MS THESIS

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EFFECT OF VARIETY AND ROW SPACING ON THE GROWTH AND YIELD OF AUS RICE

A Thesis

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A Thesis

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF VARIETY AND ROW SPACING ON THE GROWTH AND YIELD OF AUS RICE"** submitted to the **DEPARTMENT OF AGRONOMY,** Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in AGRONOMY,** embodies the results of a piece of bonafide research work carried out by **ABDULLAH AL- MAMUN CHOWDHURY,** Registration No. **08-03253**, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

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

Dated:

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Dedicated

to

My Beloved Parents

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EFFECT OF VARIETIES AND SPACING ON THE GROWTH AND YIELD OF AUS RICE

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ABSTRACT

A field experiment was conducted at the field laboratory of the Department of Agronomy, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, during the period from April to August 2010 to investigate the effect of variety and row spacing on morpho-physiological characters, yield attributes and yield of Aus rice. The experiment comprised four varieties *viz*., BR26, BRRI dhan42, BRRI dhan43 and BRRI dhan48 and four row spacings *viz*. 15, 20, 25 and 30 cm. The plant to plant distance was 15 cm. The experiment was laid out in two factors randomized complete block design with three replications. The morpho-physiological parameters such as plant height, effective and non-effective tiller number hill^{-1}, total tiller number hill^{-1}, total dry mass (TDM) hill^{-1}, absolute growth rate (AGR), relative growth rate (RGR), grain yield, harvest index (HI), and yield attributes were significantly influenced by row spacing in rice. Results revealed that plant height increased with decreasing row spacing while number of effective tillers, non-effective tillers and total tillers plant^{-1}, TDM hill^{-1}, AGR and RGR, filled and unfilled grains hill^{-1} increased with increasing row spacing but in case of unit area basis, the seed and straw yield and HI were greater at closer row spacing than wider row spacing. The higher grain and straw yield per hectare and HI were observed in 15 and 20 cm row spacings compared to 25 to 30 cm spacings with being the highest in 20 cm row spacing (3.42 and 5.68 t ha^{-1} for grain and straw yield, respectively). While the lowest seed and straw yield per hectare was recorded in 30 cm row spacing. Among the varieties, BRRI dhan48 was superior in relation to plant height, TDM hill^{-1}, AGR, RGR, total tiller number hill^{-1} and 1000-grain weight which resulted the highest grain yield hectare^{-1} (3.97 t ha^{-1}. In contrast, the lowest above studied parameters were observed in BRRI dhan42 and resulted the lowest grain yield per hectare (2.58 t ha^{-1}). The interaction effect of variety and row spacing on plant parameters was significant except 1000-grain weight. BRRI Dhan 48 in combination with any of the 4 spacings produced higher grain yield t ha^{-1} than each of the combination made by the rest 3 varieties with the spacings and the highest grain yeild is 4.40 t ha^{-1} was obtained by the variety BRRI Dhan 48 with the spacings 20 cm. BR 26 in the interaction effect performed better than those of BRRI Dhan 42 and BRRI Dhan 43 and the lowest yield 1.90 t ha^{-1} was obtained by BRRI Dhan 42 with 30 cm spacing.

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Chapter 1

Introduction

CHAPTER 1
INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the family Gramineae and is dominant over all other crops in respect of economic and social significance in Bangladesh. It is the most extensively cultivated crop and the staple food of the country. The acreage and production of aus rice in Bangladesh are about 10.54 lac hectares and 26.35 lac metric tons, respectively with an average yield of only 2.54 t ha^{-1} (BBS, 2009). Among the rice producing countries, Bangladesh ranks fourth to China, India and Indonesia both in acreage and production (FAO, 2007).

Rice is the principal food crop of Bangladesh and agro-climatic condition is favourable for its year round cultivation, but the yield of rice is much lower compared to other rice growing countries (FAO, 2007). The reasons for low yield are manifolds: some are varietal; some are climatic and some are agronomic management. The domestic production of this crop cannot entirely meet up the requirement of teeming hungry millions people of the country. Due to the shortage of land, the scope of its extensive cultivation is very limited. Therefore, attempts must be made to increase the yield per unit area by applying improved technology and management practices. The yield of transplant aus rice can be increased with the improved cultivation practices like proper spacing with appropriate cultural practices.

Planting density is one of the main factors that has an important role on growth and yield of field crops. Optimum plant density ensures proper growth of the aerial and underground parts of the plant through efficient utilization of solar radiation, nutrients, land as well as air spaces and water. There are two general concepts to describe the relationship between plant density and grain yield. Firstly, irrespective of plant spacing within and among rows, plant density must be such that the crop develops a canopy able to intercept more than 95% of the incoming solar radiation during reproductive growth and secondly, a nearly equidistant plant arrangement minimizes interplant competition and produces maximum grain yield. Baloch *et al.* (2002) reported that appropriate plant density of a cultivar is necessary for obtaining high yield and quality of rice. The optimum plant density for higher yield may differ from cultivar to cultivar and location to location. Research report on the effect of row spacing on aus rice grain yield is scarce in Bangladesh. Therefore, the present study was undertaken with the following objectives:

i. to study the effect of different row spacing on growth and yield of 4 aus rice varieties;
ii. to find out the suitable row spacing for maximizing grain yield in four aus rice varieties.
iii. to assess the interaction effect of row spacing and variety in aus rice.

Chapter 2

Review of literature

CHAPTER 2

REVIEW OF LITERATURE

Plant row spacing influence growth and yield of rice. Extensive studies have been carried out by the researchers throughout the world on various cultural practices of rice. But the information regarding the row spacing in aus rice is limited. Some of the relevant findings have been reviewed and presented in this chapter.

2.1 Effect of spacing on plant characters in rice

2.1.1 Plant height

Plant spacing has remarkable effect on plant height as reported by many researchers. Ayub *et al.* (1997) carried out an experiment with rice *cv*. Basmati 370 at 6, 11, 25 and 44 hills m^{-2} and found that plant height was unaffected. Similar result was also reported by Miah *et al*. (1990) through conducting an experiment with Nizersail and Mutant NS1 and NS2 at 15, 20, 25 and 30 cm row spacing. On the other hand, Akita and Tanaka (1992) found that spacing had effect on plant height and the tallest plant was observed at 49 hills m^{-2} compared to other spacings. Further, Aktar (2004) reported that in rice *cv*. BRRI dhan39 as plant density increased from 32 plants m^{-2}, the plant height decreased with consequent decrease in seed yield. Wang et al. (2002) reported that in SRI technique, plant height increased with decreasing row spacing of rice. Similar results were also reported in Yan (2002) in rice.

2.1.2 Total dry mass production

Total dry matter (TDM) production varies due to variation in plant density. In general, biological yield increased with increasing plant density in field crops because of increasing LAI (Haloi and Baldev, 1996). Kang *et al.* (2001) conducted an experiment to know the influence of plant density (30, 50, 70 and 90 hills m^{-2}) on TDM production and found that TDM production $plant^{-1}$ decreased with increasing planting density but reverse trend was observed in case of unit area basis in rice. Similar results were also reported by Ibrahim (2006) in rice.

Khan (2007) worked with two rice cultivars and four plant densities of 20, 30, 40 and 50 hills m^{-2} and found that increasing plant density increased DM production per unit area but decreased DM $plant^{-1}$. Bashar (2007) conducted a field trial at BAU, Mymensingh to study the response of rice genotypes to plant densities and found that mean DM increased with increasing plant density up to 20 cm × 15 cm spacing.

2.1.3 Crop growth rate

Abbas *et al.* (1994) studied the effect of plant density (25, 35, and 45 hills m^{-2}) on growth and yield of rice and reported that most of the growth and physiological parameters decreased with increasing plant density, while crop growth rate increased with increasing plant density. Jadhav *et al.* (1994) reported that crop growth rate varied for different plant spacing in rice. The author also reported that CGR increased with increasing plant density. Rahman and Miah (1995) reported from a field experiment that the lowest population density recognized the highest total dry matter $hill^{-1}$ and absolute growth rate while higher population density produced higher dry matter per unit area as well as crop growth rate. However, Ball *et al.* (2000) reported that a low density crop produced lower dry matter per unit area than higher density plant which resulting lower CGR.

2.1.4 Relative growth rate

BINA (2007) stated from a field experiment with three promising mutants lines which were grown at 15 cm × 15 cm, 15 cm × 20 cm, 20 cm × 20 spacings that both TDM plant^{-1} and RGR decreased with increased plant density and increased LAI. Zeyada *et al.* (1990) reported that leaf area plant^{-1} and RGR increased with increasing plant density but seed yield and yield component plant^{-1} decreased with increasing plant density. Bashar (2007) observed that RGR increased with increasing plant population in rice. Similar result was also reported by Khan (2007) in rice. Similarly, Tremblay *et al.* (2002) observed that RGR was greater in densely populated plants than wider populated plants.

2.1.5 Number of total tillers hill^{-1}

Uddin (2003) planted rice *cv*. BRRI dhan39 at 25 cm × 25 cm, 25 cm × 20 cm, 25 cm × 15 cm and 25 cm × 10 cm spacings and reported that the number of tillers hill^{-1} decreased with increasing plant density. Haque and Nasiruddin (1988) conducted an experiment with deep water rice at densities of 50, 100, 150, 200, 225 and 350 seedlings m^{-2} and reported that tiller number decreased with increasing plant density. Muhammad *et al*. (1987) planted rice *cv*. Basmoti 370 with 2 seedlings hill^{-1} and maintained of 6, 11, 25 and 44 hills m^{-2} and reported that the number of total tillers hill^{-1} decreased with increasing plant density. However, most of the researchers reported the similar results by studying the effect of plant density on tiller number hill^{-1} in rice (Azad *et al*., 1995; Aktar, 2004; Alam, 2004; Bari, 2004; Hassan, 2006).

