YIELD AND YIELD COMPONENTS OF TRANSPLANTED AMAN RICE WITH DIFFERENT PLANTING GEOMETRY

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CERTIFICATE

This is to certify that the thesis entitled **'Yield and Yield Components of Transplanted Aman Rice with Different Planting Geometry'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science** in **Agronomy**, embodies the result of a piece of bonafide research work carried out by **Md. Sahadat Ali**, Registration number: **08-02904** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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DEDICATED

TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted at the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from June to November, 2013 to evaluate the yield and yield components of transplanted aman rice grown under different planting geometries. The experiment comprised of two factors denoted by Factor A: Planting geometry (PG) (4 levels designated PG_1: 25 cm × 25 cm, PG_2: 25 cm × 20 cm, PG_3: 20 cm × 20 cm and PG_4: 20 cm × 15 cm) and Factor B: rice variety (3 rice varieties- V_1: BRRI dhan33, V_2: BRRI dhan62 and V_3: Chamak). The experiment was laid out in a randomized complete block design (RCBD) with three replications. In the case of planting geometry, the tallest plant (106.91 cm) at harvest was recorded from PG_3, whereas the shortest plant (101.60 cm) was found from PG_4. The longest panicle (24.87 cm) was recorded from PG_3 whereas the shortest panicle (20.64 cm) from PG_4. The highest grain yield (4.86 t ha^{-1}) was recorded from PG_3, while the lowest yield (3.70 t ha^{-1}) from PG_4. Moreover, the tallest plant (105.60 cm) was found from V_3, while the shortest plant (102.78 cm) from V_1. The longest panicle (25.26 cm) was observed from V_3, while the shortest panicle (20.99 cm) from V_1. The highest grain yield (5.16 t ha^{-1}) was observed from V_3, while the lowest yield (3.76 t ha^{-1}) from V_2. Due to the interaction effect of planting geometry and rice varieties, the tallest plant (111.06 cm) was observed from treatment combination of PG_3V_3 and the shortest plant (100.68 cm) from PG_4V_1. The longest panicle (27.70 cm) was observed from treatment combination of PG_3V_3 and the shortest panicle (19.50 cm) from PG_4V_1. The highest grain yield (5.72 t ha^{-1}) was observed from treatment combination of PG_3V_3 and the lowest yield (3.04 t ha^{-1}) from PG_4V_2. Planting geometry PG_3 (20 cm × 20 cm) appeared with highest yield and was fact in all the varieties under trial. However, Chamak showed higher yield over the varieties studied in the experiment.

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Chapter I

Introduction

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa*) is the most important food crop around the world and the staple food for approximately more than two billion people in the Asia (Hien *et al.,* 2006). Ninety percent of all rice is grown and consumed in Asia (Anon., 1997, Luh, 1991). The population of Bangladesh is increasing at an alarming rate and the cultivable land is reducing due to urbanization and industrialization resulting in shortage of food. The nation is still adding about 2.3 million every year to its total of 150 million people (Momin and Husain, 2009). Thus, the present population will swell progressively to 223 million by the year 2030 which will require additional 48 million tons of food grains (Julfiquar *et al*., 2008). Population growth demands a continuous increase in rice production in Bangladesh. So, the highest priority has been given to produce more rice (Bhuiyan, 2004). Production of rice has to be increased by at least 60% to meet up food requirement of the increasing population by the year 2020 (Masum, 2009).

In Bangladesh, the geographical, climatic and edaphic conditions are favorable for year round rice cultivation. However, the national average rice yield in Bangladesh (4.2 t ha^{-1}) is very low compared to those of other rice growing countries, like China (8.75 t ha^{-1}), Japan (8.22 t ha^{-1}) and Korea (8.04 t ha^{-1}) (FAO, 2009). In Bangladesh, rice dominates over all other crops and covers 75% of the total cropped area of which around 79% is occupied by high yielding rice varieties (BBS, 2008). Rice yield can be increased in many ways of them developing new high yielding variety and by adopting proper agronomic management practices to achieve their potential yield. Suitable planting geometry, the most obvious advantage to be the yield increase without any new seeds or chemical and mechanical inputs (Stoop *et al.*, 2002) and that is reported to be from 50% to 200% (Uphoff, 2005; Deichert and Yang, 2002; Wang *et al.*, 2002; Wang *et al.*, 2006).

