1}) closely followed by BRRI Hybrid Dhan 4 (14.92 t ha^{-1}).The lower amount of biological yield was recorded in BRRI dhan 39 (12.53th^{-1}). This result is different from the findings of Sallauddin (2012) and Sarkar (2014) who reported that hybrid rice varieties produced more biological yield than inbred one.

4.2.9 Grain Yield

Grain yield showed remarkable variation among the hybrid and inbred rice varieties (Table 6). BRRI hybrid Dhan 4produced the highest grain yield (6.25tha^{-1}).Whereas the lowest grain yield (4.57tha^{-1}) was obtained from BRRI dhan 39, which was about 20%, lowers than that of BRRI hybrid dhan-4. This result indicated that the hybrid variety BRRI hybrid Dhan 4had remarkable superiority to grain yield over the other rice varieties except BRRI dhan 51 (6.08 t ha^{-1}).

4.2.10 Harvest index

Among the hybrid and inbred rice varieties Harvest index (HI) was differed from one another considerably (Table 6). Significantly the highest harvest index found from BRRI hybrid Dhan 4 (41.89%) and then BRRI dhan 51 (40.23g). It means dry matter partitioning to economic yield was superior in BRRI Hybrid Dhan 4to the other rice. BRRI dhan 66 reported significantly the lowest harvest index (34.52%). Result reflected that the BRRI hybrid dhan-4provided higher harvest index. This finding had similarity with Sarkar (2014) and Sallauddin (2012) agreement.

Table.6 Yield components and grain yield of hybrid and inbred rice varieties in *Aman*season

Rice Variety	Panicles hill^{-1}	Non-Effective Tillers hill^{-1}	Panicle Length	Unfilled spikelets panicle^{-1}	Grains panicle^{-1}	1000 grain Weight (g)	Crop Duration (d)	Biological Yield (t ha^{-1})	Grain yield (t ha^{-1})	Harvest index (%)
BRRI dhan 32	15.69c	5.38a	26.14b	12.66c	144.12ab	25.01bc	124c	12.91b	4.82b	37.34b
BRRI dhan 39	15.34c	4.33ab	27.66b	12.35c	142.30a	23.41c	119b	12.53b	4.57b	36.47b
BRRI dhan 41	14.17d	2.67b	21.56c	15.45b	137.34b	28.96ab	122b	13.67ab	5.05b	36.94b
BRRI dhan 51	16.65b	3.30a	27.00b	6.33d	143.70c	27.06b	123b	15.11a	6.08ab	40.23b
BRRI dhan 66	14.25d	1.65b	26.33b	13.72bc	138.00b	26.10b	118ab	13.21ab	4.65ab	34.52ab
BRRI hybrid dhan 4	18.30a	3.04b	29.33a	18.23a	145.00a	30.83a	125a	14.92ab	6.25a	41.89a
$LSD_{(0.05)}$	0.71	1.29	1.58	2.68	6.96	2.42	9.50	2.10	1.95	4.22
CV (%)	5.26	8.54	3.23	14.10	2.97	3.61	6.47	17.32	18.65	12.80

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

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was done at Sher-e-Bangla Agricultural University (SAU) research farm, Sher-e-Bangla Nagar, Dhaka-1207, during *Aman* season July 2016 to November 2016 to determine the physiological attributes change and yield performance of hybrid variety BRRI hybridDhan 4and five inbred (BRRI dhan 32 and BRRI dhan 39, BRRI dhan 41,BRRI dhan 51 and BRRI dhan 66) rice varieties. A randomized complete block design with four replications was used to do the experiment. Twenty eight days old seedling was transplanted in the main field with maintaining spacing 25cm × 20 cm per hill. Each plot size was $4×2.5m^2$.All the intercultural works were done as per requirement. All the collected data from the experiment field was analyzed by statistical method.