2.1.6 Number of grains panicle^{-1}

Ghosh *et al*. (1991) obtained the highest number of grains panicle^{-1} at a spacing of 30 cm × 30 cm than those of closer spacings of 20 cm × 20 cm and 20 cm × 25 cm. Similarly, Aktar (2004) reported that the number of grains panicle^{-1} decreased with increasing plant density. The increasing planting density generally decreased the number of grains panicle^{-1} as reported by most of researchers (Venkateswarly and Singh, 1980; Murty and Murty, 1981; Akita, 1982; Miah *et al*., 1990; Rao *et al.,* 1990; Zaman *et al.,* 1990; Neelam and Nisha, 2000; Islam, 2003; Uddin, 2003; Alam, 2004; Hassan, 2006).

2.1.7 Weight of 1000-grains

Alam (2004) conducted an experiment with BINA dhan4 at 25 cm × 20 cm, 20 cm × 20 cm, 25 cm × 15 cm and 20 cm × 15 cm spacings and reported that 1000-grain weight was not influenced by spacing. Similar results were reported by Aktar (2004) and Uddin (2003) who reported that plant spacing had no influence on grain size because of grain size is mainly controlled by gene not by environment. On the other hand, Karim *et al*. (1992) found that plant spacing had effect of grain size and reported that 1000-grain weight decreased with increasing plant density in rice. Rao *et al*. (1990) in an experiment with rice to know the effect of spacing on yield and yield related traits and reported that spacing had slight effect of grain size. The 1000-grain weight was greater in wider spacing (20 cm × 20 cm) than in closer spacing 20 cm x 10 cm) but non-significant different with each other.

2.1.8 Straw yield

Plant spacing has remarkable effect on straw yield. BRRI (1999) conducted an experiment with three rice varieties at different Regional Research Stations under different spacings of 10 cm × 10 cm to 30 cm × 30 cm using normal cultural practices and reported that straw yield was varied significantly. Straw yield varied from 4.6 to 6.08 t ha^{-1} in closer spacing with an average of 6.12 t ha^{-1} whereas the yield varied from 4.80 to 8.94 t ha^{-1} in wider spacing with an average of 7.76 t ha^{-1}. Most of the varieties gave higher straw yield in wider spacing. Chandra *et al*. (1997) conducted an experiment on 12 Basmati rice varieties in wet season with 20 cm × 20 cm, 20 cm × 15 cm and 15 cm × 15 cm spacing and reported that 15 cm × 15 cm gave greater straw yield in unit area basis over 20 cm × 20 cm spacing due to higher number of tillers per unit area although total tillers $hill^{-1}$ was fewer than wider spacing.

Uddin (2003) conducted an rice experiment with four spacings of 25 cm × 25 cm, 25 cm × 20 cm, 25 cm × 15 cm and 25 cm × 10 cm and reported that 25 cm × 15 cm spacing recorded the highest straw yield $plot^{-1}$ although the straw yield $hill^{-1}$ was not greater than other two wider spacings, 25 cm × 25 cm and 25 cm × 320 cm.

2.1.9 Harvest index

Kim *et al*. (1990) found that harvest index increased by dense planting in rice. Similar result was also reported by Uddin (2003) in rice. Shah *et al*. (1991) reported that harvest index was the highest in 15 cm × 15 cm spacing compared to other wider spacings. On the other hand, Aktar (2004) reported that plant spacing had no effect on harvest index in rice. Similar result was also reported by Alam (2004) in rice.

2.2 Effect of spacing on grain yield in rice

Plant spacing of transplant rice may play an important role in interception of solar radiation, which might increase the yield of rice. Many rice researchers mentioned that spacing had tremendous effect on growth and yield of rice.

Rao *et al*. (1990) reported that the highest grain yield of rice was recorded at 20 cm × 10 cm spacing and was decreased with closer spacing due to lesser number of filled spikelets panicle^{-1} and shorter panicle length in rice *cv*. IET 8579. The yield was decreased at wider spacing despite slightly higher panicle weight.

Gupta and Sharma (1991) observed that 10 cm × 10 cm spacing produced the highest grain yield which was identical with that of 15 cm × 15 cm and both of them were significantly superior to other two wider spacings (20 cm × 15 cm and 20 cm × 20 cm) in respect of yield due to superior performance for yield contributing characters. Further, from an experiment with Binasail rice grown at 10, 15 and 20 cm within row-plant spacing, Zaman *et al*. (1991) reported grain yields of 3.93, 4.16 and 3.66 t ha^{-1}, respectively. Similarly, BRRI (1991) reported variation in tillering capacity, plant height and yield of BR1, BR12, BR14 and BR20 varieties due to the plant densities where seedlings were planted at 25 cm × 30 cm, 25 cm × 20 cm, 25 cm × 10 cm and 15 cm × 10 cm spacings.

Ramakrishna *et al*. (1992) noticed that when rice *cv*. Java grown at 10 cm × 10 cm, 20 cm × 10 cm and 20 cm × 15 cm spacings produced lower grain yield with closer plant spacing. Budhar *et al*. (1993) reported that rice (*cv*. IR 64) transplanted at row spacings of 15 cm × 20 cm, 12.5 cm × 10 cm and 10 cm × 10 cm gave grain yield of 4.33, 4.92 and 4.88 t ha^{-1}, respectively. Krishnan *et al.* (1994) carried out an experiment on rice *cv*. IR 20 with 25 cm × 10 cm, 20 cm × 10 cm and 15 × 10 cm spacings and found that grain yield was higher at wider spacing due to higher number of effective tillers $hill^{-1}$.

In a field trial, Hegazy *et al*. (1995) observed that the yield was the highest at 20 cm × 20 cm row spacing. Azad *et al*. (1995) reported that grain yield decreased with the widest plant spacing when the rice seedlings were transplanted at 20 cm × 10 cm, 25 cm × 15 cm or 30 cm × 20 cm. A simialr result was also reported by Padmajrao (1995) in Basmati rice.

Chandra *et al*. (1997) from an experiment with 12 Basmati rice varieties in wet season with 20 cm × 20 cm, 20 cm × 15 cm and 15 cm × 15 cm spacing reported that 15 cm × 15 cm gave 10-12% higher yield over 20 cm × 20 cm spacing due to higher number of effective tillers and panicle number per unit area. Further, rice *cv*. Kapilee with 20 cm × 10 cm, 15 cm × 10 cm and 10 cm × 10 cm spacings produced lesser yield with closer spacing including number of grains $panicle^{-1}$, panicle length and panicle weight but increased panicle number m^{-2} and slightly increased grain yield (Rekhasshri *et al*., 1997).

Wu *et al*. (2007) worked with hybrid rice cv. Fryou 2070 under different spacings and reported that 18 cm × 20 cm to 23 cm × 20 cm spacings were optimum for yield. However, Zhao *et al*. (2008) carried out an experiment with five planting densities *viz*. 16.7 cm × 13.3 cm, 20 cm × 13.3 cm, 23.3 cm × 13.3 cm, 26.3 cm × 13.3 cm and 30.3 cm × 13.3 cm and observed that grain yield with medium plant density (23.3 cm × 13.3 cm) produced significantly higher seed yield than the two higher and lower densities.

Rafiq *et al.* (1998) carried out an experiment where rice *cv*. Basmati 385 were transplanted with 30 cm × 25 cm, 30 cm × 20 cm, 30 cm × 16 cm and 20 cm × 20 cm spacings and obtained the highest grain yield of 4.88 t ha^{-1} with 20 cm × 20 cm spacing. Bisht *et al*. (1999) reported that hybrid rice *cv*. PRH1 showed increased seed yield in closer spacing (6.50 t ha^{-1}) by promoting panicle number m^{-2} and total spikelets m^{-2}.

BRRI (1999) conducted an experiment with three rice varieties at different Regional Research Stations under different spacings of 10 cm × 10 cm to 30 cm × 30 cm using normal cultural practices and reported that grain yield was varied significantly due to spacings. Yield varied from 2.2 to 3.54 t ha^{-1} in closer spacing with an average of 3.04 t ha^{-1} whereas the yield varied from 2.27 to 4.89 t ha^{-1} in wider spacing with an average of 3.83 t ha^{-1}. Most of the varieties gave higher grain yield in wider spacing.

Neelam and Nisha (2000) conducted an experiment with scented rice *cv*. ‘Pusa Basmoti 1’ cultivated under various plant spacings *viz*. 30 cm × 15 cm, 15 cm × 15 cm and 20 cm × 20 cm and found that spacing did not influence grain yield. A similar result was also reported by Sobhan *et al*. (2003).

Three mutants strains Basmati 370-32, Jajai 77-30 and Sonahri-6 along with their respective mother varieties Basmati 370, Jajai 77, Sonahri Sugdasi and check variety Basmati 385 were evaluated by Baloch et al. (2004) under different plant population (sapcings, 20 cm × 20 cm, 22.5 cm × 22.5 cm and 25 cm × 25 cm between plant and row) for grain yield and yield contributing characters and reported that an increase in spacing induced vagorous plant growth as well as increased the number of panicles per hill, grain yield per hill, filled grains per panicle and 1000-grain weight. The spacing 22.5 cm × 22.5 cm proved more appropriate because it produced better plant stand than other two spacings.

