STUDY ON GROWTH, PHENOPHASE AND YIELD ATTRIBUTES OF MODERN *AMAN* RICE (*Oryza sativa* L.) VARIETIES

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ABSTRACT

A field experiment was conducted at the Experimental Field of Sher-e-Bangla Agricultural University, Dhaka from July to December, 2017 to investigate the comparative morphological, phenological and yield traits of some *Aman* rice varieties. Ten BRRI released *Aman* rice varieties *viz*. BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan56, BRRI dhan57 and BRRI dhan62 were used as test crops. The experiment was laid out in RCBD design with three replications. Among the studied characters, plant height, number of total tillers hill^{-1}, flag leaf length, flag leaf breath, flag leaf area, penultimate leaf length, penultimate leaf area, panicle length, 1000-grain weight, grain yield and biological yields were significantly varied due to varietal difference. BRRI dhan44 produced the highest number oftotal tillers hill^{-1} (21.1), flag leaf area (85.33 cm^2) and penultimate leaf area (93.83 cm^2), productive tillers hill^{-1} (20.0), fertile grains panicle^{-1} (124.11) and least number of non- productive tillers hill^{-1} (1.5) and sterile grains panicle^{-1} (7.39) followed by BRRI dhan54 produced the number of total tillers hill^{-1} (17.0), flag leaf area (74.86 cm^2) and penultimate leaf area (88.36 cm^2). BRRI dhan44 takes the minimum time for panicle initiation (70 days), booting stage(80 days), panicle emergence (83 days), 50% flowering (91 days), milky stage (100 days) and dough stage (109 days) among all *Aman* varieties. BRRI dhan62 produced the lowestnumber of total tillers hill^{-1} (10.5), flag leaf area (37.89 cm^2) and penultimate leaf area (33.47 cm^2). The yield contributing attributes *viz.* 1000-grain weight (36.38 g), The grain yield (6.23 t ha^{-1}) and biological yields (15.58 t ha^{-1}) were produced by BRRI dhan44which were the highest followed by1000-grain weight (35.00 g). The grain yield (5.27 t ha^{-1}) and biological yields (14.23 t ha^{-1}) were produced by BRRI dhan54. BRRI dhan62 produced1000-grain weight (24.13 g). The lowest grain yield (3.74 t ha^{-1}) and biological yields (11.22 t ha^{-1}) were produced by BRRI dhan62.

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LIST OF ABBREVIATIONS

%	Percent
AEZ	Agro-Ecological Zone
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
PI	Panicle Initiation
PE	Panicle Emergence
Cont'd	Continued
CV%	Percentage of Coefficient of Variance
DAF	Days after flowering
DAT	Days after transplanting
DF	Degree of freedom
DM	Dry matter
et al.	and others
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate
GDP	Gross Domestic Product
IRRI	International Rice Research Institute
Kg	Kilogram
LAI	Leaf area index
LSD	Least significant difference
m^2	Square meter
Mt/ha	Million ton per hectare
MV	Modern varieties
t ha^{-1}	Ton per hectare
UNDP	United Nations Development Program
USDA	United States Department of Agriculture
viz.	Namely

CHAPTER I

INTRODUCTION

Bangladesh is an agrarian country with a huge population. The agriculture of our country is governed by intensive rice (*Oryza sativa* L.) cultivation. Rice is the staple food crop in Bangladesh and the cropping pattern of the country is predominately rice-based. Bangladesh is the 4th largest country of the world on in respect of rice cultivation (BBS, 2012). The population of Bangladesh is growing by two million every year and may increase by another 30 million over the next 20 years. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020 (BRRI, 2011). About 77 per cent of cropped area of Bangladesh is used for rice production, with annual production of 33.83 million ton from 11.41 million ha of land which contributes about 19.60 per cent of the country's GDP (BBS, 2013). The total area and production of rice in Bangladesh are about 11.3 million hectares and 35.06 million metric tons, respectively (AIS, 2017).

The increase rate of population and decreasing rate of agricultural land are 1.42 and 1%, respectively (BBS, 2010). Different growth parameters, i.e. leaf area index, dry matter production and its partitioning, tillering etc progressively influenced the yield of rice (Shams, 2002). Higher grain yield of rice are the reflection of la leaf area index (LAI), leaf area duration (LAD), CGR, NAR and RGR (Thakur and Patel, 1998). International Rice Research Institute (IRRI) as well as Bangladesh Rice Research Institute (BRRI) and commercial seed companies are the pioneer of the invention of hybrid rice technology in this world and Bangladesh. The commercial seed companies of India and China has already gained positive experience in the *Boro* season during the last ten years (Sarkar *et al.,* 2016).

Bangladesh has limited land resources and huge population density resulting, horizontal expansion of rice area is impossible. The strategies and actions of Bangladeshi agriculture are guided by the goals of 'self-sufficiency' in food grain production with main focus on rice. Over 95% people depend on rice for

their daily diets and it engages over 85% of the total agricultural labor force in Bangladesh. So the only avenue left is to increase production of rice by vertical means i.e. management practices. Variety itself is a genetic factor which contributes a lot in producing yield and yield components of a particular crop. The variety and neighboring growing environments directly influenced the yield components. There were marked differences in yield and ancillary characteristics among rice varieties (Chowdury and Bhuiyan, 1991 and Miah *et al.*,1989).

The technologies regarding modern rice cultivation should be abundantly conducted to find out and develop sustainable strategies with a view to obtaining higher yield under the prevailing local conditions in *Aman* season.

Rice is grown in the country under diverse ecosystem like irrigated, rain fed and deep water conditions in three distinct overlapping seasons namely *Aus, Aman* and *Boro*. Among these three seasons, the monsoon rice, transplanted *Aman* covers the largest area. *Aman* rice varieties are generally cultivated in rain fed ecosystem which covers about 48.97% of total rice area and contributes to 38.14% of total rice production in the country (BRRI, 2012). The breeding of high yielding modern Aman varieties is an essential component of the strategy to fulfill the demand in national and international market. Short duration T. *Aman*-rabi crops-late *Boro* cropping system is a climate resilient eco-friendly technology that would help increase system productivity by 15-20% and could help towards maintaining food security in the country (Jewel *et al*., 2016). Short duration T. *Aman* rice can also create opportunity to facilitate legume pulses and green manuring crops before late *Boro* sowing which can contributesignificantly to achieve the twin objectives of increasing productivity and improving the sustainability of the cropping system (Quayum *et al*., 2012). Some short duration T. *Aman* rice varieties (*viz*.

BRRI dhan56,BRRI dhan57) are not only photo insensitive, but also drought resistant (BRRI, 2010).

Farmers are generally replaced the local indigenous low yielding rice varieties by HYV and MV of rice developed by BRRI look forward to obtaining 20% to 30 % more yield unit^{-1} land area (Shahjahan, 2007).

In Bangladesh as well as in the world rice research is predominantly conducted to develop modern high yielding varieties. Bangladesh Rice Research Institute (BRRI) reported that in the period 1990-91 to 2016-17, adoption of modern varieties (MV) increased area by 11% in *Boro*, 246% in *Aus*and 135% in *Aman* season rice. Additionally, *Aman* rice accounts for 50% of rice land, but due to the planting of lower yield varieties, its yield increase is the lowest (39%) (USDA, Foreign Agricultural Service, 2018).

The growth duration of local cultivars is about 150-160 days that is more than modern varieties in Bangladesh in *Aman* season. Therefore, it is true thatmodern varieties in Bangladesh in *Aman* season, crop duration can be reduced by 20-40 days. In our country some suitable rice varieties have been refined and released for cultivation in *Aman* season by BRRI. However, some of the newly introduced hybrid rice varieties are BRRI dhan40, BRRI dhan41, BRRI dhan44, BRRI dhan51, BRRI dhan52, BRRI dhan53, BRRI dhan54, BRRI dhan56, BRRI dhan57, BRRI dhan62. So it is prime need to evaluate their comparative performances in *Aman* season. Considering the above facts, the present investigation has been planned to achieve the following objectives.

i) To study the growth, phenophase and yield of different varieties of BRRI released *Aman* rice.
ii) To identify the best one among the studied *Aman* rice varieties.

CHAPTER II

REVIEW OF LITERATURE

Growth and yield potentiality affect by some growth and yield characters. In the following, available literature were reviewed on various parameters relevant to growth and yield such as plant height, effective tillers, leaf area index and total dry matter production etc.

2.1 Effect of variety

Variety itself is the genetical factor which contributes a lot for producing yield and yield components. Different researcher reported the effect of rice varieties on yield contributing component and grain yield. Some available information and literature related to the effect of variety on the yield of rice are discussed below.