Growth and yield of rice are strongly influenced by genotype as well as environmental factors (BRRI, 2003). The genetic potentiality of a rice variety is almost fixed, but grain yield can be increased by the manipulation of management practices and by growing in recommended season (IRRI, 1993; BRRI, 1999). Now a days different hybrid rice variety are available in Bangladesh which have more yield potential than conventional high yielding varieties (Akbar, 2004). Improvement of rice grain yield is the main target of breeding program to develop rice varieties for diverse ecosystems. However, grain yield is a complex trait, controlled by many genes and highly affected by environment (Jennings *et al*., 1979). In addition, grain yield also related with other characteristics such as plant type, growth duration and yield components (Yoshida, 1981). Very recently various new rice varieties were developed and available as BRRI dhan and maximum of them is exceptionally high yielding. On the other hand, compared with conventional cultivars, the hybrids had larger panicles, heavier seeds, resulting in an average yield increase of 7.27% (Bhuiyan *et al*., 2014). This variety however, needs further evaluation under different adaptive condition to interact with different environmental conditions.

There are three distinct rice growing seasons in Bangladesh namely *Aus*, *Aman* and *Boro*. Among these three, *Aman* rice covers only 56.87% of the rice growing area with average yield 3.45 t ha^{-1} (BBS, 2010). The rice yield in the *Aus* season is low as compared to the other growing seasons, which need to be improved. Based on above proposition, this research work was designed to evaluate the growth and yield performance of some selected hybrid rice varieties in different planting time with the following specific objectives:

- To find out the optimum planting geometry for the maximum production of rice,
- To find out the suitable variety in different planting geometry, and
- To observe the interaction effect of planting geometry and suitable variety for attaining highest yield in transplant aman rice.

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Yield and yield contributing characteristics of rice are considerably depended on manipulation of basic ingredients of agriculture. The basic ingredients include varieties of rice, environment and agronomic practices (planting time & density, fertilizer, irrigation etc.). Among the mentioned factors planting geometry and varieties are more responsible for the growth and yield of rice. High yielding varieties (HYV) are generally more adaptive to appropriate planting geometry. The available relevant reviews related to planting geometry and varieties in the recent past have been presented and discussed under the following headings:

2.1 Effect of planting geometry on rice

Planting geometry for successful rice production widely depends on varietal life duration, sensitivity to photoperiod, temperature, rainfall and other environmental factors. Some literature related to planting geometry on growth and yield of rice are reviewed below-

Wang *et al*. (2014) conducted an experiment to determine the effects of hill seeding density (25 cm × 15 cm, 25 cm × 17 cm, 25 cm × 19 cm, 25 cm × 21 cm, and 25 cm × 23 cm; three to five seeds per hill) on plant growth and grain yield of a hybrid variety, in two fields with different fertility and reported that with increases in seeding spacing from 25 cm × 15 cm to 25 cm × 23 cm, productive tillers per hill increased by 34.2%. Panicles per m^2 declined with increases in seeding spacing. Grain yield was the maximum at 25 cm × 17 cm spacing. Results suggest that a seeding density of 25 cm × 17 cm was suitable for high-yielding hybrid rice.

In order to investigation effect of planting date and planting density a field experiment was carried out by Moradpour *et al*. (2013) with planting date in 3 levels and planting density in 4 levels (17, 34, 51, 68 plant m^{-2}). Results showed that grain yield would be increased with increasing in plant density. Most grain yield (6403 kg ha^{-1}) was obtained in 68 plant m^{2}.