Rahman (2005) conducted an experiment with rice *cv*. BR 26 with four spacings *viz*. 20 cm × 15 cm, 25 cm × 15 cm, 20 cm × 20 cm, 25 cm × 20 cm to find out the effect of spacing on yield attributes and yield and reported that the highest grain and straw yields were obtained from 20 cm x 15 cm spacing due to highest number of effective tillers m^{-2}.

From the reviews cited above, it is clear that plant spacing had a considerable influence on grain yield and yield contributing characters of rice.

Chapter 3

Materials and Methods

CHAPTER 3
MATERIALS AND METHODS

In this chapter the details of different materials used and methodology followed during the experimental period are presented under the following heads:

3.1 Experimental Site

The experiment was carried out at the Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka, during the period from April to August 2010. The location of the site is 23.774^0 N latitude and 90.335^0 E longitudes with an elevation of 8.2 m from sea level (FAO, 1988). The experimental field was medium high land belonging to the (AEZ-28, Madhupur Tract). The soil was silty loam. Fertility status is shown in the Appendix II.

3.2 Weather and Climate

The experimental field was under subtropical climate characterized by heavy rainfall during the month of April to September and scanty rainfall during October to March. The monthly means of daily maximum, minimum and average temperature, relative humidity, total rainfall and sunshine hours recorded at the experimental site during the period from April to August 2010 is presented in Appendix III.

3.3 Plant Material

Four varieties of aus rice viz., BR26, BRRI dhan42, BRRI dhan43 and BRRI dhan48 were used as test crops in the experiment. The salient feature of rice varieties are given below.

BR26: BR-26, a high yielding variety of aus rice was developed by the Bangladesh Rice Resaerch Institute and was released in 1993. It is a photo-insensitive variety. Its average plant height is 115 cm. This variety takes 115-120 days to mature. Grain long with whitish colour, low amylase content. It can give a grain yield of 4.0 t ha^{-1}. The cooked rice is very good for consumption.

BRRI dhan42: BRRI dhan42 is a short duration aus rice variety released in 2004. The average height of BRRI dhan42 is 100 cm, less tiller producing capacity. The variety is well adapted with the climatic condition of Bangladesh. Grain medium size with whitish in colour. This variety is tolerant to drought. The average yield capacity is 3.5 t ha^{-1}.

BRRI dhan43: BRRI dhan43 is a short duration aus rice variety released in 2004. The average height of BRRI dhan43 is 100 cm, less tiller producing capacity. The variety is well adapted with the climatic condition of Bangladesh. Grain medium size with whitish in colour. This variety is tolerant to drought. The average yield capacity is 3.5 t ha^{-1}. The cooked rice is very good for consumption.

BRRI dhan48: BRRI dhan48 is a high yielding variety of aus rice developed by the Bangladesh Rice Resaerch Institute and was released in 2008. It is a photo-insensitive variety. Its average plant height is 105 cm. This variety takes 110-115 days to mature. Grain mediun bold, low amylase content. It can give a grain yield of 5.5 t ha^{-1}. The cooked rice is very good for consumption.

3.4 Treatments

Two factors were included in the study as mentioned below:

A. Four varieties were taken as test crop viz., BR26 (V_1), BRRI dhan42 (V_2), BRRI dhan43 (V_3) and BRRI dhan48 (V_4).

B. Four row spacing of 15 cm (S_1), 20 cm (S_2), 25 cm (S_3) and 30 cm.

3.5 Design and lay out

The experiment was laid out in 2 factors randomized complete block design with 3 replications. There were 48 unit plots in the experiment. Each replication was divided into 16 unit plots where the treatment combinations were allocated at random. The size of each unit plot was 4.0 m × 3.0 m. The spacing between block to block and plot to plot was 1.0 m and 0.5 m, respectively.

3.6 Seed collection

Seeds of the above said varieties collected from Plant Breeding Division, Bangladesh Rice Research Institute, Gazipur-1701.

3.7 Seedbed preparation and raising of seedlings

Seeds of above four varieties were selected by specific gravity method and sprouted by immersing in water in a bucket for 24 hours and then seeds were taken out of water and kept thickly in gunny bags.

A piece of high land was puddled well with country plough followed by cleaning and leveling with a ladder. Sprouted seeds were sown in the wet nursery bed on 10 April 2010. Proper care was taken to raise healthy seedlings in the seedbed. Weeding irrigation was done when was necessary

3.8 Preparation of experimental land

The land of the experimental plot was opened on 01 April 2010 with a power tiller. Later on, the land was ploughed and cross-ploughed three times followed by laddering to level the field. The corners of the land were spaded and weeds and stubble were removed from the field. The land was thus made ready for transplanting. The layout of the experimental field was done on 10 April 2010 according to the design adopted. Individual plots were levelled with wooden plank.

3.9 Fertilization

A fertilizer dose of 75-60-34-5.0 kg ha^{-1} of TSP, MP, gypsum and zinc sulphate, respectively, was applied at the time of final land preparation. Urea was applied @ 200 kg ha^{-1} at three times equal splits at 15, 35 and 50 days after transplanting (BARC, 2005).

3.10 Uprooting and Transplanting of Seedlings

Thirty day-old seedlings were uprooted carefully from the Seedbed without causing any mechanical injury to the roots. Seedlings were transplanted on well-puddled experimental plots on 10 April at the rate of 2 seedlings per hill maintaining spacing according to the treatments.

3.11 Gap Filling: After one week of transplanting, gap filling was done.

3.12 Irrigation

Irrigation was done regularly when needed for normal plant growth and development. The crop was irrigated by flood irrigation and steps were taken to maintain constant level of standing water up to 4-5 cm in the field. During tillering, the field was left to dry out for 2-4 days. The field was finally drained out before 10 days of harvesting.

3.13 Weeding: Two hand weedings were done at 25 and 50 DAT .

3.14 Plant protection measures: The plots were infested with stem borer which was successfully controlled by applying Furadan 5G @ 10 kg ha^{-1}. There was no disease infestation in the field.

3.15 Growth parameters

Two harvests were made at 35 and 50 days after transplanting to study growth characteristics, a total of. From each sampling, five hills were randomly selected from each plot and uprooted for collecting necessary parameters. The plants were separated into leaves, stems and roots and the corresponding dry weight were recorded after oven drying at 80 ± 2^0C for 72 hours. The leaf area of each sample was measured by LICOR automatic leaf area meter (Model: LICOR 3000 USA). The growth analysis like AGR and RGR were carried out following the formulae of Hunt (1978).

i) Absolute growth rate: Rate of dry matter production per unit of time per hill.

$$\text{i.e. AGR} = \frac{W_2 - W_1}{(T_2 - T_1)} \quad \text{g hill}^{-1}\ \text{day}^{-1}$$

where W_2 and W_1 are the weight of dry matter at time T_2 and T_1, respectively.

ii) Relative growth rate: Rate of dry matter production per unit of dry matter per unit of time.

$$\text{i.e. RGR} = \frac{\text{Ln } W_2 - \text{Ln } W_1}{T_2 - T_1} \quad \text{mg g}^{-1}\ \text{day}^{-1}$$

where W_2 and W_1 are the DM at time T_2 and T_1, respectively.
Ln-Natural Logarithm

3.16 Sampling, Harvesting, Threshing, Cleaning and Processing

Ten hills (excluding border ones) were selected at random from each plot and tagged for recording necessary data prior to harvest. After sampling, the crop was harvested plot-wise at full maturity. The harvested crop was bundled, tagged and brought to the threshing floor. The crop was threshed, cleaned and sun dried to record the yields of grain and straw $plot^{-1}$ and then converted to tons $hectare^{-1}$ ($t\ ha^{-1}$).

3.17 Data Collection

Data on the following crop characters were recorded at final harvest from the plants of the sample hills except the grain and straw yields.

Plant height (cm): Length between the base of the plant to the tip of the leaf was taken at 20, 35, 50, 65 and at harvest.

Number of total tillers: Number of tillers was counted from each hill.

Number of effective tillers: The tiller, which had at least one grain was considered as effective tiller.

Number of non-effective tillers: The tiller, which had no grain or panicle was regarded as non effective tiller.

Spikelets $panicle^{-1}$ (no.): Grains of 10 ramdomly selected panicles of each plot were counted and then the average number of grains for each panicle was determined.

Unfilled spikelets $panicle^{-1}$ (no.): Spikelet lacking any food material inside was considered as unfilled spikelets.

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Weight of 1000-grain (g): One thousand clean and sun-dried grains were counted from the seed stock and weighed by an electronic balance.

Grain yield: The grains per plot were sun-dried and weighed. The grain weight was finally converted to ton hectare^{-1}.

Straw yield: Straw obtained from each unit plot was sun-dried and weighed and then converted to ton hectare^{-1}.

Harvest index (%): Harvest index is the ratio of grain yield to biological yield and was calculated with the following formula.

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

3.18 Statistical Analysis

The collected data were analyzed statistically following the analysis of variance technique and the mean differences were adjudged with Duncan’s Multiple Range Test (DMRT) using the statistical computer package program, MSTAT (Russell, 1986).

Chapter 4

Results and Discussion

CHAPTER IV
RESULTS AND DISCUSSION

The results of the study regarding the effect of variety and row spacing on morpho-physiological characters, yield and yield related traits of aus rice have been presented and possible interpretations have been made in this chapter.

4.1 Effect of variety, row spacing and their interaction on morpho-physiological characters of Aus rice

4.1.1 Plant height

The plant height varied significantly due to variety (Fig. 2). The taller plant was observed in BRRI dhan48 (104.47 cm) than the other varieties. The shortest plant was recorded in BRRI dhan42 (90.10 cm). Genotypic variation in plant height was also observed by Baloch *et al.* (2002) in rice that supported the present experimental result.