Different morphological and physiological characters likes plant height, tillers $hill^{-1}$, leaves $hill-^1$, TDM, leaf area, LAI, CGR, RGR and yield attributes like effective tillers $hill^{-1}$, unfilled and filled grains panicle, panicle length, 1000- grain weight, crop duration, biological yield (BY), grain yield and harvest index (HI) were studied of the selected Hybrid and inbred varieties in this experiment. The inbred rice variety BRRI dhan 51 and inbred BRRI dhan 39 showed superiority in respect of growth parameters like tillers $hill^{-1}$, leaf area $hill^{-1}$, leaf area $hill^{-1}$, LAI, CGR, RGR over the rest varieties. In all test varieties, number of total tillers $hill^{-1}$ and number of leaves increased up to heading stage and then declined.

In this experiment, we found that the maximum height of the rice plant was BRRI hybrid dhan 4 (110.91 cm) which followed by BRRI dhan 51 (108.26 cm) and minimum height found in BRRI dhan 39 (96.62 cm). At 50, 70 and 90 DAT, maximum number of tillers hill^{-1} were collected from BRRI hybrid dhan 4 (16.26,

21.56 and 21.87). As the number of tillers per hill decreases the production of rice also decrease. After proper vegetative stage or in 70 DAT and in reproductive stage or in 90 DAT, we found maximum number of leaves hill^{-1} in BRRI hybrid dhan 4 (87.32 and 96.96). In 50 and 70 DAT, the highest leaf area hill^{-1} was produced by BRRI hybrid dhan 4 (1309 cm^2 and 2091 cm^2).

From this experiment we found increased amount of stem and root dry matter accumulation in BRRI hybrid dhan 4 and followed by BRRI dhan 51 and in those case lowest (17.76 g m^{-2} d^{-1}) followed by BRRI dhan 51 (16.58 g m^{-2} d^{-1}) while the minimum CGR were found in BRRI dhan 32 (11.825 g m^{-2} d^{-1}) and BRRI dhan 41 (26.23 g m^{-2} d^{-1}). At reproductive stage (70-90DAT), the highest CGR was recorded in BRRI dhan 66 (17.57 g m^{-2} d^{-1}) closely followed by BRRI dhan 51 (13.47 g m^{-2} d^{-1}). The minimum CGR at 70-90 DAT was observed in BRRI dhan 39 (9.00 g m^{-2} d^{-1}) and at par with BRRI dhan 41 (11.05 g m^{-2} d^{-1}). BRRI dhan 51 produced the highest RGR (1.86 mg g^{-1} d^{-1}) at 50-70 DAT followed by BRRI dhan 39 (1.73 mg g^{-1} d^{-1}). Whereas BRRI dhan 66 and BRRI dhan 32 showed the lower RGR (1.113 mg g^{-1} d^{-1} and 1.61 mg g^{-1} d^{-1}). The highest number of effective tillers hill^{-1} (18.30) was recorded in BRR hybrid dhan 4 followed by BRRI dhan5 (16.65). Whereas, the lowest number of panicles hill^{-1} was recorded in BRRI dhan 41 (14.17) which was closely followed by

BRRI dhan 66 (14.25). The minimum number of non-effective tillers hill^{-1} was recorded from BRRI dhan 66 (1.67). It was statistically identical with BRRI dhan 41 (2.04). The longest panicle was recorded in the hybrid BRRI hybrid dhan 4 (29.33 cm) followed by BRRI dhan 39 (27.66 cm) and then BRRI dhan 66 (24.00 cm). The shortest panicle was found in BRRI dhan 41 (21.56 cm). While, the lowest number of BRRI dhan 39 (12.35). BRRI hybrid dhan 4 provided the maximum the number of grains panicle^{-1}(145.00) followed by BRRI dhan 51 (143.7). Whereas, BRRI dhan 41 gave the lowest number of grains panicle^{-1} (137.3). BRRI hybrid dhan 4 showed the highest 1000-grain weight (30.83g).Whereas, unfilled spikelets panicle^{-1} was recorded in BRRI dhan 51 (6.33) followed by BRRI dhan 39 showed the lowest l000-grain weight (23.41 g). Result indicated that all the varieties required shorter days to maturity than BRRI hybrid dhan 4 (125 DAT). The highest BY was achieved in BRRI dhan 51 (15.11 t ha^{-1}) closely followed by BRRI hybrid dhan 4 (14.92 t ha^{-1}). BRRI hybrid dhan 4 produced the highest grain yield (6.25 t ha^{-1}) whereas; the lowest grain yield (4.57 t ha^{-1}) was obtained from BRRI dhan 39, which was about 20%, lowers than that of BRRI dhan 51. Significantly the highest harvest index found from BRRI hybrid dhan 4 (41.89%) and then BRRI dhan 51 (40.23 g). BRRI dhan 66 reported significantly the lowest harvest index (34.52%).