2.1.1 Effect on growth characters

A field experiment was conducted by Mahamud *et al.*, (2013) at the experimental field of Sher-e-Bangla agricultural university during July to December 2010 to find out the effect of 1, 2, or 3 seedling(s) per hill on growth, dry matter production and yield performance of a modern inbred (BRRI dhan49) and four hybrid (BRRI hybrid dhan2, Heera, Tia and Aloron) transplant *Aman* rice varieties. They reported that rice cultivars significantly varied in growth characters, such as plant height, tillers number, chlorophyll content and dry matter weight of different plant parts, panicle length, filled grain, unfilled grain, filled grain percentage, 1000-grain weight, grain yield and straw yield.

2.1.1.1 Plant height

Om *et al.*,(1998) in an experiment with hybrid rice cultivars ORI 161 and PMS 2A x IR 31802 found taller plants, more productive tillers, in ORI 161 than in PMS 2A x IR 31802.

BINA (1993) evaluated the performance of four rice varieties- IRATOM 24, BR14, BINA13 and BINA19. It was found that varieties differed significantly in respect of plant height.

BRRI (1991) conducted that plant height differed significantly among BR3, BR11, BR14, *Paijam* and *Zagali* varieties in *Boro*season.

Hossain and Alam (1991) found that the plant height in modern rice varieties in*Boro*season BR3, BR11, BR14 and pajam were 90.4, 94.5, 81.3 and 100.7 cm respectively.

Miah *et al.*, (1990) conducted an experiment where rice cv. *Nizersail* and mutant lines *Mut. NSI* and Mut. NSS were planted and found that plant height were greater in *Mut. NSI* than *Nizersail.*

Shamsuddin*et al*., (1988)conducted a field trial with nine different rice varieties and observed that plant height differed significantly among varieties.

Sawant*et al.*,(1986) conducted an experiment with the new rice lines R73-1-1, R-711 and the traditional cv. *Ratna* and reported that the traditional cv. *Ratna* was the shortest.

2.1.1.2 Tillering pattern

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.

Islam (1995) in an experiment with four rice cultivars *viz.* BR10, BR11, BR22 and BR23 found that the highest number of non-bearing tillers hill^{-1} was produced by cultivar BR11 and the lowest number was produced by the cultivar BR10.

Hossain and Alam (1991) also found that the growth characters like total tillers hill^{-1} differed significantly among BR3, BR11, Pajam and Jaguli varieties in *Boro* season.

Idris and Matin (1990) stated that number of total tillers hill^{-1} was identical among the six varieties studied.

2.1.1.3 Leaf area index

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.

Roy (1999) reported that in *Nizersail*, leaf area index peaked around panicle initiation stage and in BRRI Dhan 31, although maximum leaf area index was attained at or just before heading stage, the increase of leaf area index from panicle initiation stage to heading stage was only small.

2.1.1.4 Totaldry matter production

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, Bansfulchikon*) 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.

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.

2.1.2 Effect on yield contributing characters

Sarkar *et al.,* (2016) conducted a field experiment at the experimental farm, Sher-e-Bangla Agricultural University, Bangladesh during the period from April to November 2013 along with five hybrid varieties (Aloron, BRRI hybrid dhan 2, Shakti 2, Suborna 8 and Tia) and one inbred check variety (BRRI dhan 33) to investigate the comparative performance of five selected hybrid rice varieties in *Aman* Season. They found that the hybrid varieties showed higher yield attributes *viz*. effective tillers $hill^{-1}$, 1000-grain weight, biological yield and harvest index (HI) over the inbred. The highest grain yield was achieved

from Tia (7.82 t ha^{-1}), which was closely followed by Shakti 2 (7.65 t ha^{-1}). These two hybrid varieties produced 24.0% higher yield over the inbred BRRI dhan33. Effective tillers $hill^{-1}$ and higher filled grains $panicle^{-1}$ mainly contributed to the higher grain yield of hybrid varieties.

2.1.2.1 Effective tillers $hill^{-1}$

Devaraju *et al.,* (1998) also reported that the increased yield of KRH2 was mainly attributed due to the higher number of productive tillers $plant^{-1}$.

Chowdhury*et al*., (1993) reported that the cultivar BR23 showed superior performance over *Pajam* in respect of yield and yield contributing characters i.e. number of productive tillers $hill^{-1}$.

2.1.2.2 Panicle length and 1000-grain weight

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

Guilani *et al.,* (2003) studied on crop yield and yield components of rice cultivars (Anboori, Champa and LD183) in Khuzestan, Iran, during 1997. Grain number $panicle^{-1}$ was not significantly different among cultivars. The highest grain number $panicle^{-1}$ was obtained with Anboori. Grain fertility percentages were different among cultivars. Among cultivars, LD183 had the highest grain weight.

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

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

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

BRRI (1991) also reported that the filled grains penicle^{-1} of different modern varieties were 95-100 in BR3, 125 in BR4, 120-130 in BR22 and 110-120 in BR23 when they were cultivated in transplant *Aman* season.

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

Singh and Gangwer (1989) conducted an experiment with rice cultivars C14-8, CR-1009, IET-5656 and IET-6314 and reported that grain number panicle^{-1}, 1000 grain weight were higher for C-14-8 than those of any other three varieties.

Rafey *et al*., (1989) carried out an experiment with three different rice cultivars and reported that weight of 1000 grains differed among the cultivars studied.

Shamsuddin *et al.,* (1988) also observed that panicle number hill^{-1} and 1000-grain weight differed significantly among the varieties.

Kamal *et al.,* (1988) evaluated BR3, IR20, and Pajam2 and found that number of grain panicle^{-1} were 107.6, 123.0 and 170.9 respectively, for the varieties.

Costa and Hoque (1986) studied during kharif-II season, 1985 at Tangail FSR site, Palima, Bangladesh with five different varieties of T. *Aman* BR4, BR10, BR11, *Nizersail* and *Indrasail*. Significant differences were observed in panicle length and number of unfilled grains panicle^{-1} among the tested varieties.

BRRI (1979) reported that weight of 1000 grains of *Haloi, Tilocha-Chari, Nizersail* and *Latisail* were 26.5, 27.7, 19.6 and 25.0 g respectively.

2.1.3 Effect on grain yield and straw yield

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

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

Patel (2000) studied 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.

Julfiquar *et al*., (1998) reported that BRRI evaluated 23 hybrids along with three standard checks during B*oro* 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.

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

Rajendra *et al.,* (1998) carried out an experiment with hybrid rice cv. Pusa 834 and Pusa HR3 and observed that mean grain yields of Pusa 834 and Pusa HR3 were 3.3t ha^{-1} and 5.6 tha^{-1}, respectively.

BRRI (1997) reported that three modern upland rice varieties namely, BR 20, BR 21, BR 24 was suitable for high rainfall belts of Bangladesh. Under proper management, the grain yield was 3.5 ton for BR20, 3.0 ton for BR21 and 3.5 ton for BR24 ha^{-1}.

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

BRRI (*Nizersail* produced yields of 4.38, 3.18, 3.12, 3.12 and 2.70t ha^{-1}, respectively.

Chowdhury (1995) conducted an experiment to find out varietal performances of BR4, BR10, BR11, BR22, BR23 and BR25 varieties including to local checks Challish and *et al.*,(1995) studied on seven varieties of rice, of which three were native (*Maloti, Nizersail* and *Chandrashail*) and four were improved (BR3, BR11, *Pasam* and *Mala*). Straw and grain yields were recorded and found that both the grain and straw yields were higher in the improved than the native varieties. Liu (1995) conducted a field trial with new indica hybrid rice II-You 92 and found an average yield of 7.5 t ha^{-1} which was 10% higher than that of standard hybrid Shanyou 64.

In field experiments at Gazipur in 1989-1990 rice cv. BR11 (weakly photosensitive), BR22, BR23 and Nizersail (strongly photosensitive) were sown at various intervals from July to Sept. and transplanted from Aug. to Oct. Among the cv. BR22 gave the highest grain yield from most of the sowing dates in both years (Ali *et al.,* 1993).

Chowdhury *et al.,* (1993) also reported that the cultivar BR23 showed superior performance over *Pajam* in respect of yield and yield contributing characters i.e., grain yield and straw yield.

Suprithatno and Sutaryo (1992) conducted an experiment with seven IRRI hybrids and 13 Indonesian hybrids using 1R64 and weigh-seputih. They observed that TR64 was highest yielding, significantly out yielding IR64616H, IR64618, IR64610H and IR62829A/IR54 which in turn out yielded way-seputih.

Chandra *et al.,* (1992) reported that hybrid IR58025A out yielded the IR62829A hybrids and the three control varieties Jaya, IR36 and hybrids IR58025A x 9761-191R and IR58025A IR58025Ax 1R35366-62-1-2-2-3R.