The effect of row spacing on plant height at different days after transplanting (DAT) was statistically significant at $P \leq 0.05$ in aus rice varieties (Fig. 1). Results showed that plant height increased with decreasing row spacing. The tallest plant was recorded in the row spacing of 15 cm at most of the growth stages followed by the row spacing 20 cm. In contrast, the plants grown with wider row spacing always maintained the shortest plant height. The taller plant in densely populated plants might have resulted due to competition for sunlight than those of wider spacing.

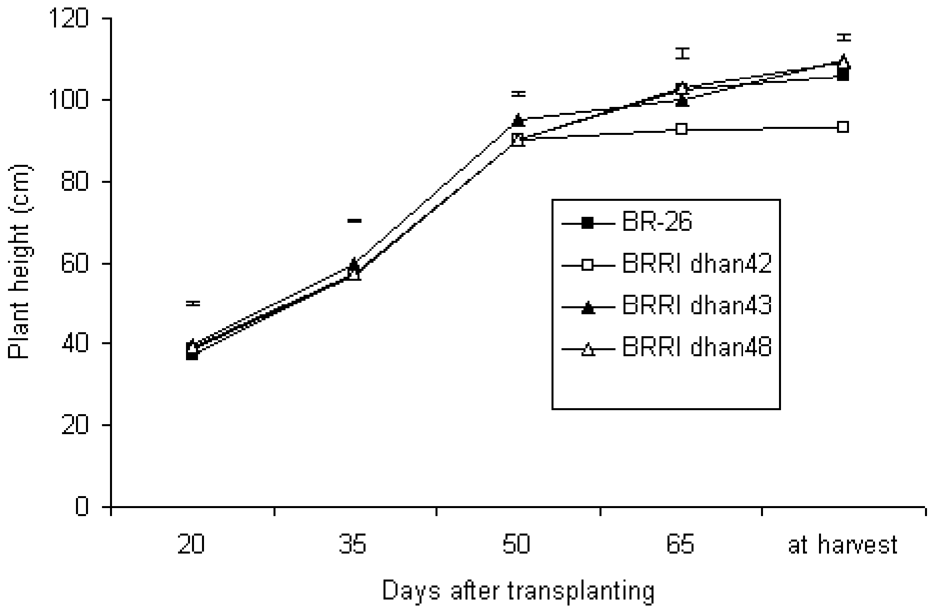

Fig. 1. Varietal variation in plant height at different days after transplanting in Aus rice. Vertical bars reprents SE value.

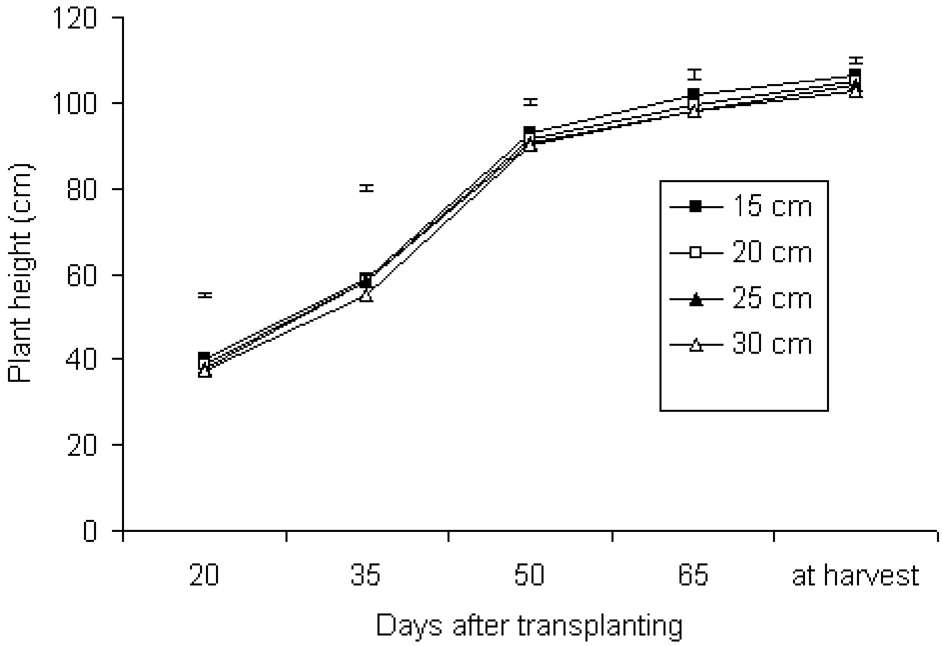

Fig. 1. Effect of row spacings on plant height at different age. Vertical bars represent SE value.

These results are in agreement with that of Abbas *et al.* (1994) who reported that population density had significant effect on plant height of rice. Similar results were also reported by Akita *et al*. (1992) in rice.

The interaction between variety and row spacing had significant effect on plant height at different growth stages of Aus rice (Table 1). The highest plant height was recorded in the treatment combination of BR-26 with closer row spacing of 15 cm (109.5 cm) and the lowest/lower was recorded in the treatment combination of BRRI dhan42 with wider row spacing of 25 and 30 cm (92.73 cm).

4.1.2 Total dry mass hill^{-1}

In varieties, TDM hill $^{-1}$ varied significantly (Table 2). The highest TDM hill $^{-1}$ was recorded in BRRI dhan48 (9.79 and 31.91 g hill-1 for 35 and 50 DAT, respectively) which was significantly greater than the other varieties. In contrast, BRRI dhan43 produced the lowest TDM hill $^{-1}$ (6.60 and 18.53 g hill^{-1} for 35 and 50 DAT, respectively) due to produced fewer tillers hill^{-1} (Table 2) with shorter plant (Table 1).

Row spacing had significant influence on total dry mass hill plant^{-1} at 35 and 50 DAT in aus rice (Table 2). Results revealed that TDM hill^{-1} increased with increased row spacing. The highest TDM hill^{-1} was observed at 30 cm row spacing both at 35 (8.87 g hill^{-1}) and 50 DAT (27.84 g hill^{-1}) followed by 25 cm row spacing (8.33 and 27.10 g hill $^{-1}$ for 35 and 50 DAT, respectively).. In contrast, the

Table 1. Interaction effect of variety and row spacing on plant height at different days after planting in Aus rice varieties

Interaction	Plant height at days after transplanting (DAT) of				
	20	35	50	65	Harvest
$V_1 \times S_1$	39.47 a-c	58.27 b-d	91.67 a-c	106.4 ab	109.5 a
$V_1 \times S_2$	37.33 cd	57.80 b-e	90.00 bc	106.2 ab	101.3 b-d
$V_1 \times S_3$	37.07 cd	56.73 c-f	89.30 bc	106.2 ab	99.00 cd
$V_1 \times S_4$	34.33 d	55.47 d-f	89.47 bc	105.1 b	99.13 cd
$V_2 \times S_1$	39.40 a-c	57.00 c-f	93.07 a-c	95.60 c	93.30 e
$V_2 \times S_2$	39.28 a-c	56.53 c-f	89.80 bc	93.80 c	91.67 e
$V_2 \times S_3$	37.13 cd	58.87 bc	88.60 c	92.91 c	92.73 e
$V_2 \times S_4$	39.73 a-c	54.73 ef	88.33 c	90.60 c	92.73 e
$V_3 \times S_1$	40.33 a-c	61.93 a	95.70 a	113.5 a	101.1 b-d
$V_3 \times S_2$	41.15 ab	60.60 ab	94.60 ab	109.7 ab	101.2 b-d
$V_3 \times S_3$	40.00 a-c	59.60 a-c	94.73 ab	107.3 ab	98.93 cd
$V_3 \times S_4$	37.80 c	56.40 c-f	94.40 ab	108.2 ab	98.30 d
$V_4 \times S_1$	42.30 a	58.13 b-d	90.60 a-c	110.2 ab	103.4 b
$V_4 \times S_2$	37.80 c	59.30 a-c	91.75 a-c	110.0 ab	103.5 b
$V_4 \times S_3$	37.60 c	58.53 b-d	89.20 bc	109.6 ab	101.6 b-d
$V_4 \times S_4$	38.20 bc	54.20 f	88.40 c	107.5 ab	102.4 bc
F-test	*	*	*	*	**
SE	0.990	0.9529	1.2202	2.2447	1.2022
CV (%)	4.43	2.86	2.32	3.72	2.10

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; NS = Non significant; * and ** indicate significance at 5% and 1% level of probability, respectively.

V_1 = BR26; V_2 = BRRI dhan42; V_3 = BRRI dhan43; V_4 = BRRI dhan48; S_1 = Row spacing 15 sm; S_2 = Row spacing 20 cm; S_3 = Row spacing 25 cm and S_4 = Row spacing 30 cm

Table 2. Effect of variety and row spacing on physiological parameters in aus rice

Treatments	Total dry mass hill^{-1} (g) at		Absolute growth rate at 35-50 DAP (g/hill/day)	Relative growth rate (mg/g/day)
	35 DAT	50 DAT		
Variety				
BR-26	8.84 b	29.13 b	1.35 b	75.59 a
BRRI dhan42	6.93 c	20.99 c	0.90 c	74.35 a
BRRI dhan43	6.60 d	18.53 d	0.80 d	71.69 b
BRRI djhan48	9.79 a	31.91 a	1.47 a	75.13 a
F-test	**	**	**	**
SE	0.1126	0.5008	0.0269	0.872
Row spacing				
15	7.17 d	20.81 c	0.91 c	70.45 c
20	7.80 c	24.82 b	1.09 b	73.65 b
25	8.33 b	27.10 a	1.25 a	75.33 ab
30	8.87 a	27.84 a	1.26 a	77.32 a
F-test	**	**	**	*
SE	0.112	0.5008	0.0269	0.8726
CV (%)	4.85	6.90	8.27	4.07

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; NS = Non significant; * and ** indicate significance at 5% and 1% level of probability, respectively.

lowest TDM production plant^{-1} was recorded at closer row spacing of 15 cm (7.17 and 20.81 g hill^{-1} for 35 and 50 DAT, respectively). Reduction in TDM hill^{-1} in closer row spacing might be due to increased number of plants per unit area. This increased number of plants per unit area exerted competition among plants for nutrients and light that caused a reduction in photosynthetic area (leaf area) resulting lower TDM production hill^{-1}. Similar results were also reported by Reddy *et al*. (2001) in rice. The authors reported that there was a decrease in TDM production hill-1 in closer spacing than wider spacing in rice.