Conclusion:

- BRRI dhan 66 and BRRI dhan 51 exhibited higher crop growth rate then the rest varieties but BRRI hybrid dhan 4 accumulated the highest dry matter.
- BRRI hybrid Dhan 4 provided the highest yield (6.25 t ha^{-1}), which attributed through the accumulation of higher panicles $hill^{-1}$(18.30), grains $panicle^{-1}$ (145.0) and 1000-grains weight (30.83 g). The second highest yield (6.08 t ha^{-1}) was obtained from BRRI dhan 51.

Recommendation:

- BRRI hybrid Dhan 4 should be cultivated for getting high yield.
- Further study may be needed for insuring growth and better yield performance in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.

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APPENDICES

Appendix I: Experimental site showing in the map under the present study

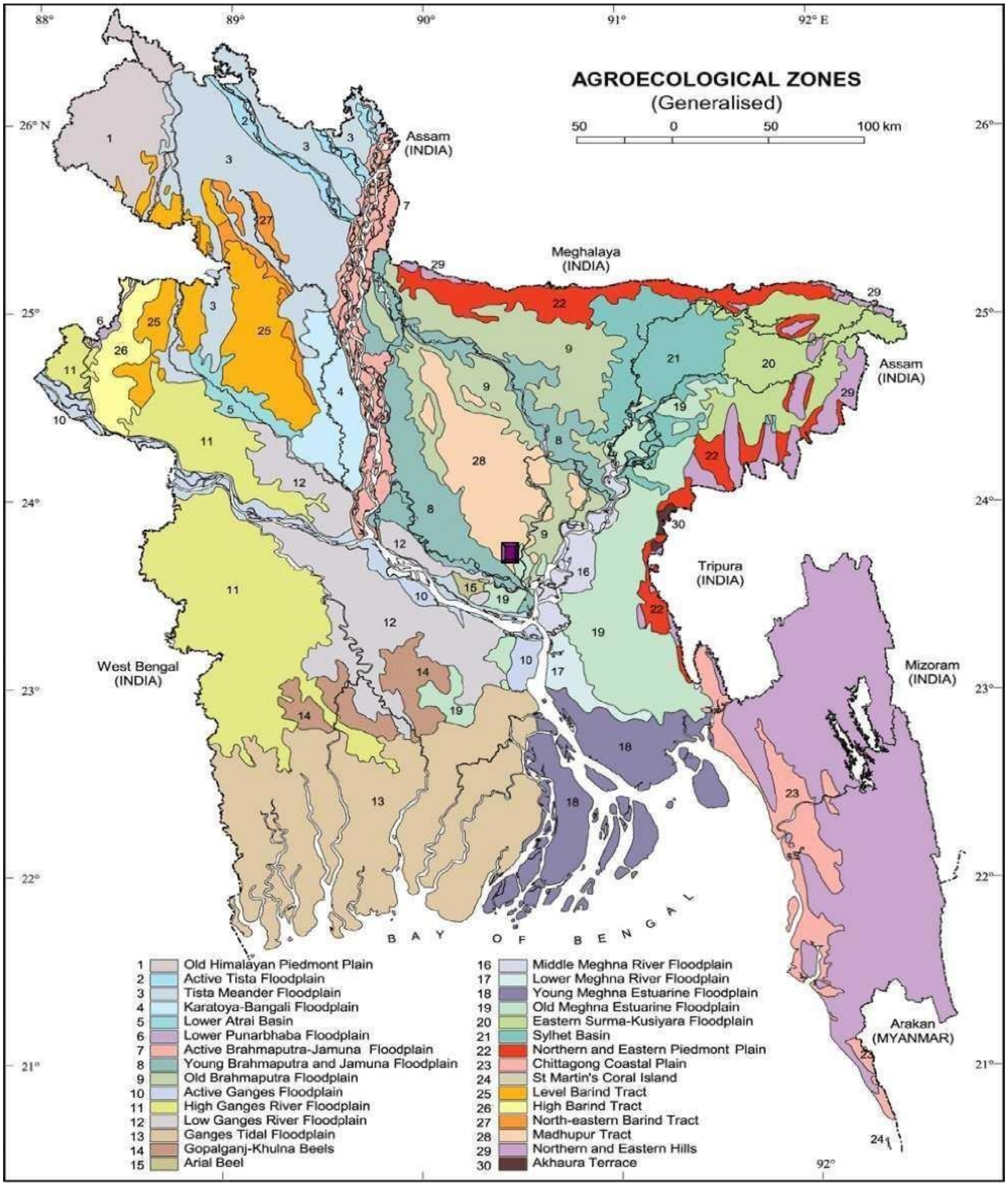

Fig 3. Experimental site

Appendix II. Monthly recorded average rainfall, temperature, relative humidity and sunshine of the experimental site in year 2016

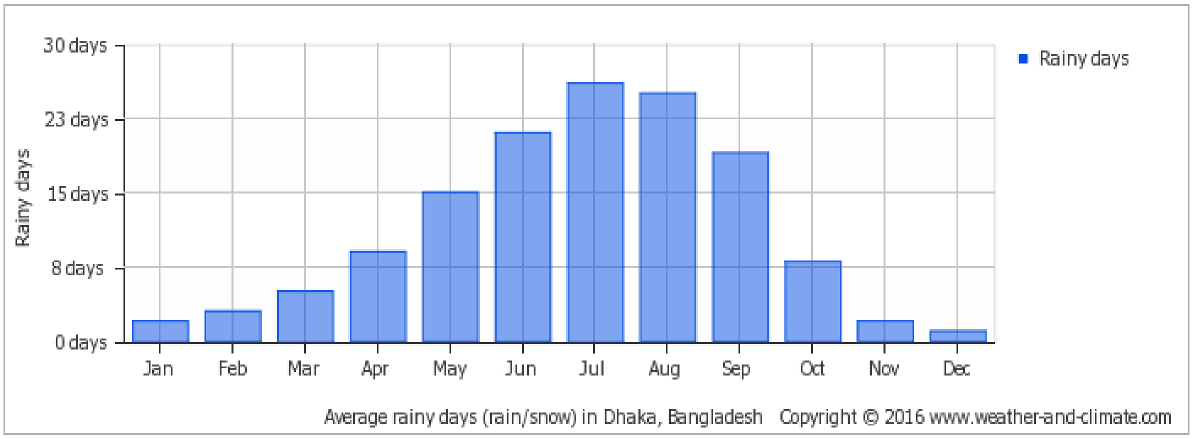

Fig. 4. Average rainy days (rain/snow) in Dhaka, Bangladesh (year 2016)