Hossain and Alam (1991) also studied farmers production technology in haor area and found that the grain yield of modern varieties of *Boro* rice were 2.12, 2.18, 3.17, 2.27 and 3.05 t ha^{-1}, with BR14, BR11, BR9, IR8 and BR3, respectively.

In evaluation of performance of four HYV and local varieties-BR4, BR16, *Rajasail* and *Kajalsail* in *Aman* season, BR4 and BR16 were found to produce more grain yield among four varieties (BRRI, 1985).

BRRI (1979) also reported that Haloi gave the highest yield (2.64 t ha^{-1}) which was not different from *Nizersail* (2.64 t ha^{-1}) and *Latisail* (2.74 t ha^{-1}).

2.1.4 Effect of spacing

Paul and Samad (2013***)*** conducted a field experiment at Agronomy Field Laboratory, Bangladesh Agricultural University during July to December 2011 to evaluate the effect of spacing on the performance of four rice cultivars in *Aman* season. They found that he highest plant height (118.79cm), number of total tillers $hill^{-1}$ (16.04), number of effective tillers $hill^{-1}$ (13.19), number of grains $panicle_{-1}$ (144.48), grain yield (5.04 t ha^{-1}), straw yield (6.29 t ha^{-1}) and biological yield (11.33 t ha-1) were recorded from BRRI dhan52 while the lowest number of total tillers $hill^{-1}$ (13.08), number of effective tillers $hill^{-1}$(9.29), number of grains $panicle^{-1}$ (127.46), grain yield (4.22 t ha^{-1}), straw yield (5.65 t ha^{-1}) and biological yield (9.88 t ha^{-1}) were recorded from BRRI dhan41.

An experiment was conducted by Tyeb *et al.,* (2013) at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensinghduring July to December 2011 to evaluate the effect of spacing on the performance of four rice cultivars in *Aman* season. They found that the highest plant height (118.79 cm), number of total tillers hill-1 (16.04), number of effective tillers $hill^{-1}$ (13.19), number of grains $panicle^{-1}$ (144.48), grain yield (5.04 t ha^{-1}), straw yield (6.29 t ha^{-1}) and biological yield (11.33 t ha^{-1}) were recorded from BRRI dhan52; while the lowest number of total tillers hill-1 (13.08), number of effective tillers $hill^{-1}$(9.29), number of grains $panicle^{-1}$ (127.46), grain yield (4.22 t ha^{-1}), straw yield (5.65 t ha^{-1}) and biological yield (9.88 t ha^{-1}) were recorded from BRRI dhan41.

2.1.5.Effect of date of harvesting

Jewel *et al*., (2016) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, during the period from February to July 2015.Along with BINA dhan 14 and BRRI dhan51 to know the effect of variety and date of harvesting on yield performance of *Boro* rice. They mentioned that the variety BRRI dhan58 was found significantly superior to Binadhan-14, BRRI dhan28 and Hera hybrid2 in respect of effective tillers, grains panicle^{-1}, grain yield, biological yield and harvest index. Among three harvesting times, the highest grain yield (4.39 tha^{-1}) and straw yield (5.50 t ha^{-1}) were obtained when the crop was harvested at 27 days after flowering.

CHAPTER III

MATERIALS AND METHODS

This chapter describes materials and methods of the experiment steered in the field. The field experiment was conducted at the in the experimental farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during *Aman* season (June to December), to investigate the comparative morphological, phenological and yield traits of some *Aman* rice varieties. The materials used and methods followed in the experiment are presented under the following section.

3.1 Description of the experimental site

3.1.1 Location and site

The experiment was set up at the in the experimental farm, Sher-e-Bangla Agricultural University, Bangladesh during the period, during the Aman season, 2017. The location of the experimental site is 23 074/N latitude and 90035/E longitude and an elevation of 8.2 m from sea level. The land of the experimental site was a medium high land belonging to the Agro-ecological zone (AEZ-28) named Madhupur Tract (Appendix-I).

3.1.2 Soil

The soil of the experimental area belongs to the Madhupur Tract under AEZ No. 28 and was dark grey terrace soil. The selected plot was mediumhigh land and the soil series was Tejgaon. The characteristics of the soil under the experimental plot were analyzed in the Soil Testing Laboratory, SRDI, Khamarbari, Dhaka (Appendix-II).

3.1.3 Climate and weather

The research work was conducted during *Aman* season (June to December) which is also known as Kharif-2 season. The experimental area possesses subtropical climatic condition (Appendix-III).

3.2 Experimental treatments

The study consisted of the single factor with three replications.

Factor-A: Variety

V_1= BRRI dhan40
V_2= BRRI dhan41
V_3= BRRI dhan44
V_4= BRRI dhan51
V_5= BRRI dhan52
V_6= BRRI dhan53
V_7= BRRI dhan54
V_8= BRRI dhan56
V_9= BRRI dhan57
V_{10}= BRRI dhan62

3.3 Test crop

Table1. Characteristics of existing Aman rice varieties used in the present research

Varieties	Releasing year	Plant height (cm)	Life span (days)	Grain size	Grain yield (t ha^{-1})	Major traits
BRRI 40	2003	115	145	Light thick	4.5	Medium salt tolerant
BRRI 41	2003	115	148	thick	4.0-4.5	Medium salt tolerant
BRRI 44	2005	128	145	thick	6.5	Good response in flood condition
BRRI 51	2010	90	143	thin	4.5-5.0	Flood tolerant
BRRI 52	2010	116		thin	4.5-5.0	Flood tolerant
BRRI 53	2010	106	125	Light thin	5.0	Medium salt tolerant
BRRI 54	2010	115	135	Medium	5.5	Medium salt tolerant
BRRI 56	2011	115	107	thick	4.5-5.0	Drought tolerant
BRRI 57	2011	113	102	thin	4.0-4.5	Medium drought tolerant
BRRI 62	2013	98	100	thin	3.5-4.0	Medium drought tolerant and contains zinc

3.4 Fertilization

Recommended doses of other inorganic fertilizers of Urea, TSP, Mop, and Gypsum were applied at the rate of 150,120, 100 and 110 kg ha^{-1}, respectively.

3.5 Experimental design and layout

The experiment was laid out in a randomized complete block design where three replications and ten varieties were used. Each of the replication represented a block in the experiment. Each block was divided into ten unit plots that were allocated at random. Therefore, the total number of plots of this experiment was 30. The size of unit plot was 3.0 m × 2.0 m. The distance between and were 50 cm and 25 cm, respectively.

3.6 Procedure of the Experiment

3.6.1 Raising of seedlings

3.6.1.1 Seed collection

The seeds of ten rice varieties were collected from Bangladesh Rice Research Institute (BRRI), Joydevpur, Gazipur.

3.6.1.2 Seed sprouting

Healthy seeds were selected by specific gravity method. Seeds were then immersed in water in a bucket for 24 hours. Then seeds were taken out of water and kept thickly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours of steeping.

3.6.1.3 Preparation of seedling nursery and seed sowing

A piece of high land was selected at the experimental farm, Sher-e-Bangla Agricultural University, Bangladesh, for raising seedlings. The land was puddled with country plough, cleaned and leveled with ladder. Then the sprouted seeds were sown in the nursery beds on 25 June, 2016. Weeds were removed and irrigation was provided in the seedling nursery as and when necessary.

3.6.2 Preparation of experimental land

The experimental land was first opened with a tractor drawn disc plough. The land was then puddled thoroughly by repeated ploughing and cross ploughing with a country plough and subsequently leveled by laddering. The field layout

was made on 13 July, 2017 according to experimental specification immediately after final land preparation. Weeds and stubble were cleared off from individual plots and finally plots were leveled so properly by wooden plank that no water pocket could remain in the puddled field.

3.6.3 Application of fertilizers and manures

The land was fertilized as per treatment specifications. Well decomposed cow dung was applied on 16 July, 2016, 10 days before transplanting. Full dose of TSP, MP, gypsum and zinc sulphate were applied one day before transplanting where zinc sulphate was the main treatment. Nitrogen from urea was applied per treatments in three equal splits. The first split of urea was applied as top dressing after 20 days of transplanting. The second split of urea was applied after 35 days of transplanting and the third split of urea was applied after 55 days of transplanting. The nutrient supplied to the crop and their sources along with their rates have been presented in treatments in 3.5 (Experimental treatments).

3.6.4 The uprooting of seedlings

The nursery beds were made wet by application of water one day ahead of uprooting the seedlings. Thirty days old seedlings were uprooted carefully without causing any mechanical injury to the root.