The interaction between variety and row spacing had significant effect on TDM production hill^{-1} of 35 and 50 DAT in aus rice (Table 3). The highest TDM hill^{-1} was recorded in the treatment combination of BRRI dhan48 with wider spacing of 30 cm (11.5 and 35.68 g hill^{-1} for 35 and 50 DAT, respectively) The lowest TDM hill-1 was recorded in the treatment combination of BRRI dhan43 with closer spacing of 15 cm (6.09 and 16.25 g hill^{-1} for 35 and 50 DAT, respectively).

4.1.3 Absolute growth rate

The AGR varied significantly due to variety (Table 2). The highest AGR was observed in BRRI dhan48 (1.47 g hill^{-1} day^{-1}) due to increased production of TDM hill^{-1} and the lowest was recorded in BRRI dhan43 (0.80 g hill^{-1} day^{-1}). Genotypic variation in AGR was also observed by BINA (2007) in rice that supported the present experimental result.

The effect of row spacing on absolute growth rate (AGR) was significantly influenced in aus rice varieties (Table 2). Results showed that AGR increased with

Table 3. Interaction effect of variety and row spacing on physiological parameters in aus rice

Interaction	Total dry mass hill^{-1} (g) at		Absolute growth rate at 35-50 DAT (g/hill/day)	Relative growth rate at 35-50 DAT (mg/g/day)
	35 DAT	50 DAT		
$V_1 \times S_1$	7.97 fg	23.63 de	1.04 c	72.45 c-f
$V_1 \times S_2$	8.72 de	28.23 c	1.30 b	70.83 ef
$V_1 \times S_3$	9.18 cd	31.78 b	1.51 a	78.45 ab
$V_1 \times S_4$	9.51 bc	32.87 ab	1.55 a	80.62 a
$V_2 \times S_1$	6.43 i-k	17.88 hi	0.76 de	68.18 fg
$V_2 \times S_2$	6.81 h-j	20.66 e-h	0.77 de	73.99 b-e
$V_2 \times S_3$	7.12 hi	22.64 d-g	1.04 c	77.12 a-d
$V_2 \times S_4$	7.37 gh	22.78 d-f	1.02 c	78.10 a-c
$V_3 \times S_1$	6.09 k	16.25 i	0.68 e	65.43 g
$V_3 \times S_2$	6.17 jk	18.33 hi	0.81 de	72.59 b-f
$V_3 \times S_3$	7.02 hi	19.53 gh	0.84 de	71.54 d-f
$V_3 \times S_4$	7.14 hi	20.03 f-h	0.86 d	77.20 a-d
$V_4 \times S_1$	8.18 ef	25.48 cd	1.15 bc	75.75 a-e
$V_4 \times S_2$	9.50 bc	32.06 b	1.50 a	77.20 a-d
$V_4 \times S_3$	10.0 b	34.44 ab	1.63 a	74.21 b-e
$V_4 \times S_4$	11.5 a	35.68 a	1.61 a	73.36 b-f
F-test	**	*	*	**
SE	0.2253	1.0016	0.0539	1.745
CV (%)	4.85	6.90	8.27	4.07

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; NS = Non significant; * and ** indicate significance at 5% and 1% level of probability, respectively.

V_1 = BR-26; V_2 = BRRI dhan42; V_3 = BRRI dhan43; V_4 = BRRI dhan48; S_1 = Row spacing 15 sm; S_2 = Row spacing 20 cm; S_3 = Row spacing 25 cm and S_4 = Row spacing 30 cm

increasing row spacing due to increased TDM in wider spacing. The highest AGR was observed in wider spacing of 30 cm (1.26 g $hill^{-1}$ day^{-1}). The lowest AGR was observed in closer spacing of 15 cm (0.91 g $hill^{-1}$ day^{-1}). These results are in disagree with that of Yan *et al.* (2007) who reported that CGR was greater in closer spacing than wider spacing in rice because of increased number of hill accommodation per meter square in closer spacing than wider spacing.

The interaction between variety and row spacing had significant effect on AGR in Aus rice (Table 3). The higher AGR was recorded in the treatment combination of BRRI dhan48 with 30 and 25 cm row spacings (1.61-1.63 g $hill^{-1}$ day^{-1}) and the lowest was recorded in the treatment combination of BRRI dhan43 with 15 cm row spacing (0.68 g $hill^{-1}$ day^{-1}).

4.1.4 Relative growth rate

The RGR showed significant differences among the varieties (Table 2). The higher RGR was recorded in BR-26, BRRI dhan42 and BRRI dhan48 with being the highest in BR-26 (75.59 mg g^{-1} d^{-1}). On the other hand, the lowest RGR (71.69 mg g^{-1} d^{-1}) was observed in BRRI dhan43 due to production of lower TDM $plant^{-1}$ (Table 2). Genotypic variations in RGR were also observed by BINA (2007) in rice which supported the present experimental result.

Relative growth rate (RGR) was significantly influenced by row spacing in Aus rice (Table 3). Results showed that RGR decreased with decreasing row spacing. The highest RGR was observed in wider spacing of 30 cm (77.32 mg g^{-1} d^{-1}) followed by 25 cm row spacing (75.33 mg g^{-1} d^{-1}) with same statistical rank. The lowest RGR was recorded in closer spacing of 15 cm (70.45 mg g^{-1} d^{-1}). The result is consistent with the findings of Chowdhury (2008) who reported that RGR in Aman rice decreased with decreasing row spacing.

The interaction effect of variety and row spacing in relation to RGR was significant (Table 3). The highest RGR was observed in BR-26 with 30 cm row spacing (80.62 mg g^{-1} d^{-1}). The lowest RGR was observed in BRRI dhan43 with 15 cm row spacing (65.43 mg g^{-1} d^{-1}).

4.2 Effect of variety, row spacing and their interaction on tillering pattern of aus rice

4.2.1 Number of effective tillers hill^{-1}

Variation in effective tiller number hill^{-1} among the studied varieties was statistically significant (Table 4). The highest number of effective tillers hill^{-1} was observed in BR-26 (14.68) followed by BRRI dhan48 (13.73). In contrast, BRRI dhan42 and BRRI dhan43 produced lower number of effective tillers hill^{-1} with being the lowest in BRRI dhan42 (9.29). Genotypic variations in effective tillers hill^{-1} was also observed by many workers (Ghosh *et al*., 1991; Hassan, 2006; Ibrahim, 2006; Chowdhury, 2008).

The effect of row spacing on number of effective tillers hill^{-1} was statistically significant (Table 4). Results showed that number of effective tillers hill^{-1} increased with increasing row spacing. The highest number of effective tillers hill^{-1} was recorded at 30 cm row spacing (13.62) followed by 25 cm row spacing (12.27). The lowest number of effective tillers hill^{-1} was observed in closer spacing of 15 cm (10.08). Reduction in effective tillers hill^{-1} in closer spacing might be due to increased number of plants per unit area. This increased number of plants per unit area exerted competition among plants for nutrients and light that caused a reduction in tiller number. Similar results were also reported by Baloch *et al*. (2002) in rice.

The interaction effect of variety and row spacing in relation to effective tiller number hill^{-1} was also statistically significant (Table 5). The higher effective tiller

Table 4. Effect of variety and row spacing on tiller characters in aus rice

Treatments	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Total tillers hill^{-1} (no.)
Variety			
BR-26	14.68 a	3.28 c	17.89 a
BRRI dhan42	9.29 c	3.51 b	12.81 b
BRRI dhan43	9.56 c	4.01 a	13.57 b
BRRI djhan48	13.73 b	3.66 b	17.39 a
F-test	**	**	**
SE	0.1899	0.0661	0.2958
Row spacing			
15	10.08 d	3.23 b	13.24 d
20	11.28 c	3.41 b	14.69 c
25	12.27 b	3.83 a	16.11 b
30	13.62 a	3.99 a	17.62 a
F-test	**	**	**
SE	0.1899	0.0661	0.2958
CV (%)	5.57	6.34	6.65

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; ** indicate significance at 5% and 1% level of probability

Table 5. Interaction effect of variety and row spacing on tiller characters in aus rice

Interaction	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Total tillers hill^{-1} (no.)
$V_1 \times S_1$	12.73 c	2.67 g	15.10 ef
$V_1 \times S_2$	14.60 b	3.13 f	17.73 cd
$V_1 \times S_3$	15.40 ab	3.70 b-d	19.10 a-c
$V_1 \times S_4$	16.00 a	3.63 b-e	19.63 ab
$V_2 \times S_1$	7.87 f	3.27 ef	11.14 h
$V_2 \times S_2$	8.53 ef	3.37 c-f	11.90 gh
$V_2 \times S_3$	9.67 e	3.73 bc	13.40 fg
$V_2 \times S_4$	11.07 d	3.67 b-e	14.80 ef
$V_3 \times S_1$	8.13 f	3.73 bc	11.86 gh
$V_3 \times S_2$	9.00 ef	3.93 ab	12.93 gh
$V_3 \times S_3$	9.63 e	4.07 ab	13.70 fg
$V_3 \times S_4$	11.47 d	4.33 a	15.80 e
$V_4 \times S_1$	11.60 d	3.27 d-f	14.87 ef
$V_4 \times S_2$	13.00 c	3.20 f	16.20 de
$V_4 \times S_3$	14.40 b	3.83 b	18.23 bc
$V_4 \times S_4$	15.93 a	4.33 a	20.26 a
F-test	*	*	*
SE	0.3798	0.132	0.5916
CV (%)	5.57	6.34	6.65

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; * indicates significance at 5% level of probability

V_1 = BR-26; V_2 = BRRI dhan42; V_3 = BRRI dhan43; V_4 = BRRI dhan48; S_1 = Row spacing 15 sm; S_2 = Row spacing 20 cm; S_3 = Row spacing 25 cm and S_4 = Row spacing 30 cm

number hill^{-1} was observed in BR-26 with 30 cm row spacing and BRRI dhan48 with 30 cm row spacing with being the highest in BR-26 with 30 cm row spacing (16.0) and the lowest was recorded in BRRI dhan42 with closer spacing of 15 cm (7.87).