The experiment was conducted by Islam *et al*. (2013) to find out the effect of planting density on the performance of hybrid rice variety Aloran with different planting densities were maintained using different spacings and number of seedlings per hill. These include 25 cm × 20 cm, 25 cm × 10 cm, 20 cm × 10 cm, 20 cm × 15 cm with single seedling per hill and 20 cm × 15 cm with two seedlings per hill and 20 cm × 15 cm with three seedlings per hill. Density of 20 cm × 10 cm with 1 seedling hill^{-1} i.e. 50 hills m^{-2} produced the highest grain yield of 7.5 t ha^{-1} and 4.6 t ha^{-1} in DS and WS respectively, which was significantly higher than the yield with recommended density (20 cm × 15 cm with 1 seedling per hill).

Bozorgi *et al*. (2011) carried out a study with three levels of plant spacing (a : 15×15, a : 20×20 and a : 25×25 cm) and three levels of number of seedling per hill. Results showed that, highest grain yield among plant spacing levels was found from 15×15 cm treatment with 3415 kg ha^{-1}.

The field experiment was conducted by Sridhara *et al*. (2011) at College of Agriculture, Navile Farm, Shivamogga during Kharif to assess the response of genotypes, planting geometry and methods of establishment on root traits and yield of aerobic rice. The study revealed that among planting geometry, 30 cm × 30 cm recorded significantly higher root length (24.4 cm), root volume (60.30 cc), root number (154.2) and root weight (6.5 g) as compared to 45 cm × 20 cm. Direct seeded recorded significantly higher root length (25.9 cm), root volume (67.66 cc), root number (161.1) and root weight (7.6 g) compared to other methods. Significantly higher dry matter accumulation, number of panicles plant^{-1}, test weight was recorded in BI-43 with 30 cm × 30 cm spacing under direct seeding.

Krishna *et al.* (2008) conducted an investigation to evaluate the influence of system of rice intensification (SRI) on seed yield and quality in rice variety BPT-5204 was conducted at Agricultural Research Station (Paddy), Sirsi during kharif 2004-05. Wider spacing of 40 × 40 cm found to have significant influence on growth parameters.

Karmakar *et al*. (2004) reported that, conventional practice (25 cm ×15 cm spacing with 15 days old seedlings) gave higher yield that the SRI practices with wider spacing. Number of tillers and panicle per unit area were higher in closer spacing that contributed to obtain higher yield.

Mazid *et al.* (2003) found that conventional practices of rice cultivation gave significantly higher grain yield compared to the SRI method of crop establishment. SRI method with 30 cm × 30 cm and 40 cm × 40 cm spacing and younger seedlings increased number of panicles hill^{-1} but total number of panicles per unit area was found to be low.

Venkatachalapathy and Veerabadran (2002) conducted a field experiment at the Agricultural College and Research Institute, Killikulam, Tamil Nadu, India on wet-seeded rice cv. ADT-36. The highest yield was recorded in drum seeding with 2 cm intra row spacing. However, the net return per rupee invested was higher with drill seeding at 2 cm. Direct seeding an effective alternative technology to transplanting, since it gave more gain without extra expenditure.