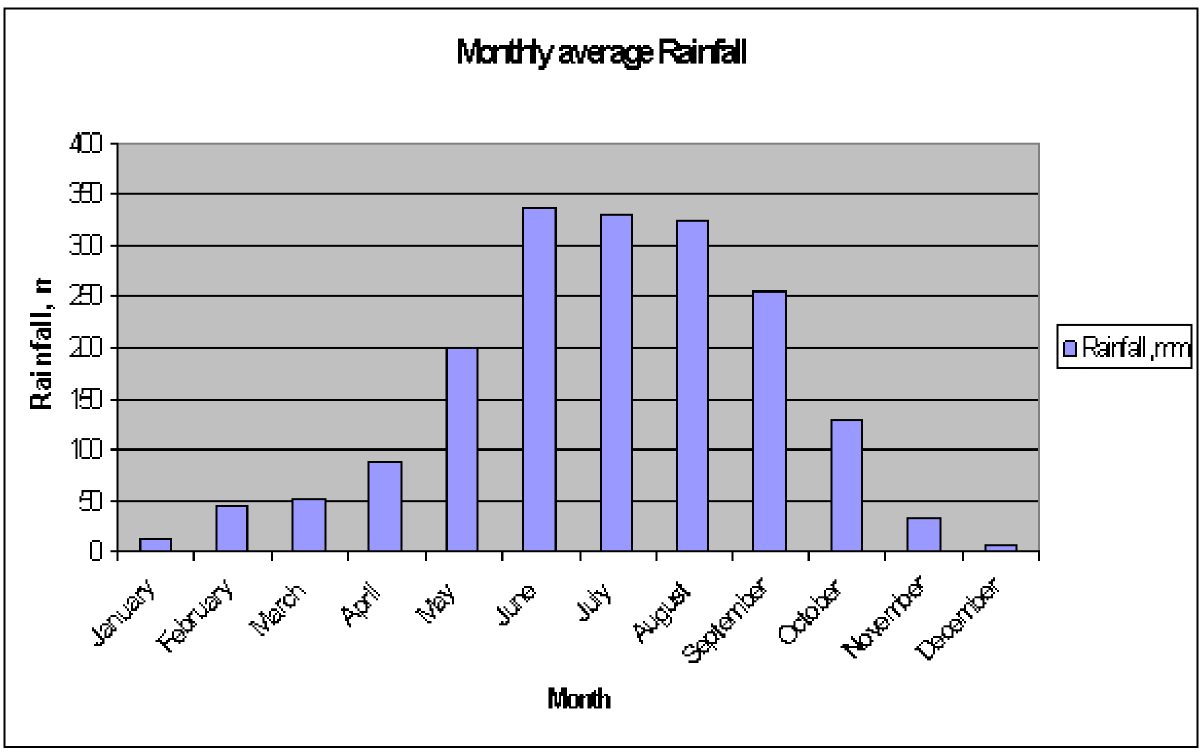

Fig. 5. Monthly average Rainfall

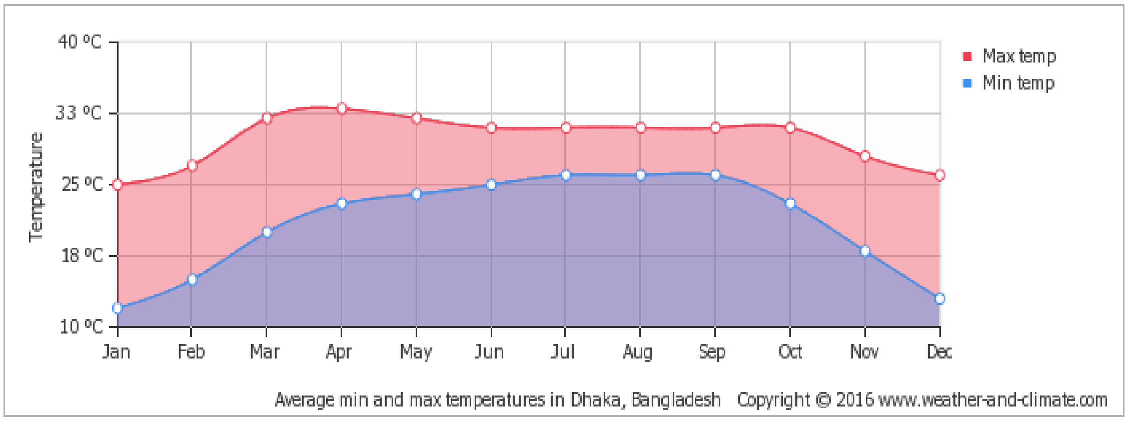

Fig. 6. Average min and max temperature in Dhaka, Bangladesh (year 2016)