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

Variation in non-effective tillers hill^{-1} among the studied varieties was statistically significant (Table 4). The highest number of non-effective tillers hill^{-1} was observed in BRRI dhan43 (4.01). The lowest number of non-effective tillers hill^{-1} was recorded in BR26 (3.28). Genotypic variations in non-effective tillers hill^{-1} was also observed by many workers (Karim *et al.*, 1992; Kang *et al.*, 2001; Islam 2003; Khan, 2007).

Row spacing had significant influence on non-effective tiller production in rice (Table 4). Results revealed that non-effective tillers hill^{-1} increased with increasing row spacing. The higher non-effective tillers hill^{-1} was observed when planted wider row spacing of 25-30 cm but the highest was recorded in 30 cm row spacing (3.99). In contrast, the lowest number of non-effective tillers hill^{-1} was recorded in closer row spacing of 15 cm (3.23). Reduction in non-effective tiller number in densely populated area might be due to plant can not able to produce fertile tillers at later growth stages. The tillers which produced after 50 DAT, can not initiate effective panicle. Therefore, lower number of non-effective tillers was observed in closer row spacing in the present study.

The interaction effect of variety and row spacing in relation to non-effective tiller number hill^{-1} was also statistically significant (Table 5). The higher non-effective tiller number hill^{-1} was observed in BRRI dhan42 and BRRI dhan48 with 30 cm row spacing (4.33) and the lowest was recorded in BR-26 with with closer spacing of 15 cm (2.67).

4.2.3 Number of total tillers hill^{-1}

Variation in total tiller number hill^{-1} among the studied varieties was statistically significant (Table 4). The highest number of total tillers hill^{-1} was observed in BR26 (17.89) followed by BRRI dhan48 (17.39) with same statistical rank. In contrast, BRRI dhan42 and BRRI dhan43 produced lower number of total tillers hill^{-1} with being the lowest in BRRI dhan42 (12.81). Genotypic variations in effective tillers hill^{-1} was also observed by many workers (Ghosh *et al*., 1991; Hassan, 2006; Ibrahim, 2006; Chowdhury, 2008).

The effect of row spacing on number of total tillers hill^{-1} was statistically significant (Table 4). Results showed that number of total tillers hill^{-1} increased with increasing row spacing. The highest number of total tillers hill^{-1} was recorded at 30 cm row spacing (17.62) followed by 25 cm row spacing (16.11). The lowest number of total tillers hill^{-1} was observed in closer spacing of 15 cm (13.24). Reduction in total tillers hill^{-1} in closer spacing might be due to increased number of plants per unit area. This increased number of plants per unit area exerted competition among plants for nutrients and light that caused a reduction in tiller number. Similar results were also reported by Baloch *et al*. (2002) in rice.

The interaction effect of variety and row spacing in relation to total tiller number hill^{-1} was also statistically significant (Table 5). The higher total tiller number hill^{-1} was observed in BR26 with 30 cm row spacing and BRRI dhan48 with 30 cm row spacing with being the highest in BRRI dhan48 with 30 cm row spacing (20.26) and the lowest was recorded in BRRI dhan42 with closer spacing of 15 cm (11.14).

4.3 Effect of variety, row spacing and their interaction on yield attributes and yield of aus rice

4.3.1 Number of filled spikelets panicle $^{-1}$

Variety had no significant effect on the number of filled grains panicle^{-1} (Table 6). However, apparently the higher filled grain number panicle-1 was observed BR26 (120.4) and the lower was recorded in BRRI dhan42 (116.8).

The effect of row spacing on filled grain numbers panicle^{-1} was statistically significant (Table 6). Results revealed that the number of filled grains panicle^{-1} increased with increasing row spacing but increased significantly till 20 cm row spacing and further increment of row spacing, had no significant increment in filled grain number panicle^{-1}. The highest number of filled grains panicle^{-1} was observed in 30 cm row spacing (121.4) followed by 25 cm row spacing (119.9) and 20 cm row spacing (118.3) with same statistical rank. In contrast, the lowest number of filled grains panicle^{-1} was recorded in closer spacing of 15 cm (115.5). Reduction in the number of filled grains panicle $^{-1}$ under closer spacing might be due to increased number of plants per unit area. This increased number of plants per unit area exerted competition among plants for nutrients and light that might have

Table 6. Effect of variety and row spacing on yield attributes and yield grain in aus rice

Treatments	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-grain weight (g)	Grain yield hill^{-1} (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Variety							
BR-26	120.4	12.74 c	22.16 b	33.62 b	2.96 b	6.22 b	32.15 c
BRRI dhan42	116.8	12.24 c	21.18 c	22.55 d	2.58 c	4.22 c	37.74 b
BRRI dhan43	119.2	14.18 b	22.45 b	25.16 c	2.71 c	3.78 d	41.62 a
BRRI dhan48	118.7	17.53 a	24.40 a	39.75 a	3.97 a	6.88 a	36.62 b
F-test	NS	**	**	**	**	**	**
SE	1.2764	0.2961	0.2133	0.726	0468	0.0570	0.6357
Row spacing							
15	115.5 b	13.45 b	22.40	25.25 d	3.27 a	5.56 a	37.74 a
20	118.3ab	14.37ab	22.58	29.05 c	3.42 a	5.68 a	37.96 a
25	119.9ab	13.70 b	22.73	31.98 b	3.07 b	5.20 b	37.56 a
30	121.4 a	15.17 a	22.49	34.78 a	2.48 c	4.67 c	34.87 b
F-test	*	**	NS	**	**	**	**
SE	1.2764	0.2961		0.726	0.0468	0.0570	0.6357
CV (%)	3.72	7.24	3.28	8.32	5.30	3.74	5.95

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT;   NS = Non significant; * and ** indicate significance at 5% and 1% level of probability, respectively.

caused lower crop growth rate with consequently a reduction in the number of effective grains panicle $^{-1}$. Further, the differential response for row spacing might be due to the fact that wider spacings have fewer number of plants per unit area which allowed more nutrients for producing more number of filled grains panicle$^{-1.}$ Similar results were also reported by many workers (Miah et al., 1990; Neelam and Nisha, 2000; Baloch et al., 2002; Rahman, 2005; Khan, 2007).

They observed that filled grains panicle^{-1} increased with increasing row spacing up to certain level in rice.

The interaction effect of variety and row spacing for filled grains panicle $^{-1}$ was also significant at $P \leq 0.05$ (Table 7). Results revealed that there had no significant influence in row spacings on filled grain number panicle^{-1} of BRRI dhan48. The highest filled grains panicle $^{-1}$ was observed in BRRI dhan42 with 30 cm row spacing (125.5). In contrast, the lowest number of filled grains panicle $^{-1}$ was observed in BRRI dhan42 with 15 cm row spacing (112.3).

4.3.2 Number of unfilled grains panicle $^{-1}$

Variation in unfilled grains panicle $^{-1}$ among the varieties was statistically significant (Table 6). The highest number of unfilled grains panicle $^{-1}$ was observed in BRRI dhan48 (17.53). The lowest number of unfilled grains panicle^{-1} was recorded in BRRI dhan42 (12.24). Genotypic variations in unfilled grains panicle $^{-1}$ was also observed by many workers (Karim *et al.*, 1992; Kang *et al.*, 2001; Islam 2003; Khan, 2007).