3.6.5 Planting technique

3.6.5.1 Transplanting

Thirty day old seedlings were transplanted on 25th July, 2017 in the well puddled plot. Three seedlings were transplanted in each hill with a spacing of 25 cm × 15 cm.

3.6.6 Intercultural operations

The following intercultural operations were done for ensuring and maintaining normal growth of the crop.

3.6.6.1 Gap filling

Seedlings in some hills died off and these were replaced by gap filling after one week of transplanting with seedlings from the same source.

3.6.6.2 Weeding

Weed infestation appeared to be a severe problem during the early stage of crop establishment. The plots were kept weed free up to 15, 30 and 50 days after transplanting of the seedling by hand pulling

3.6.6.3 Irrigation and drainage

Experimental field was given flood irrigation to maintain a constant level of standing water up to 6-8 cm in early stage to enhance tillering and 10-12 cm at later stage to discourage late tillering. The field was finally drained out before 15 days of harvest to enhance maturity.

3.6.6.4 Bund repairing

The bunds around the individual plots were repaired as and when necessary so that water along with nutrient elements did not move between plots.

3.6.6.5 Plant protection measure

No remarkable infestation of insect and disease organisms was noticed in the field. So, no plant protection measure was taken.

3.6.7 Harvesting and post-harvest process

The crop was harvested at maturity on 30th November, 2016. Five hills were randomly selected for measuring plant height and tiller production and to record data on yield contributing characters. The harvested crops of each plot was separately bundled, properly tagged and then brought to threshing floor. Threshing of grains was done by manually. The grains were cleaned and sun dried to moisture content of 14 %. Straws were also dried properly. After sun dried, grain and straw yields plot^{-1} were recorded and converted to t ha^{-1}.

3.7 Collection of plant sample

Five hills were randomly selected from each plot at maturity to record the yield contributing characters. Grain and straw samples were kept for chemical analysis.

3.8 Data recorded

The following parameters were recorded at various stages:

A. Growth parameters

i) Plant height
ii) Flag leaf length
iii) Flag leaf breath
iv) Flag leaf area
v) Penultimate leaf length
vi) Penultimate leaf breath
vii) Penultimate leaf area
viii) Number of total tillers hill^{-1}
ix) Productive tillers hill^{-1}
x) Non-productive tillers hill^{-1}
xi) Panicle length

B. Phenological parameters

xii) Days to panicle initiation (PI)
xiii) Days to booting stage
xiv) Days to emergence
xv) Days to milking stage
xvi) Days to dough stage
xvii) Days to Maturity

C. Yield parameters

xviii) Grains panicle^{-1}
xix) Fertile grains panicle^{-1}
xx) Sterile grains panicle^{-1}
xxi) Weight of 1000 grains
xxii) Grain yield
xxiii) Straw yield
xxiv) Biological yield
xxv) Harvest index

3.9 Data collection

3.10 Phenological data

3.10.1 Panicle Initiation (PI) –

Panicle initiation is determined when the panicle premordia initiate the production of a panicle in the uppermost node of the culm. At this point, the panicle is not visible to the naked eye.

3.10.2 Booting stage–

This stage isdetermined as that period characterized by a swelling of the flag leaf sheath which is caused by an increase in the size of the panicle as it grows up the leaf sheath. Full or late boot occurs when the flag leaf has completely extended.

3.10.3 Heading stage–

This is the time when the panicle begins to exsert from the boot. Heading may take over 10 to 14 days due to variations within tillers on the same plant and between plants in the field.

3.10.4 Anthesis or Flowering stage

The flowering stage begins with the emergence of the first anthers from the 'uppermost spikelets on each panicle.

3.10.5 The Milk stage

The endosperm first begins to form as a milky liquid. Rice at the milk stage is very susceptible to attack by sucking insect pests.

3.10.6 The Dough Stage

The milky liquid begins to solidify into a sticky white pas tot Bird pests generally begin to be a serious problem.

3.10.7 The Maturity stage

The grain is mature, or ripe, when the endosperm becomes hard and opaque. While the grains ripen, the leaves of the plant begin to turn yellow as nitrogen is transferred from the leaves to the seed. The full maturity stage is reached when more than 90% of the grains in the panicles have ripened.

3.11 Morphological and yield contributing data

3.11.1 Plant height

Plant height (selected five plants) was measured from the ground level to the tip of the longest panicle. Plants of five hills were measured and averaged for each plot.

3.11.2 Flag leaf length

Flag leave length was measured from panicle. Flag leaves of five plants were measured and observed for each plot.

3.11.3 Flag leaf breadth

Flag leave breadth was measured from panicle. Flag leaves of five plants were measured and observed for each plot.

3.11.4 Flag leaf area

Flag leave area was measured by multiplying flag leaf length and flag leaf breath.

3.11.5 Penultimate leaf length

Penultimate leaf length was measured from below the flag leaf. Penultimate leaf length of five plants were measured and observed for each plot.

3.11.6 Penultimate leaf breadth

Penultimate leaf breath was measured from below the flag leaf. Penultimate leaf breath of five plants were measured and observed for each plot.

3.11.7 Penultimate leaf area

Penultimate leaf area was measured by multiplying penultimate leaf length and penultimate leaf breath.

3.11.8 Number of total tillers hill^{-1}

Tillers which had at least one leaf visible were counted. It included both productive and non-bearing tillers. Five hills were taken at random and total numbers of tillers was calculated.

3.11.9 Number of productive tillers hill^{-1}

Tillers having panicles which had contain at least one grain were considered as productive tillers.

3.11.10 Number of non-productive tillers hill^{-1}

The tillers which had no panicle were regarded as non-productive tillers.

3.11.11 Panicle length

Panicle length was measured from three plants and panicle length of 3 hills were observed for each plot.

3.11.12 Number of grains panicle^{-1}

Presence of any food material in the spikelet was considered as grain and total number of grains present on each panicle was counted.

3.11.13 Number of fertile grains panicle^{-1}

Number of fertile grain of each panicle was counted from each panicle.

3.11.14 Number of sterile grains panicle^{-1}

Number of sterile grain of each panicle was counted from each panicle

3.11.15 1000-grains weight

One thousand grains were randomly selected from sample of each plot and were adjusted at moisture content 14 % and weighed by an electrical balance separately.

3.11.16 Grain yield

Grains were threshed from the plants, cleaned, dried and then weighed carefully. Dry weight of grains of each plot was converted into grain yield (t ha^{-1}).

Final grain weight was adjusted to 14 % moisture content by using the following formula:

$$\text{Moisture (\%)} = \frac{\text{Fresh weight} - \text{Oven dry weight}}{\text{Fresh weight}} \times 100$$

3.11.17 Straw yield

After the separation of grain from rice plant, the straw were collected from each plot were dried and weighted carefully. Finally Straw yield was converted into t ha^{-1}.

3.11.18 Biological yield

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

Biological yield (t ha^{-1}) = Grain yield (t ha^{-1}) + Straw yield (t ha^{-1}).

3.11.19 Harvest index (%)

Harvest index was calculated on the basis of adjusted grain and straw yields. Harvest index (%) was calculated with the following formula:

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

3.12 Statistical analysis

Data were compiled and tabulated in proper form for statistical analysis. The recorded data on various plant characters were statistically analyzed to find out the significance of variation resulting from the experimental treatments. All the collected data were analyzed following the analysis of variance (ANOVA) technique and mean differences were adjudged by LSD Test (Gomez and Gomez, 1984) using a computer operated program namely, MSTAT-C.

CHAPTER IV

RESULTS AND DISCUSSION

This chapter contains results of the experiment and the follow up discussion. Results obtained from the present study regarding growth, yield and phenological responses of ten elite *Aman* rice varieties have been presented and discussed below:

4.1 Plant height

The plant height at the different stages varied significantly due to rice varieties (Table 2). The tallest plant height (123.00 cm) was obtained from BRRI dhan44 while the smallest plant height (76.25 cm) was obtained in BRRI dhan62 at harvesting stage among all varieties. Similar traits were found in all growth stages. Variation in plant height might be due to the differences of genetic makeup. Sarker *et al.* (2016) observed variation in plant height due to varietal differences. Similar results were reported by Om *et al.* (1998**),** Shamsuddin *et al*. (1988) and Kabir *et al.* (2004)

4.2 Tillers hill^{-1}

From Table 2, it was evident that the number of total tillers hill^{-1} was significantly influenced by the rice varieties. The maximum number of tillers hill^{-1} (21.1) was obtained from BRRI dhan44 while BRRI dhan62 produced the minimum (10.5) among all varieties at 95 DAT. BRRI dhan51, BRRI dhan52, BRRI dhan53 and BRRI dhan54 produced the medium tillers per hill^{-1} in all growth stages.This confirms the report of Sawnat *et al.,* (1986), who reported that variable effect variety on the number of effective tillers hill^{-1}. The same result was reported by Schnier *et al.,* (1990). With the decrease of tillers hill^{-1}, yield also decease considerably (Hoque, 2004).