Aziz and Hasan (2000) reported that in SRI practice, the average number of tillers hill^{-1} and effective tillers hill^{-1} were 117 and 103; respectively in Parija variety at Rajshahi. The highest number of effective tillers m^{-2} (531) was found with 35 cm × 35 cm spacing in Department of Agricultural Extension trials at Kishoregonj. But with the same spacing the number was 342 m^{-2} in locality intensified farming enterprises trials at Kishoregonj. On the other hand, in farmers practice the average number of effective tillers m^{-2} was 290 and 393 with 20 cm × 20 cm and 20 cm × 15 cm spacing, respectively. At Kisoregonj the average number of filled grains per panicle with 35 cm × 35 cm spacing was found more promising, which was 173 filled grains per panicle and 42 unfilled grains per panicle. At Rajshahi the average number of filled grains per panicle was 106 in case of SRI practice for local Parija variety and 70 in case of farmers practices. The grain weight was found 12% higher with SRI practice over farmers' practice (FP). The weight of 1000 grains was the lowest (18.75 g) with 20 cm × 15 cm spacing in case of farmers practice (FP) and the higher (28 g) with 40 cm × 40 cm spacing in case of SRI. Spacing of 35 cm × 35 cm showed better performance both at locally Intensified Farming Enterprises and Department of Agricultural Extension trial at Kishoregonj where the average yield was 7.5 and 8.9 t ha^{-1}, respectively. On the other hand, in case of farmers practice the average yields were 5.2 and 4.7 t ha^{-1} with 20 cm × 15 cm spacing, respectively.

Sorour *et al*. (1998) observed in field experiments in 1993-94 at Kafr El-Sheikh, Egypt, the short duration rice cultivar Giza 177 and the traditional cultivar Giza 176 were planted using the following methods: traditional transplanting (TT, no fixed number of hills or seedlings $hill^{-1}$), hand transplanting (HT) in hills at a spacing of 20 × 20 or 15 × 15 cm, mechanical transplanting (MT) in hills at a spacing of 30 × 14 or 30 × 12 cm, broadcasting (B), mechanical drilling (MD), or planted in puddled soil (D) in hills at a spacing of 20 × 20 cm or 15 × 15 cm. D 15 × 15 cm, HT 15 × 15 cm and MT 30 × 12 cm gave significantly better results than TT as regards dry matter production, LAI, crop growth rate, plant height, number of panicles m^{-2} and grain yield $feddan^{-1}$. The net assimilation rates for B, MD, TT and HT 20 × 20 cm exceeded those for other methods.

Rao (1990) conducted an experiment with plant derived from primary, secondary and tertiary tillers and transplanted at 20 × 10 cm spacing produced harvest index which were 45.3, 45.3, 9.1 and 45.1% for plants derived from primary, secondary and tertiary tillers and control plants respectively.

Rao *et al*. (1981) conducted a field experiment and reported that number of productive tillers m^{-2} were higher in local method of planting as compared to transplanting in 15 cm × 10 cm spacing but both grain yield and straw yield were higher in transplanting in row than local planting method with transplanting in 15 cm × 10 cm. They further found no significant difference in panicle length, number of grains and1000-grains weight between local planting method and transplanting in rows.

2.2 Effect of rice varieties

Rice is the staple food and around ninety per cent of rice is grown and consumed in south and Southeast Asia, the highly populated area. Bangladesh produces hybrid rice varieties and most of them have excellent production and eating quality for regular consumption. Different researcher reported the effect of rice varieties on yield contributing component and grain yield. However, some of the important and informative works and research findings related to the yield and quality of hybrid, so far been done at home and abroad, reviewed below-

2.2.1 Plant height

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of plant growth and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on plant height at maturity.

Two field experiments were conducted by Salem *et al*. (2011) at the Rice Research and Training Center (RRTC), Sakha, Kafr-El Sheikh Governorate, Egypt during summer seasons to study the effect of nitrogen fertilizer and seedling age on Giza 178, H1 and Sakha 101. The results indicated that Sakha 101 variety surpassed than other varieties in terms of plant height.

A field experiment was conducted by Khalifa (2009) at the experimental farm of Rice research and training centre (RRTC), Sakha, Kafr-El sheikh governorate, Egypt rice season for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 were evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties in terms of plant height.

Masum *et al*. (2008) found that plant height of rice affected by varieties in *Aman* season where Nizershail produced the taller plant height than BRRI dhan 44 at different days after transplanting (DAT).

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and observed that Mukti gave the longest plant compared to the others.

Chen-Liang *et al*. (2000) showed that the cross between Peiai 64s and the new plant type lines had longest plant height.