Table 7. Interaction effect of variety and row spacing on yield attributes and yield grain in aus rice

Interaction	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-grain weight (g)	Grain yield hill^{-1} (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
$V_1 \times S_1$	115.9 bc	13.20 c	22.16	28.27 ef	3.20 de	6.67 c	32.45 gh
$V_1 \times S_2$	119.0 a-c	13.30 c	21.79	33.22 d	3.43 cd	6.80 bc	33.53 f-h
$V_1 \times S_3$	124.3 ab	13.20 c	22.80	35.99 c	2.90 ef	5.93 d	32.84 f-h
$V_1 \times S_4$	122.3 ab	11.27 d	21.90	36.98 c	2.33 h	5.50 e	29.76 h
$V_2 \times S_1$	112.3 c	11.27 d	20.92	18.49 k	2.93 ef	4.43 fg	39.97 a-d
$V_2 \times S_2$	116.8 a-c	13.30 c	21.32	21.24 ij	2.90 f	4.53 f	39.03 a-e
$V_2 \times S_3$	118.0 a-c	11.20 d	21.00	23.96gh	2.60 g	4.13 gh	38.63 b-e
$V_2 \times S_4$	119.9 a-c	13.20 c	21.48	26.51 fg	1.90 i	3.80 h	33.33 f-h
$V_3 \times S_1$	115.7 bc	14.27 c	22.12	20.81 jk	3.03 ef	4.00 h	43.08 a
$V_3 \times S_2$	118.9 a-c	13.90 c	22.40	23.55 hi	2.93 ef	4.13 gh	41.56 a-c
$V_3 \times S_3$	116.8 bc	10.93 d	22.90	26.02fg	2.77 fg	3.80 h	42.16 ab
$V_3 \times S_4$	125.5 a	17.60 b	22.40	30.24 e	2.10 hi	3.20 i	39.66 a-d
$V_4 \times S_1$	118.1 a-c	15.07 c	24.40	33.43 d	3.90 b	7.13 ab	35.45 e-g
$V_4 \times S_2$	118.5 a-c	16.97 b	24.80	38.20 c	4.40 a	7.27 a	37.70 c-e
$V_4 \times S_3$	120.4 a-c	19.47 a	24.20	41.96 b	4.00 b	6.93abc	36.60 d-f
$V_4 \times S_4$	117.8 a-c	18.60ab	24.20	45.41 a	3.60 c	6.20 d	36.73 d-f
F-test	*	**	NS	*	*	*	*
SE	2.552	0.5922	0.4265	1.453	0.0936	0.1141	1.2715
CV (%)	3.72	7.24	3.28	8.32	5.30	3.74	5.95

In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; NS = Non significant; * and ** indicate significance at 5% and 1% level of probability, respectively.

V_1 = BR-26; V_2 = BRRI dhan42; V_3 = BRRI dhan43; V_4 = BRRI dhan48; S_1 = Row spacing 15 sm; S_2 = Row spacing 20 cm; S_3 = Row spacing 25 cm and S_4 = Row spacing 30 cm

Row spacing had significant influence on unfilled grains panicle^{-1} in rice (Table 6). Result revealed that unfilled grains panicle $^{-1}$ increased with increasing row spacing. The highest unfilled grains panicle $^{-1}$ was observed in wider spacing of 30 cm (15.17). In contrast, the lowest unfilled grains panicle $^{-1}$ was recorded in closer row spacing of 15 cm (13.45).

The interaction effect of variety and row spacing in unfilled grains panicle^{-1} was also statistically significant (Table 7). The higher unfilled grain number panicle^{-1} was observed in BRRI dhan48 with 25 and 30 cm row spacing with being the highest in 25 cm row spacing (19.47). The lowest unfilled grains panicle-1 was recorded in BRRI dhan42 with 25 cm row spacing (11.20).

4.3.3 Thousand-grain weight

A significant difference in 1000-grain weight was also observed in studied varieties of aus rice (Table 6). The highest 1000-grain weight was recorded in BRRI dhan48 (24.40 g). In contrast, the lowest 1000-grain weight was recorded in BRRI dhan42 (21.18 g). Genotypic variation in 1000-grain weight was also observed by many workers in rice (Ghosh et al., 1991; Bisht et al., 1999; Hassan, 2006; Chowdhury, 2008) that also supported the present experimental result.

The effect of row spacing on 1000-grain weight was non- significant at $P \leq 0.05$ (Table 6). This results indicate that seed size control by genes not by environment. This results disagree with many workers (Ramakrishna *et al.*, 1992; Baloach *et al.*, 2002; Rahman, 2005; Yan *et al.*, 2007). They observed that 1000-seed weight decreased with increasing plant density in rice. On the other hand, BINA (2007) reported that plant density had no influenced on 1000-grain weight in rice.

The interaction effect of seed rate and variety for 1000-grain weight was non-significant (Table 7).

4.3.4 Grain yield hill^{-1} and per hectare

Variety had significant effect on grain yield both hill^{-1} and unit^{-1} area basis (Table 6). The highest grain yield both hill^{-1} (39.75 g) and unit^{-1} area (3.97 t ha^{-1}) was recorded in BRRI dhan48 due to superiority in effective tiller number, 1000-grain weight and grains panicle^{-1}. BRRI dhan42 showed the lowest grain yield hill^{-1} (22.55 g) and hectare^{-1} (2.58 t ha^{-1}). The other two varieties BR26 and BRRIdhan42 were in the middle in respect of their yield performance and BR26 had in significantly higher yield than that of BRRIdhan42. Genotypic variations in seed yield was also observed by many workers in rice (Ramakrishna et al., 1992; Verma *et al.*, 2002; Uddin, 2003; Rahman, 2005).

Row spacing had significant effect on grain yield hill^{-1} and hectare^{-1} (Table 6). Results revealed that seed yield hill^{-1} increased with increasing row spacing in aus rice. The highest grain yield hill^{-1} was recorded in wider spacing of 30 cm (34.78 g) followed by 25 cm row spacing (31.98 g). Grain yield hill^{-1} increased under wider spacing was due to greater number of effective tillers hill $^{-1}$ and grains panicle $^{-1}$. The lowest grain yield hill^{-1} was recorded in closer row spacing of 15 cm (25.25 g) was might be due to lesser amount of assimilate produced by the plants through lesser photosynthetic area plant^{-1} and competition of nutrients uptake by the plants.

However, in case of unit area basis, the grain yield was greater at closer row spacing (3.27-3.42 t ha^{-1}) compared to wider row spacing (25 and 30 cm row spacings) (2.48-3.07). The highest grain yield was recorded in 20 cm row spacing (3.42 t ha^{-1}) which was statistically similar (3.27 t ha^{-1}) to 15 cm row spacing indicating 15-20 cm row spacings are the optimum for increased grain yield of aus rice. In contrast, the lowest grain yield per unit area was recorded in wider spacing of 30 cm (2.48 t ha $^{-1}$) although grain yield $hill^{-1}$ was the highest in 30 cm row spacing. Similar results were also reported by many workers (Neelam. and Nisha, 2000; Kang et al., 2001; Baloach et al., 2002; Islam, 2003; Ibrahim, 2006; Khan, 2007). They observed that grain yield increased with increasing plant spacing up to certain levels (20-25 cm row spacing) and thereafter decreased.

The interaction effect of variety and row spacing on seed yield both $hill^{\mathbf{-1}}$ and $hectare^{\mathbf{-1}}$ was significant at $P \leq 0.05$ (Table 7). In case of unit area, the variety and BRRI dhan48 produced the highest grain yield (4.40 t ha^{-1}) in 20 cm row spacing with superior dry matter partitioning to economic yield (Table 7). In the interaction effect, the variety BRRIdhan48 with spacing 15 and 25 cm obtained the identical grain yield which were 3.90 t ha^{-1} and 4.00 t ha^{-1} respectively but with the spacing 30 cm it produced lower grain yield of 3.60 t ha^{-1} than with the former two spacing. Further, it appears from the interaction effect that BRRIdhan48 with any of the 4 spacings, produced significantly higher grain yield (t ha^{-1}) than any of the combinations of 4 spacing with the rest 3 varieties of aus rice. BR26 of course was found to obtain higher yield (t ha^{-1}) in combination with any of the 4 spacings than that of BRRIdhan42 and BRRIdhan43 while BRRIdhan42 with the spacing 30 cm produced the lowest grain yield of 1.90 t ha^{-1}.

4.3.5 Straw yield

The straw yield showed significant differences among the studied varieties (Table 6). BRRI dhan48 produced the highest straw yield (6.88 t ha-1) followed by BR26 (6.22 t ha^{-1}) due to production of higher tillers hill^{-1}. On the other hand, BRRI dhan43 produced the lowest straw yield (3.78 t ha^{-1}) due to production of lesser tillers hill^{-1} with shorter plant stature (Table 1). Genotypic variations in straw yield was also observed by Wang et al. (2002) in rice which supported the present experimental result.

The effect of row spacing on straw yield was statistically significant (Table 6). Results showed that straw yield decreased with increasing row spacing from 20 cm row. The higher straw yield were recorded in 15 and 20 cm row spacing with being the highest in 20 cm row spacing (5.68 t ha-1).The lowest straw yield was recorded in wider spacing of 30 cm (4.67 t ha-1). The result is consistent with the findings of Baloach et al. (2002) who reported that straw yield in rice decreased with increasing row spacing. It is possible because of hill number per unit area increased with decreasing row spacing (Table 4).

The interaction effect of variety and row spacing in relation to straw yield was significant (Table 7). The highest straw yield was observed in BRRI dhan48 with 20 cm row spacing (7.27 t ha-1) and the lowest was recorded in BRRI dhan43 with 30 cm row spacing (3.20 t ha-1).

4.3.6 Harvest index

Variation in HI among the studied varieties was statistically significant (Table 7). The highest HI was recorded in BRRI dhan43 (41.62%). The lowest harvest index was observed in BR26 (32.15%). Genotypic variations in harvest index was also observed by many workers (Zaman et al., 1991; Yan, 2002; Uddin, 2003; Wu et al., 2007: Yan et al., 2007).

The effect of row spacing on harvest index (HI) was statistically significant (Table 6). Results showed that HI decreased after 25 cm row spacing. The HI recorded in 15, 20 and 25 cm row spacings were statically identical with being the highest in 20 cm row spacing (37.96%) indicating dry matter partitioning to economic yield was better in 20 cm row spacing. The lowest harvest index was observed in wider row spacing of 30 cm (34.87%).