Table 2. Effect of different varieties on plant height and total tillers per hill in *Aman* rice

Varieties	Plant height (cm)			Total tillers hill^{-1}		
	57 DAT	85 DAT	Harvesting	35 DAT	65 DAT	95 DAT
BRRI dhan40	66.21bc	77.33b	90.45bc	7.1b	10.0b	13.1bc
BRRI dhan41	72.32abc	83.33ab	94.57bc	7.9b	11.0ab	14.3bc
BRRI dhan44	86.70a	98.00a	123.00a	12.1a	15.0a	21.1a
BRRI dhan51	63.00bc	74.50b	82.50bc	10.0ab	12.4ab	16.0abc
BRRI dhan52	69.74ab	81.00b	96.75b	10.0ab	12.1ab	15.0abc
BRRI dhan53	71.67abc	83.33ab	90.81bc	9.1ab	12.5ab	16.0abc
BRRI dhan54	80.67ab	87.76ab	92.56bc	10.0ab	13.0ab	17.0ab
BRRI dhan56	74.45abc	81.70b	88.21bc	8.2b	10.0b	11.5bc
BRRI dhan57	71.63abc	78.13b	94.52bc	8.1b	10.0b	13.0bc
BRRI dhan62	60.00c	72.50c	76.25c	7.5b	9.2b	10.5c
LSD	17.66*	14.47**	16.55**	3.32**	3.71**	5.95**
CV (%)	10.53	10.36	7.61	16.28	18.97	17.33

The values with same letters(s) in a column are not significantly different as per LSD test

4.3 Penultimate leaf length

Table showed that penultimate leaf length significantly influenced by the rice genotypes (Table 3). The smallest (34.78 cm) and longest (52.73 cm) penultimate leaf length were reported from BRRI dhan56 and BRRI dhan44, respectively among all rice genotypes. BRRI dhan56 showed statistically identical penultimate leaf length with BRRI dhan62.

4.4 Penultimate leaf breadth

Rice variety significantly influenced the penultimate leaf breath (Table 3). Effect of different rice genotypes on penultimate leaf breath ranged from 0.97 to 1.93 cm. BRRI dhan44 produced the longest penultimate leaf breath(1.93 cm) that was statistically significant similar with BRRI dhan51 and superior to other varieties and the smallest (0.97 cm) from the BRRI dhan62.

4.5 Penultimate leaf area

Experimental result showed that penultimate leaf area significantly influenced by different rice varieties (Table 3). The maximum penultimate leaf area (93.83 cm^2) was obtained from BRRI dhan44 which is statistically significant over all other genotypes. The minimum penultimate leaf area (33.47 cm^2) was obtained from BRRI dhan62 which is statistically par with BRRI dhan56 and BRRI dhan57.

Table 3. Effect of varieties on morphological parameters and panicle length of *Aman* rice

Varieties	Penultimate leaf length (cm)	Penultimate leaf breath (cm)	Penultimate leaf area (cm^2)
BRRI dhan40	43.30bcd	1.51bcd	81.20b
BRRI dhan41	47.60abc	1.78abc	83.23ab
BRRI dhan44	52.73a	1.93a	93.83a
BRRI dhan51	45.2bcd	1.81ab	79.37b
BRRI dhan52	41.43cde	1.42cd	64.43c
BRRI dhan53	45.15bcd	1.51bcd	80.59b
BRRI dhan54	50.10ab	1.45bcd	88.36ab
BRRI dhan56	34.78e	1.25de	37.31d
BRRI dhan57	38.43de	1.06e	34.33d
BRRI dhan62	35.78e	0.97e	33.47d
LSD	6.48**	0.36**	11.26**
CV(%)	6.35	9.92	7.09

The values with same letters(s) in a column are not significantly different as per LSD test

4.6 Flag leaf length

The flag leaf length was significantly influenced by the rice varieties (Table 4). BRRI dhan44 and BRRI dhan62 produced the longest (43.08 cm) and smallest (25.50 cm) flag leaf length among all rice genotypes. BRRI dhan40, BRRI dhan40, BRRI dhan41, BRRI dhan51 and BRRI dhan52 produced the statistically similar flag leaf length among all genotypes.

4.7 Flag leaf breadth

The flag leaf breath progressively varied due to different varieties of rice (Table 4). The longest flag leaf breath (2.10 cm) was recorded in BRRI dhan44 which is statistically identical with BRRI dhan56 whereas the smallest (1.41cm) was recorded from BRRI dhan62 that also statistically identical with BRRI dhan57 among all rice varieties.

4.8 Flag leaf area

Different rice genotypes significantly influenced the flag leaf area (Table 4). In present investigation, among all varieties, BRRI dhan44 produced the highest

flag leaf area (85.33 cm^2) that is statistical identical with BRRI dhan54 and the lowest (37.89 cm^2) was observed in BRRI dhan62. The medium flag leaf area were produced by BRRI dhan40, BRRI dhan41, BRRI dhan51, BRRI dhan52 and BRRI dhan53.The result is also supported by the result of Chandra and Das (2007) in rice. The result indicated that hybrid rice varieties produced the higher leaf area than the check variety and the variation in leaf area.

4.9 Panicle length

The effect of rice genotypes on panicle length was significant (Table 4). BRRI dhan44 produced the longest panicle (32.29 cm) which is statistically similar with BRRI dhan51 and BRRI dhan54 while the smallest (20.23 cm) was found in BRRI dhan62 among all of the varieties. The variation might be due to the genetic background of variety. These results are in agreement with the findings of Mahamud *et al.,* (2013) who reported that panicle length was differed due to variety. Higher yield in rice can be achieved from panicle length as mentioned by Salam *et al.,* (1990), Ahmed *et al.,* (1997) and Idris and Matin (1990).

Table 4. Effect of different varieties on morphological parameters of *Aman* rice

Varieties	Flag leaf length (cm)	Flag leaf breath (cm)	Flag leaf area (cm^2)	Panicle length (cm)
BRRI dhan40	29.17bcd	1.71bcd	63.47abc	27.31ab
BRRI dhan41	31.17bcd	1.80b	69.55abc	29.08ab
BRRI dhan44	43.08a	2.10a	85.33a	32.29a
BRRI dhan51	32.27bcd	1.79bcd	65.47abc	30.25a
BRRI dhan52	28.23bcd	1.59cde	63.36abc	28.18ab
BRRI dhan53	35.00b	1.85bc	64.33abc	26.80abc
BRRI dhan54	34.18bc	1.74bcd	74.86ab	31.15a
BRRI dhan56	27.17cd	1.89ab	54.11bcd	21.21cd
BRRI dhan57	33.27bc	1.51de	47.20cd	23.25bc
BRRI dhan62	25.50d	1.41e	37.89d	20.31d
LSD	6.26**	0.23**	20.07**	5.68**
CV(%)	8.36	6.18	13.66	8.95

The values with same letters(s) in a column are not significantly different as per LSD test

4.10 Days of panicle initiation

Days of panicle initiation (PI) significantly affected due to variety to variety. BRRI dhan44 takes the minimum time (70 days) for the panicle initiation while the maximum time (91 days) requires for panicle initiation in BRRI dhan51 (Table 5a).

4.11 Booting stage

The booting stage of rice significantly influenced due to varietal effect (Table 5a). The highest time (104 days) require for the booting of rice plant in BRRI dhan54 while the shortest time (80 days) was recorded in BRRI dhan44 among all rice varieties.

4.12 Panicle emergence

The emergence of panicle in rice progressively influenced by *Aman* rice genotypes (Table 5a). BRRI dhan44 and BRRI dhan51 takes the minimum (83 days) and maximum time (111 days), respectively for the emergence of panicle among all genotypes.

Table 5a. Differences among *Aman* rice varieties in relation to phenologcal parameters

Variety	PI stage (days)	Booting stage (days)	PEstage (days)
BRRI dhan40	74de	90cde	90e
BRRI dhan41	79cd	88def	98d
BRRI dhan44	70e	80g	83f
BRRI dhan51	91a	103a	111a
BRRI dhan52	83bc	92cd	101c
BRRI dhan53	74de	83fg	87e
BRRI dhan54	92a	104a	107b
BRRI dhan56	88ab	95bc	102c
BRRI dhan57	85abc	99ab	103c
BRRI dhan62	75de	85efg	89e
LSD	6.72**	5.12**	2.94**
CV(%)	3.53	2.38	1.29

The values with same letters(s) in a column are not significantly different as per LSD test.