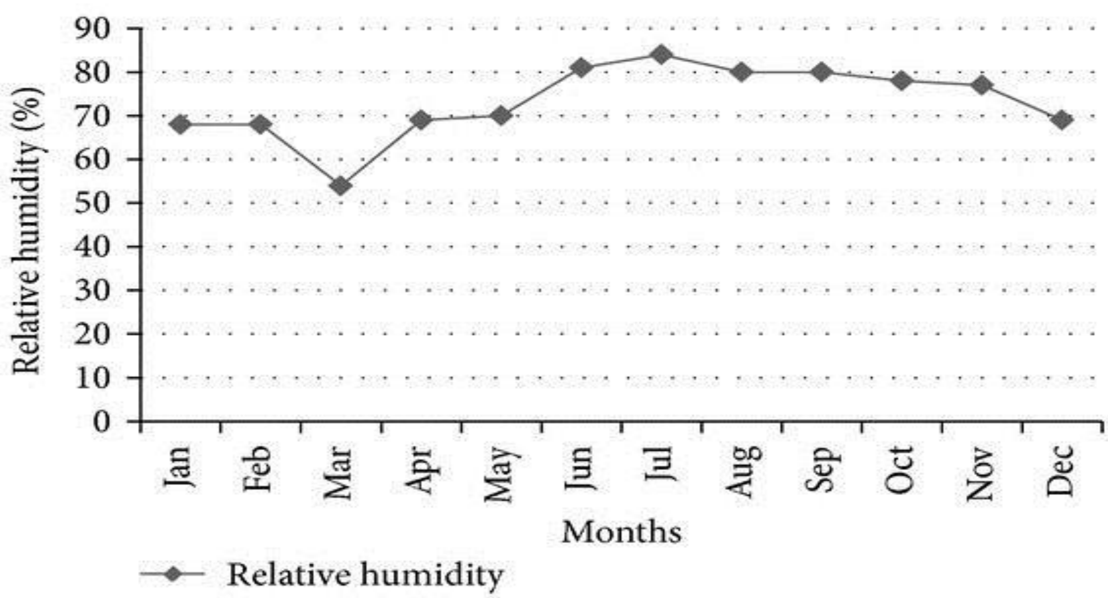

Fig. 7. Average monthly relative humidity in Dhaka, Bangladesh

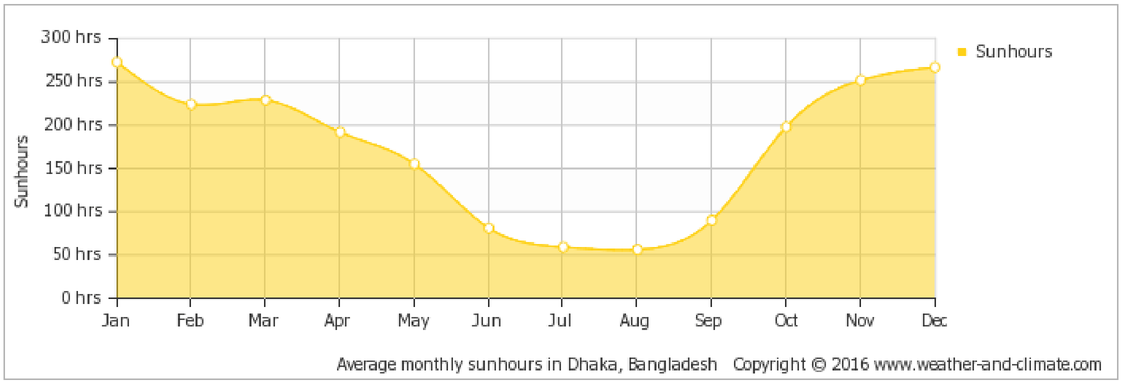

Fig. 8. Average monthly sun hours in Dhaka, Bangladesh (year 2016)