The interaction effect of variety and row spacing in relation to HI was also statistically significant (Table 6). Results showed that HI decreased with increased row spacing in two varieties *viz.*, BRRI dhan42 and BRRI dhan43. In BR26 and BRRI dhan48, the highest HI was observed in 20 cm row spacing indicating 20 cm row spacing is the best suited for BR-26 and BRRI dhan48 cultivation. In all the varieties, HI was the lowest/lower in wider spacing of 25 and 30 cm indicating wider row spacings of 25 and 30 cm is not suited for aus rice cultivation under Bangladesh environmental condition.

Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the field laboratory of the Department of Agronomy, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, during the period from April to August 2010 to investigate the effect of variety and row spacing on morpho-physiological characters, yield attributes and yield of Aus rice. The experiment comprised four varieties *viz.*, Br26, BRRI dhan42, BRRI dhan43 and BRRI dhan48 and four row spacings *viz*. 15, 20, 25 and 30 cm.

The morpho-physiological parameters such as plant height, effective and non-effective tiller number hill^{-1}, total tiller number hill^{-1}, total dry mass (TDM) hill, absolute growth rate (AGR) and relative growth rate (RGR) were significantly influenced by row spacing in rice. Results revealed that plant height increased with decreasing row spacing while number of effective tillers, non-effective tillers and total tillers plant^{-1}, TDM hill^{-1}, AGR and RGR increased with increasing row spacing. The highest plant height (101.8 cm) was observed in closer row spacing of 15 cm and the lowest was recorded in wider row spacing of 30 cm (98.14 cm). The highest number of effective tillers hill^{-1} (13.62), non-effective tillers hill^{-1} (3.99) and total tillers hill^{-1} (17.62) was observed in wider row spacing of 30 cm and the lowest was recorded in closer row spacing of 15 cm. The highest TDM (27.84 g hill^{-1}), AGR (1.26 g hill^{-1} day^{-1}) and RGR (77.32 mg g^{-1} day^{-1}) was recorded in wider row spacing of 30 cm and the lowest was recorded in closer spacing of 15 cm.

The effects of row spacing on number of filled and unfilled grains panicle^{-1}, seed yield both hill^{-1} and hectare^{-1}, straw yield and harvest index (HI) were significant but 1000-grain weight was non-significant. Results revealed that number of filled and unfilled grains panicle^{-1} and grain yield hill^{-1} increased with increasing row spacing while reverse trend was observed in grain and straw yield per hectare and HI. The highest grain yield hill^{-1} was recorded in wider row spacing of 30 cm (34.78 g) due to increased number of filled grains panicle^{-1} but in case of unit area basis, the seed yield and HI was greater at closer row spacing than wider row spacing. The higher grain and straw yield hectare^{-1} and HI was observed in 15 and 20 cm row spacings than 25 and 30 cm row spacing with being the highest in 20 cm row spacing. The yield was higher in 15 and 20 cm row spacings because of increased number of plants per unit area although plant^{-1} yield was inferior in closer spacing. In contrast, the lowest seed and straw yield hectare^{-1} was recorded in 30 cm row spacing.

The effect of variety on morpho-physiological, yield attributes and yield was significant. Results revealed that the variety BRRI dhan48 was superior in relation to plant height, TDM hill^{-1}, AGR, RGR, total tiller number hill^{-1} and 1000-grain weight which resulted its highest grain yield hectare^{-1} (3.97 t ha^{-1}). In contrast, the lowest above studied parameters were observed in BRRI dhan42 and resulting the lowest grain yield hectare^{-1} (2.58 t ha^{-1}).

The interaction effect of variety and row spacing on plant height, TDM $hill^{-1}$, AGR, RGR, effective tillers $hill^{-1}$, non-effective tillers $hill^{-1}$, total tillers $hill^{-1}$, yield attributes and grain yield was significant except 1000-grain weight. In case of unit area, the varieties BR26 and BRRI dhan48 produced higher yield in 20 cm row spacing than 15 cm spacing while the grain yields of BRRI dhan42 and BRRI dhan43 were higher in 15 cm than 20 cm spacing.

Based on the experimental results, it may be concluded that-

i) The effect of row spacing had tremendous effect on morphological growth, yield attributes and yield in aus rice;

ii) The variety BRRI dhan48 performed best regarding yield performance; and

iii) The row spacing of 20 cm for BR26 and BRRI dhan48 and the row spacing of 15 cm for BRRI dhan42 and BRRI dhan43 appears to be the best among the treatments regarding yield of aus rice for AEZ-28.

However, these findings need to be further investigated and evaluated on different agro-ecological zone before final recommendation to the farmers.

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Appendices

APPENDICES

Appendix I. Morphological characteristics of the experiment field

Characters	SAU farm
Locality	SAU, Dhaka
Geographic position	24.09^o North Latitude 90.5^o Eeast Longitude 8.2 m height above the mean sea level
Agro-ecological zone (FAO and UNDP, 1988)	Madhupur Tract (AEZ-28)
General soil type	Shallow Grey Terrace Soil
Taxonomic soil classification:	
Order	Inceptisols
Sub-order	Aquept
Sub-group	Aeric Albaquept
Soil series	Chhiata
Parent material	Madhupur terrace
Topography	Fairly level
Drainage	Well drained
Flood level	Above Flood level

Appendix II. Physical and chemical characteristics of the soil

Characteristics	BARI farm
Mechanical fractions:	
% Sand (0.2-0.02 mm)	27.4
% Silt (0.02-0.002 mm)	33.3
%Clay (< 0.002 mm)	39.3
Textural class	Clay loam
Colour	Grey
Consistency	Sticky and mud when wet
pH (1:2.5 Soil-Water)	6.2
CEC (cmol kg^{-1})	18.4
Exchangeable K (meq/100 g)	0.39
Exchangeable Ca (meq/100 g)	3.20
Exchangeable Mg (meq/100 g)	1.34
Exchangeable Na (meq/100 g)	0.16
Organic C (%)	0.99
Total N (%)	0.052
Available P (mg kg^{-1})	13.1
Available S (mg kg^{-1})	8.51
Available Zn (mg kg^{-1})	1.52
Available Cu (mg kg^{-1})	0.66
Available Fe (mg kg^{-1})	16.8
Available Mn (mg kg^{-1})	3.1
Available boron (mg kg^{-1})	0.33

Appendix III. Average monthly rainfall, air temperature and relative humidity during the experimental period between April to September, 2010 at the SAU area, Dhaka

Month	Monthly average air temperature (^{0}C)			Average rainfall (mm)	Average relative humidity (%)	Average daily sunshine (hrs)
	Maximum	Minimum	Average			
March	31.28	19.10	25.19	11.7	82.03	8.55
April	30.56	22.14	26.35	96.6	78.57	7.42
May	32.80	23.34	28.07	266	82.50	5.66
June	31.27	26.46	29.09	153.4	86.29	6.20
July	32.60	26.46	29.53	163.4	87.10	5.96
August	32.66	26.80	29.73	369.7	88.16	6.10
September	32.08	26.09	29.08	288.1	86.97	7.22

Source: Weather Yard, SAU, Dhaka

Appendix IV. Analysis of variance (mean square) on plant height of aus rice at different days after planting

Source of variation	df	Plant height (cm) at days after planting of				
		20	35	50	65	At harvest
Replication	2	12.151	11.391	1.000	9.265	0.776
Varierty (A)	3	16.345 **	19.959 **	70.381 **	717.183 **	261.015 **
Spacing (B)	3	19.216 **	35.168 **	16.794 **	27.384 ns	36.748 **
A×B	9	7.465 *	5.469 *	7.848 *	16.567 *	15.669 **
Error	30	2.941	2.724	2.467	5.116	4.336

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

ns = Non significant

Appendix V. Analysis of variance (mean square) on physiological parameters in aus rice at different days after planting.

Source of variation	df	Total dry mass hill^{-1} (g) at		Absolute growth rate at 35-50 DAP (g/hill/day)	Relative growth rate (mg/g/day)
		35 DAT	50 DAT		
Replication	2	0.055	0.109	0.024	7.938
Varierty (A)	3	27.950 **	490.597 **	1.330 **	36.446 *
Spacing (B)	3	6.384 **	119.892 **	0.328 **	101.417 **
A×B	9	0.634 **	8.118 *	0.024 *	34.514 **
Error	30	0.152	3.009	0.009	9.137

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

Appendix VI. Analysis of variance (mean square) on tiller characters, straw yield and harvest index in Aus rice

Source of variation	df	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Total tillers hill^{-1} (no.)	Straw yield (t ha^{-1})	Harvest index (%)
Replication	2	0.012	0.072	0.060	0.008	5.250
Varierty (A)	3	93.586 **	1.134 **	80.828 **	27.287 **	182.23 **
Spacing (B)	3	26.983 **	1.502 **	42.392 **	2.447 **	25.20 **
A×B	9	1.455 *	0.145 *	4.156 *	0.069 *	11.225 *
Error	30	0.433	0.053	1.050	0.039	4.850

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

Appendix VII. Analysis of variance (mean square) on yield attributes and yield in Aus rice

Source of variation	df	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000-grain weight (g)	Grain weight hill^{-1} (g)	Grain yield (t ha^{-1})
Replication	2	22.750	4.118	2.740	8.602	0.066
Varierty (A)	3	27.472 ns	68.103 **	21.837 **	747.28 **	4.794 **
Spacing (B)	3	75.683 *	7.079 **	0.227 ns	200.00 **	2.006 **
A×B	9	49.507 ns	11.169 **	0.385 ns	6.960 *	0.071 *
Error	30	19.550	1.052	0.546	2.336	0.026

*, ** indicate significant at 5% and 1% level of probability, respectively; ns = non significant