4.13 Days to 50% flowering

Flowering in rice progressively varied due to varietal effect. The earliest 50% flowering (91 days) was recorded in BRRI dhan44 while the maximum

delaying flowering (115 days) was recorded by BRRI dhan51 among all of the rice genotypes (Table 5b)

4.14 Milky stage

Different variety significantly influenced the milky stage in rice (Table 5b). BRRI dhan44 and BRRI dhan54 produced earlier (100 days) and late milky stage (124 days) among all genotypes.

4.15 Dough stage

In case of dough stage of rice progressively varied by varietal effect (Table 5b). Among all genotypes, BRRI dhan44 and BRRI dhan54 produced earlier (109 days) and late milky stage (132 days).

4.16 Maturity stage

Maturity stage was significantly varied among the studied varieties. BRRI dhan51 and BRRI dhan54 took the maximum days (145) to reach maturity which was statistically at par with BRRI dhan40 (143 days). BRRI dhan44 (121 days) reached the maturity earlier compared to the rest of the varieties.

Table 5b. Differences among *Aman* rice varieties in relation to phenologcal parameters

Variety	50% flowering (days)	Milky stage (days)	Dough stage (days)	Maturity stage (days)
BRRI dhan40	108bc	118b	128ab	143a
BRRI dhan41	101de	108c	119c	132b
BRRI dhan44	91f	100d	109d	121c
BRRI dhan51	115a	123ab	132a	145a
BRRI dhan52	104cd	111c	122c	133b
BRRI dhan53	97e	103d	112d	124c
BRRI dhan54	116a	124a	132a	145a
BRRI dhan56	105	111c	122c	133b
BRRI dhan57	98cd	103d	112c	123c
BRRI dhan62	103 cd	112c	123bc	135b
LSD	4.29*	4.98**	4.88**	6.37**
CV(%)	11.74	8.88	9.75	4.52

The values with same letters(s) in a column are not significantly different as per LSD test.

4.17 Effect on yield and yield attributes of *Aman* rice

These parameters included length of panicle (cm), thousand grain weight (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%).

4.17.1 Number of productive tillers $hill^{-1}$

The productivity of rice plant is greatly dependent on the number of productive tiller (tillers which bears panicle) rather than the total number of tillers (Table 6). Maximum number of effective tillers $hill^{-1}$ (20.0) was recorded in BRRI dhan44. The minimum number of productive tillers $hill^{-1}$ (7.0) was produced in BRRI dhan62. These results are well corroborated with the findings of (Yang *el al.,* 2007; Shrirame and Muley, 2003; Munshi, 2005)

4.17.2 Non-productive tillers $hill^{-1}$

The effect rice varieties on non-productive tillers $hill^{-1}$ was significant (Table 6). Numerically the highest number of non-effective tillers $hill^{-1}$ (6.5) was obtained from BRRI dhan41. The lowest (1.5) number of non- effective tillers $hill^{-1}$ was found in BRRI dhan which was statistically identical to the number of effective tillers $hill^{-1}$ under BRRI dhan56. This result is in line with findings of Sarkar *et al.,* (2016), opined the highest number of effective tillers $hill^{-1}$ with different rice genotypes.

4.17.3 Grains $panicle^{-1}$

Effect of Aman rice varieties on grains $panicle^{-1}$ was statistically significant (Table 6). The result from the Table 7.Showed that the grains $panicle^{-1}$ varied from 63.61 to 131.49. The highest number of grains $panicle^{-1}$ (131.49) was obtained in BRRI dhan44 and the lowest no. of grain $panicle^{-1}$ (63.61) was found in BRRI dhan40. This result is in agreement with the result of Dutta *et al.,* (2002) who observed that yield was affected by the filled grains $panicle^{-1}$.

4.17.4 Fertile grains $panicle^{-1}$

The number of fertile grains $panicle^{-1}$ was significantly increased due to *Aman* rice varieties and it was statistically significant (Table 6). The highest number of fertile grains $panicle^{-1}$ (124.41) was obtained in BRRI dhan44 and lowest

number of fertile grain panicle^{-1} (41.59) was found in BRRI dhan40. Similar trends were reported by Sarkar *et al.*,(2016) in *Aman* rice.

4.17.5 Sterile grains panicle^{-1}

From the Table 6 showed that number of sterile grains panicle^{-1} decreased due to rice genotypes and it was statistically significant. The higher no. of sterile grains (22.01) panicle^{-1} was found in BRRI dhan40 and the lower no. of sterile grains (7.39) panicle^{-1} was found in BRRI dhan44. Sarkar *etal*., (2016) and Chowdhury *et al.*, (1995) reported differences in number of sterile grains panicle^{-1} due to varietal character.

Table 6. Effect of varieties on yield and yield contributing traits of *Aman* rice

Varieties	Productive tillers hill^{-1}	Non-productive tillers hill^{-1}	Grains panicle^{-1}	Fertile grains panicle^{-1}	Sterile grains panicle^{-1}
BRRIdhan 40	9.1 d	4.0b	63.61g	41.59h	22.01 a
BRRI dhan41	8.0 de	6.5a	89.53e	75.63e	13.89 bc
BRRI dhan44	20.0a	1.5e	131.49a	124.11a	7.39 f
BRRI dhan51	14.3b	2.3d	118.17b	109.15b	9.03 ef
BRRI dhan52	11.5c	4.1b	106.14c	96.45d	9.69 def
BRRI dhan53	13.3c	3.2bc	79.80e	64.27e	15.53 b
BRRI dhan54	15.0b	2.0d	108.17c	100.15c	8.03 ef
BRRI dhan56	10.0c	1.5e	74.80f	60.27g	14.53 b
BRRI dhan57	8.5d	5.3ab	92.53d	75.03e	17.50 bc
BRRI dhan62	7.0e	3.2bc	80.32e	72.03e	8.50 bc
LSD	4.97**	2.34**	9.31*.	8.76**	5.61*
CV (%)	7.28	24.34	14.23	66.44	15.07

The values with same letters(s) in a column are not significantly different as per LSD test

4.17.6 1000-grain weight

There was a significant variation for 1000-grains weight after harvest due to different rice genotypes (Table 7). From the obtained result in Table also found that the 1000-grains weight significantly varied from 36 to 18.2 g. The highest 1000-grains weight (36.38) was observed in BRRI dhan54 which statistically similar with BRRI dhan44, BRRI dhan52 and BRRI dhan54 whereas BRRI dhan57 produced the minimum 1000-grains weight (18.2 g) among all varieties.

Mondal *et al.,* (2005) studied with 17 modern cultivars of transplant *Aman* rice and reported that 1000-grain weight differed significantly among the cultivars studied. This result is an agreement with the findings of Islam *et al.,* (2013) who stated that weight of 1000- grain differed due to the varietal differences.

4.17.7 Grain yield

The data depicted that grain yield hill^{-1} increased in all the treatments and grain yield significantly varied due to various varieties (Table 7). The maximum grain yield (6.23 t ha^{-1}) was observed in BRRI dhan44 and BRRI dhan62 produced the minimum grain yield (3.74 t ha^{-1}). This higher yield may be contributed with higher yield at components.

This finding is in conformity with that of Jewel *et al*., (2016) who reported that yield progressively influenced by varietal effect. This result confirms with the finding of Tyeb *et al*., (2013) who reported that grain yield greatly varied due to different genotypes.

4.17.8 Straw yield

A non-significant variation on straw yield was observed due to varietal effect (Table 7). Among all rice genotypes, BRRI dhan53 and BRRI dhan62 produced the maximum and minimum straw yield, respectively.