Appendix III. Morphological characteristics of soil of the experimental plot

Morphological features	Characteristics
Location	Research farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow Red Brown Terrace Soil
Land Type	Medium high land
Soil Series	Tejgaon fairly leveled
Topography	Fairly level
Flood Level	Above flood level
Drainage	Well drained
Texture	Loamy

Appendix IV. Physical and chemical properties of soil of the experimental plot

A. Physical properties:

Properties	Value
%sand(0.2-0.02mm)	26
%Silt(0.02-0.002mm)	45
% Clay (< 0.002mm)	39
Textural Class	Silty Clay

B. Chemical properties:

Constituents	0-15cm depth
P^H	5.45-5.61
Total N (%)	0.07
Available P (µ g/g)	18.49
Exchangeable K (µ g/g)	0.07
Available S (µ g/g)	20.82
Available Fe (µ g/g)	229
Available Zn (µ g/g)	4.48
Available Mg (µ g/g)	0.825
Available Na (µ g/g)	0.32
Available B (µ g/g)	0.94
Organic matter (%)	0.83

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

Appendix V: Lay out of the experiment field

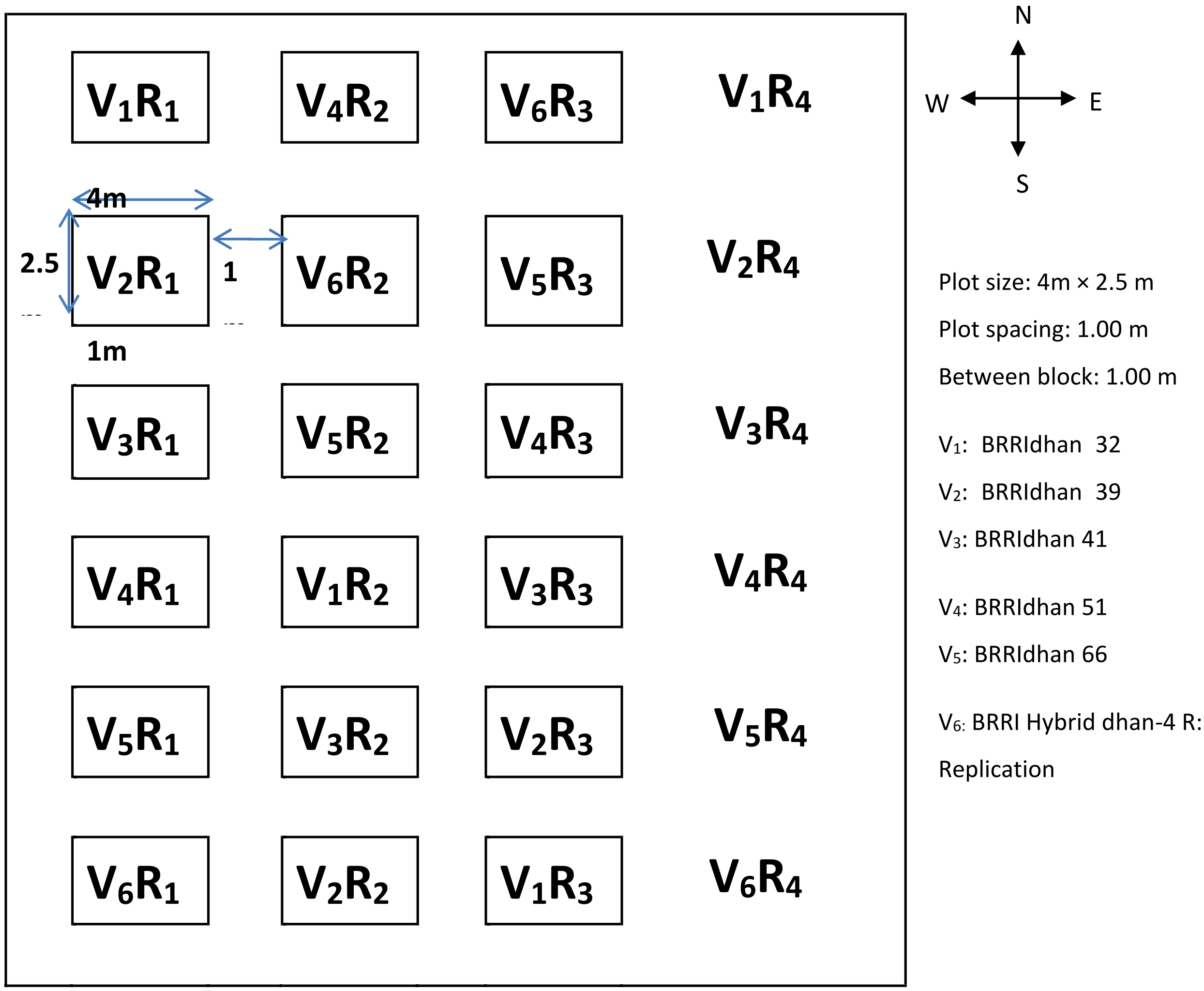

Fig. 9. Layout of the experiment field

Appendix VI: Significant effect of variety on plant height in *Aman* rice varieties

Sources of variation	Degrees of freedom	Mean square of plant height			
		50 DAT	70 DAT	90 DAT	At harvest
Replication	2	3.2093	56.4336	52.1939	7.965
Variety	5	29.0203*	63.1520**	36.9324*	104.943**
Error	10	9.4839	3.8181	8.9544	4.219

* and ** indicates significant at 0.05 and 0.01 level of probability, respectively

Appendix VII: Significant effect of variety on tillers hill^{-1} at different DAT