Xu and Li (1998) observed that the maintainer lines were generally shorter than restorer line.

Munoz *et al.* (1996) noted that IR8025A hybrid rice cultivar produced 16% longer plant than the commercial variety Oryzica Yacu-9.

BINA (1993) evaluated the performance of four rice varieties (IRAATOM 24, BR14, BINA dhan13 and BINA dhan19). It was found that varieties differed significantly in respect of plant height.

BRRI (1991) observed the plant height differed significantly among BR3, BR11, BR14, Pajam and Zagali varieties in the *Boro* season.

Hosain and Alam (1991) carried out an experiment and found that the plant height in modern rice varieties BR3, BR11, BR14 and Pajam were 90.4, 94.5, 81.3 and 100.7 cm, respectively.

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

Shamsuddin *et al*. (1988) conducted a field trial with nine different rice varieties and observed that plant height and other yield contributing characters and yield differed significantly among the varieties tested.

Sawant *et al*. (1986) conducted an experiment with the new rice lines R-73-1-1, R-711 and the traditional cv. Ratna and reported that the traditional cv. Ratna was the shortest.

2.2.2 Tillering pattern

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on number of tillers, number of productive tillers. RGBU010A × SL8R is therefore recommended as planting material among hybrid rice varieties because it produced more productive tillers.

A field experiment was conducted by Khalifa (2009) at the experimental farm of Rice research and training centre (RRTC), Sakha, Kafr-El sheikh governorate, Egypt for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 were evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties in consideration of effective and total tillers hill^{-1}.

Masum *et al*. (2008) stated that number of total tillers hill^{-1} was significantly influenced by cultivars at all stages of crop growth. Nizersail was achieved maximum (25.63) tiller at 45 DAT, then with advancement to age it declined up to maturity, whereas in the case of BRRI dhan44, maximum (18.92) tiller production was observed around panicle initiation stage at 60 DAT.

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and observed that Mukti gave the highest tillers hill^{-1} compared to the others.

Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers. They observed that CNHR2 produced more number of productive tillers (413.4 m^{-2}) than other tested varieties.

Ahmed *et al*. (1998) obtained 11 better maintainer lines with good maintainability for corresponding CMS lines in an evaluation program of 64 maintainers with respective CMS lines from different countries and recorded differences for number of effective tillers.

Devaraju *et al*. (1998) in a study with two rice hybrids, Karnataka Rice Hybrid 1 (KRHI) and Karnataka Rice Hybrid-2 (KRH2), using HYV IR20 as the check, found that 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 by BR10.

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 $hill^{-1}$.

BINA (1993) conducted an experiment with four varieties or advance lines (IRATOM24, BR14, BINA dhan13 and BINA dhan19) and reported significant variation in number of non-bearing tillers $hill^{-1}$.

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

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

2.2.3 Dry matter

In order to evaluate the response to planting date in rice hybrids Line dry method of working, was carried out by Shaloie *et al*. (2014) at the Agricultural Research Station, Agriculture and Natural Resources Research Center of Khuzestan Shavuor. Hybrid rice Hb2 and Hb1 was used in the sub plots. Results showed traits were significantly affected in terms of dry matter and mentioned trait was more in hybrid Hb_2 than Hb_1.

Masum *et al*. (2008) found that total dry matter production differed due to varieties. Total dry matter of BRRI dhan 44 Nizershail significantly varied at different sampling dates.

Xie *et al.* (2007) found that Shanyou-63 variety gave the higher yield (12 t ha^{-1}) compared to Xieyou46 variety (10 t ha^{-1}). Amin *et al.* (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (*viz.* Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (*viz.* KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety.

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

2.2.4 Panicle length, filled & unfilled grains panicle^{-1} and 1000-grains weight

An experiment was conducted by Hosain *et al*. (2014) at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during *Aus* season (March to July 2010) to observe the effect of transplanting dates on the yield and yield attributes of exotic hybrid rice varieties. The experiment comprised of three rice varieties (two hybrids-Heera2, Aloron and one inbred- BRRI dhan48). Hybrid varieties Heera2 (3.03 t ha^{-1}) and Aloron (2.77 t ha^{-1}) gave the higher spikelet sterility.