Table 7. Yield contributing parameters of *Aman* rice as influenced by varieties

Varieties	1000-grain weight (g)	Grain yield (tha^{-1})	Straw yield (tha^{-1})
BRRIdhan40	25bc	3.98de	7.96
BRRIdhan41	31.17ab	4.17cde	8.17
BRRIdhan44	35.00a	6.23a	9.35
BRRIdhan51	21.01c	4.38cde	8.76
BRRIdhan52	33.07a	4.53cd	8.98
BRRIdhan53	22.50c	4.76bc	9.52
BRRIdhan54	36.38a	5.27b	8.96
BRRIdhan56	33.17a	4.32cde	8.64
BRRIdhan57	18.2c	4.06cde	8.12
BRRIdhan62	24.13bc	3.74e	7.48
LSD	7.39**	0.67**	NS
CV(%)	11.28	6.19	12.01

The values with same letters(s) in a column are not significantly different as per LSD test

4.17.9 Biological yield

Experimental analyzed data showed that different varieties positively influenced grain yield and straw yield which ultimately resulted in higher biological yield (Figure1). The highest biological yield (15.58 t ha^{-1}) was obtained from BRRI dhan44 which statistically identical with BRRI dhan53 and BRRI dhan54 and the lowest (11.22 t ha^{-1}) was found in BRRI dhan53. Munshi (2005) and Chowdhury *et al.* (1995) reported that grain yield was positively correlated with biological yield in rice

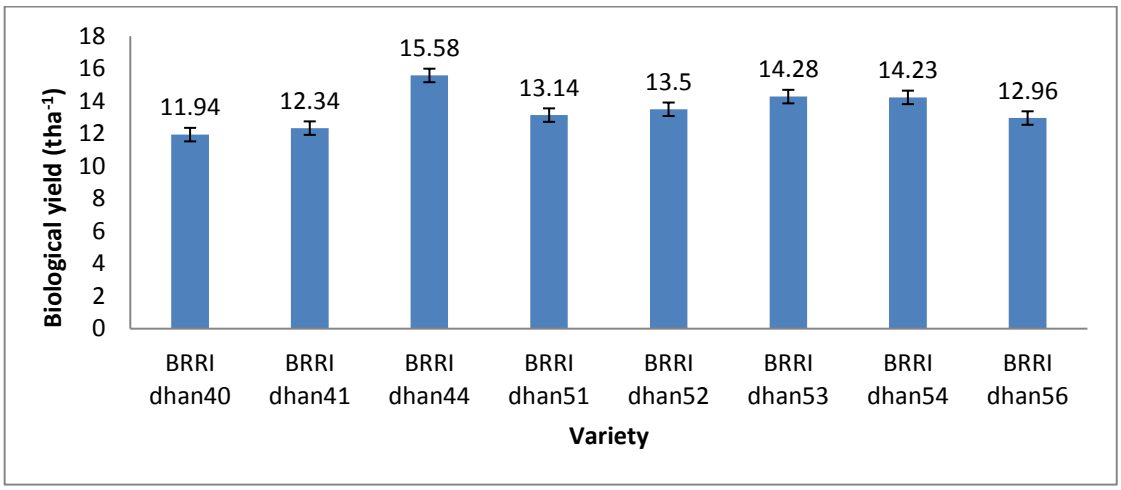

Figure 1. Effect of different varieties on biological yield of*Aman* rice

4.17.10 Harvest index (%)

Analysis of variance data on harvest index (HI) was non-significant due to varietal effect. The highest harvest index (39.89 %) was recorded in BRRI dhan44 and the lowest harvest index (34.39 %) was recorded in BRRI dhan62 (Figure 2).

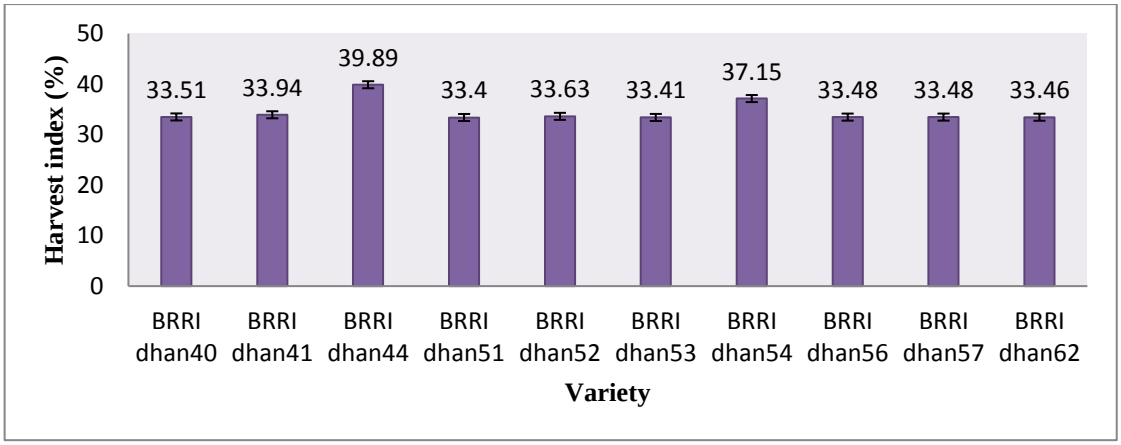

Figure 2. Effect of different varieties on harvest index (%) of *Aman* rice

CHAPTER V
SUMMARY AND CONCLUSION

The present experiment was conducted at the at the Research Farm, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during *Aman* season (June to December) 2017, to investigate the comparative morphological, phonological and yield traits of some Aman rice varieties. The experiment was laid out in Randomized Complete Block Design (RCBD) method with three replications and single factors. Factor A consisted ten elite Aman rice. The size of unit plot was 3.0 m × 2.0 m. The spacing between blocks and plots were 50 cm and 25 cm, respectively. The total number of plots was 30 (treatment combinations: 10 × 3). The recommended doses of urea, TSP, MP and gypsum were 150, 120, 100 and 110 kg ha^{-1}, respectively. The TSP, MP and gypsum were applied to the plots as basal during final land preparation. Urea was applied in three equal splits. Thirty day old seedlings were transplanted in the experimental plot. Intercultural operations like gap filling, weeding, irrigation and drainage were done as and when required to normal crop growth.

The crop was harvested at maturity and five hills were randomly selected for measuring plant height and tiller production and to record data on yield contributing characters. Grain and straw yields were recorded and the grain yield was expressed on 14 % moisture basis while the straw yields on sundry basis. All the data were statistically analyzed by MSTAT-C package program and the mean differences were adjudged by LSD test.

The plant height at the different stages varied significantly due to rice varieties. The tallest plant height (123.00 cm) was obtained from BRRI dhan44 while the smallest plant height (76.25 cm) was obtained in BRRI dhan62 at harvesting stage among all varieties.The number of total tillers $hill^{-1}$ was significantly influenced by the rice varieties. The maximum number of tillers $hill^{-1}$ (21.1) was obtained from BRRI dhan44 while BRRI dhan62 produced the minimum (10.5) among all varieties at 95 DAT. BRRI dhan51, BRRI dhan52, BRRI dhan53 and BRRI dhan54 produced the medium tillers per $hill^{-1}$ in all growth

stages.The smallest (34.78 cm) and longest (52.73 cm) penultimate leaf length were reported from BRRI dhan56 and BRRI dhan44, respectively among all rice genotypes.BRRI dhan44 produced the longest penultimate leaf breath (1.93 cm) that was statistically significant similar with BRRI dhan51 and superior to other varieties and the smallest (0.97 cm) from the BRRI dhan62. The maximum penultimate leaf area (93.83 cm^2) was obtained from BRRI dhan44 which is statistically significant over all other genotypes. The minimum penultimate leaf area (33.47 cm^2) was obtained from BRRI dhan62 which is statistically par with BRRI dhan56 and BRRI dhan57.

BRRI dhan44 and BRRI dhan62 produced the longest (43.08 cm) and smallest (25.50 cm) flag leaf length among all rice genotypes. BRRI dhan40, BRRI dhan40, BRRI dhan41, BRRI dhan51 and BRRI dhan52 produced the statistically similar flag leaf length among all genotypes.The longest flag leaf breath (2.10 cm) was recorded in BRRI dhan44 which is statistically identical with BRRI dhan56 whereas the smallest (1.41cm) was recorded from BRRI dhan62.BRRI dhan44 produced the highest flag leaf area (85.33 cm^2) that is statistical identical with BRRI dhan54 and the lowest (37.89 cm^2) was observed in BRRI dhan62.

BRRI dhan44 takes the minimum time for panicle initiation (70 days), booting stage (80 days), panicle emergence (83 days), 50% flowering (91 days), milky stage (100 days) and dough stage (109 days) among all *Aman* varieties.

Maximum number of effective tillers $hill^{-1}$ (20.0) was recorded in BRRI dhan44. The minimum number of productive tillers $hill^{-1}$ (7.0) was produced in BRRI dhan62.The number of fertile grains $panicle^{-1}$ was significantly increased due to *Aman* rice varieties and it was statistically significant. The highest number of fertile grains $panicle^{-1}$ (124.41) was obtained in BRRI dhan44 and lowest number of fertile grain $panicle^{-1}$(41.59) was found in BRRI dhan40.The highest 1000-grains weight (36.38) was observed in BRRI dhan54 which statistically similar with BRRI dhan44, BRRI dhan52 and BRRI dhan54 whereas BRRI dhan57 produced the minimum 1000-grains weight (18.2 g) among all varieties.