Sources of variation	Degrees of freedom	Mean square of Tillers hill^{-1} at different days		
		50 DAT	70 DAT	90 DAT
Replication	2	11.1037	3.0547	44.9743
Variety	5	32.7532*	20.5754**	45.0030**
Error	10	6.9080	3.5535	6.8902

* and ** indicates significant at 0.05 and 0.01 level of probability, respectively

Appendix VIII: Significant effect of variety on stem dry matter hill^{-1} at different DAT

Sources of variation	Degrees of freedom	Mean square of Stem dry matter hill^{-1} (g)			
		50 DAT	70 DAT	90 DAT	At harvest
Replication	2	8.2971	2.44787	0.2665	1.60376
Variety	5	11.6799**	5.04970*	14.8419**	3.58517*
Error	10	0.5484	1.37749	1.8822	1.16076

* and ** indicates significant at 0.05 and 0.01 level of probability, respectively

Appendix IX: Significant effect of variety on leave area hill^{-1} at different DAT

Sources of variation	Degrees of freedom	Mean square of leave area index (LAI)		
		50 DAT	70 DAT	90 DAT
Replication	2	22.2093	66.4336	42.1939
Variety	5	41.0203*	78.1520**	95.9324*
Error	10	3.5839	3.7181	5.0544

* and ** indicates significant at 0.05 and 0.01 level of probability, respectively

Appendix X: Significant effect of variety on leave area index at different DAT

Sources of variation	Degrees of freedom	Mean square of leave area index		
		50 DAT	70 DAT	90 DAT
Replication	2	0.129	0.187	0.569
Variety	5	6.5327*	5. 7545**	7.0301**
Error	10	1.9080	1.5535	2.3902

* and ** indicates significant at 0.05 and 0.01 level of probability, respectively

Plate-1: experimental field

Plate-2: Working in the experimental field