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on number of filled and unfilled grains, length of panicle and yield. RGBU010A × SL8R is therefore recommended as planting material among hybrid rice varieties because it produced longer panicles and heavy seeds. In the absence of this variety, RGBU02A × SL8R, RGBU003A × SL8R and RGBU0132A × SL8R may also be used as planting material.

In order to evaluate the response to planting date in rice hybrids Line dry method of working, was carried out by Shaloie *et al*. (2014) at the Agricultural Research Station, Agriculture and Natural Resources Research Center of Khuzestan Shavuor. Hybrid rice Hb2 and Hb1 was used in the sub plots. Results showed traits were significantly affected in terms of panicle length, fertility percentage, and mentioned traits was more in hybrid Hb_2 than Hb_1.

Forty five aromatic rice genotypes were evaluated by Kaniz Fatema *et al*. (2011) to assess the genetic variability and diversity on the basis of nine characters. Significant variations were observed among the genotypes for all the characters. Thousand grain weight have been found to contribute maximum towards genetic diversity in 45 genotypes of aromatic rice.

Two field experiments were conducted by Salem *et al*. (2011) at the Rice Research and Training Center (RRTC), Sakha, Kafr-El Sheikh Governorate, Egypt during summer seasons to study the effect of nitrogen fertilizer and seedling age on Giza 178, H1 and Sakha 101. The results indicated that Sakha 101 variety surpassed than other varieties in terms of 1000 seeds weight.

A field experiment was conducted by Khalifa (2009) at the experimental farm of Rice research and training centre (RRTC), Sakha, kafr- El sheikh governorate, Egypt in 2008 rice season for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 were evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties for studied characters except for number of days to panicle initiation and heading date.

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%.

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

Obulamma *et al.* (2004) recorded hybrid APHR 2 significantly higher grain yield than hybrid DRRH 1. The increased grain yield was due to increase in number of panicles m^{-2} and number of filled grain panicle^{-1} in hybrid APHR 2 than hybrid DRRH 1.

Guilani *et al*. (2003) studied on crop yield and yield components of rice cultivars (Anboori, Champa and LD183) in Khusestan, Iran. They observed that 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 the lowest.

BINA (1993) evaluated the performance of four varieties IRATOM 24, BR14, BINA dhan13 and BINA dhan19. They found that varieties differed significantly on panicle legth and sterile spikelets $panicle^{-1}$. It was also reported that varieties BINA dhan13 and BINA dhan19 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 $panicle^{-1}$ 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 the *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 C-14-8, CR-10009, 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 grain 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* 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 varieties tested.

2.2.5 Straw and grain yield

Kanfany *et al*. (2014) conducted an experiment by at the Africa Rice Sahel Regional Station during two wet seasons with the aim of assessing the performances of introduced hybrid cultivars along with an inbred check cultivar. There were significant cultivar effects for all traits. The grain yield of rice hybrids (bred by the International Rice Research Institute) was not significantly higher than that of the check cultivar widely grown in Senegal.

An experiment was conducted by Hosain *et al*. (2014) at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during *Aus* season to observe the effect of transplanting dates on the yield and yield attributes of exotic hybrid rice varieties. The experiment comprised of three rice varieties (two hybrids-Heera2, Aloron and one inbred- BRRI dhan48). BRRI dhan48 produced the highest grain yield (3.51 t ha^{-1}).

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on yield. RGBU010A × SL8R is therefore recommended as planting material among hybrid rice varieties because it produced favorable yield.

Samonte *et al*. (2011) reported that the two elite lines recommended for release are high yielding in Texas. RU0703190 is also very early maturing conventional long grain rice. The high yield potential of these new releases will impact grain production of rice farmers and their income. The germination and seedling cold tolerant donors that were identified will be useful in developing variety for early plantings.