Grain yield significantly varied among the studiedvarieties. The maximum grain yield (6.23 t ha^{-1}) was observed in BRRI dhan44 and BRRI dhan62 produced the minimum grain yield (3.74 t ha^{-1}). This higher yield may be contributed with higher yield at components. different varieties positively influenced grain yield and straw yield which ultimately resulted in higher biological yield. The highest biological yield (15.58 t ha^{-1}) was obtained from BRRI dhan44 which statistically identical with BRRI dhan53 and BRRI dhan54 and the lowest (11.22 t ha^{-1}) was found in BRRI dhan53. The highest harvest index (39.89 %) was recorded in BRRI dhan44 and the lowest harvest index (34.39 %) was recorded in BRRI dhan62

Finally it can be concluded that-

- The studied BRRI released *Aman* rice varieties showed significant differences among themselves and in respect of growth and phenological parameters as well as yield.
- BRRI dhan44 (6.23 t ha^{-1}) provided the highest grain yieldclosely followed by BRRI dhan54 (5.27 t ha^{-1}) and the lowest yield was produced by BRRI dhan62 (3.74 t ha^{-1}).

Recommendation

- ❖ BRRI dhan44 can be preferedmore to cultivate in *Aman* season for obtaining maximum productivity as well as for economic benefits.
- ❖ For wider acceptability, the same experiment should be repeated at differentAgro-ecological zones of the Bangladesh.

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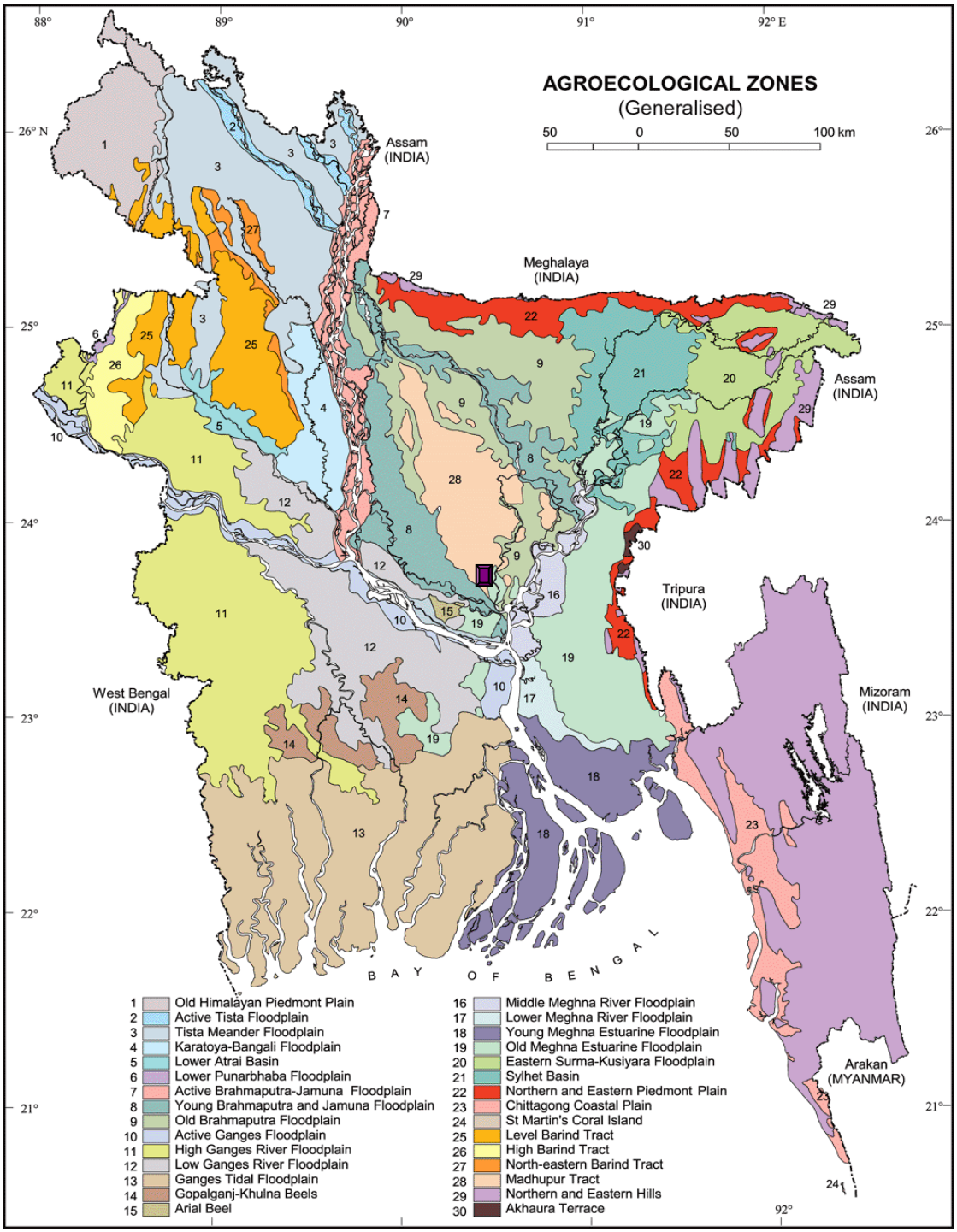
APPENDICES

Appendix I. Experiment was conducted in Sher-e-Bangla Agricultural University, Dhaka (AEZ-28) on the map of Agro-ecological Zones of Bangladesh

Map showing the experimental sites under study



The experimental site under study

Appendix II. Physical and chemical properties of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka

Characteristics	Value
Particle size analysis	
% Sand	26
% Silt	41
% Clay	33
Textural class	Silty-clay
pH	5.7
Organic carbon (%)	0.45
Organic matter (%)	0.72
Total N (%)	0.04
Available P (ppm)	18.00
Exchangeable K (me/100 g soil)	0.12
Available S (ppm)	42

Appendix III. Monthly average air temperature, rainfall and relative humidity of the experimental site during the period from July to November 2017

Months	**Air temperature (°C)**		**Relative humidity (%)**	**Total rainfall (mm)**
	Maximum	**Minimum**		
July, 2017	31.6	25.9	81.5	674.86
August, 2017	32.6	26.9	79.1	352.02
September, 2017	32.6	23.1	67.5	181.06
October, 2017	34.3	24.1	61.3	67.06
November, 2017	32.3	23.1	57.3	56.06

Source: SAU Meteorological Yard,Sher-e-Bangla Nagar, Dhaka-1207.

Appendix IV. Analysis of variance of the data of penultimate leaf in *Aman* rice

Source of variation	Degrees of freedom	Mean square of penultimate leaf		
		length (cm)	breath (cm)	area (cm^2)
Replication	3	0.728	1.018	1.362
Factor B	8	16.389*	14.597*	22.514*
Error	24	1.122	0.607	1.211

Appendix V. Analysis of variance of the data of flag leaf in *Aman* rice

Source of variation	Degrees of freedom	Mean square of flag leaf		
		length (cm)	breath (cm)	area (cm^2)
Replication	3	0.513	0.094	0.495
Factor A	8	1.280**	3.033*	2.151*
Error	24	0.117	0.241	2.267

Appendix VIa. Analysis of variance of the data of phenophase in *Aman* rice

Source of variation	Degrees of freedom	Mean square of phenophase		
		PI stage (days)	Booting stage (days)	PEstage (days)
Replication	2	2.099	0.122	1.087
Factor A	1	18.777*	26.283*	32.624*
Error	30	0.116	1.126	2.544

Appendix VIb. Analysis of variance of the data of phenophase in *Aman* rice

Source of variation	Degrees of freedom	Mean square of phenophase			
		50% flowering (days)	Milky stage (days)	Dough stage (days)	Maturity stage (days)
Replication	3	0.120	0.591	1.051	1.022
Factor A	8	7.770*	9.40**	8.300*	10.684*
Error	24	2.266	10.012	13.107	2.871

** and *significant at 5% and 1% level of probability, respectively

Appendix VII: Analysis of variance of the data on plant height and Number of leaves per hill, Number of tillers hill^{-1}, Panicle length, Grains panicle^{-1}, of rice as influenced by cultivation system and different variety

Sources of Variation	Degrees of freedom	Mean Square				
		Plant height (cm)	Number of leaves hill^{-1}	Number of tillers hill^{-1}	Panicle length (cm)	Grain panicle^{-1}
Replication	3	1455.82	85.41	8.44	12.59	5833.67
Factor A	8	1922.08*	121.37*	3.77*	39.02*	4513.89*
Error	24	542.51	73.57	7.05	7.81	1.29

Appendix VIII: Analysis of variance of the data on yield and yield contributing character of rice as influenced by different variety

Sources of Variation	Degrees of freedom	Mean Square				
		1000-grains weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	3	452.76	15.14	14.02	58.28	661.07
Factor A	8	27.64*	1.66*	4.17*	9.88*	63.29*
Error	24	0.49	0.17	0.27	0.37	20.04

** and *significant at 5% and 1% level of probability, respectively