Tabien and Samonte (2007) observed that several elite lines at the multi-state trials had high yield potential relative to the check varieties and these can be released as new varieties after series of yield trials. With improved yield, the new varieties are expected to increase rice production. The elite lines generated are also potential germplasm for rice improvement projects. The initial effort to identify high biomass rice will enhance the development of dedicated feedstock for bioenergy production.

Swain *et al*. (2006) 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 statistically similar to the hybrid line 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 the varietal performance of Kranti and IR36. He observed that Kranti produced significantly higher grain and straw yield than IR36 did. 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. It was reported that five hybrids (IR58025A × IR54056, IR54883, PMS8A × IR46R) out yielded the check varieties (BR14 and BR16) with significant yield difference. Two hybrids out yielded the check variety of same duration yielded 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 3.3 t ha^{-1} and 5.6 t ha^{-1}, respectively.

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

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 under the name Nemat, which gave an average grain yield of 8 t ha^{-1}, twice as much as local cultivars.

BRRI (1995) conducted an experiment to find out varietal performances of BR4, BR10, BR11, BR22, BR23 and BR25 varieties including two local check Challish and Nizersail, produced yields of 4.38, 3.18, 3.12, 3.12 and 2.70 5 t ha^{-1}, respectively.

Chowdhury *et al*. (1995) studied three native (Maloti, Nizersail and Chandrashail) and four improved (BR3, BR11, Pasam and Mala) variety and reported 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 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 rice cv. BR11 (weakly photosensitive), BR22, BR23 and Nizersail (strongly photosensitive) were sown at various intervals from July to September and transplanted from August to October. Among the cv. BR22 gave the highest grain yield from most of the sowing dates for both of the years (Ali *et al*., 1993). Chowdhury *et al*. (1993) reported that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e. grain yield straw yield.

Suprihatno and Sutaryo (1992) conducted an experiment with seven IRRI hybrids and 13 Indonesian hybrids using IR64 and way-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 × 9761-191R and IR58025A IR58025A × 1R35366-62-1-2-2-3R.

Hosain and Alam (1991) 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).

From the above literature, it is evident that planting geometry and varieties have a significant influence on yield and yield components of rice. The literature suggests that optimum planting geometry and suitable variety increases the grain yield of rice. Reduction in grain yield is mainly attributed by the reduced number of tiller $hill^{-1}$, grains $panicle^{-1,}$ panicle length and thousand grain weight due to restriction of development of these parameters for the effect of planting geometry and variety itself.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to evaluate the yield and yield components of transplanted aman rice grown under different planting geometries. The details of the materials and methods i.e. location of experiment, soil and climate condition of the experimental plot, materials used, design of the experiment, data collection procedure and procedure of data analysis that followed in this experiment has been presented under the following headings:

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from June 2013 to November 2013.

3.1.2 Site description

The present piece of research work was conducted in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude with an elevation of 8.2 meter from sea level.

3.1.3 Climatic condition

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by three distinct seasons, namely winter season from the month of November to February, the pre-monsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris *et al.*, 1979). Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment has been presented in Appendix I.

3.1.4 Soil characteristics of the experimental plot

The soil belonged to "The Modhupur Tract", AEZ-28 (FAO, 1988). Top soil was Silty Clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and had organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details have been presented in Appendix II.

3.2 Experimental details

3.2.1 Planting material

BRRI dhan33, BRRI dhan62 and Chamak were used as the test crop in this experiment.

3.2.2 Treatment of the experiment

The experiment comprised of two factors.

Factor A: Planting geometry: 4 levels

i. PG_1: 25 cm × 25 cm

ii. PG_2: 25 cm × 20 cm

iii. PG_3: 20 cm × 20 cm

iv. PG_4: 20 cm × 15 cm

Factor B: Different rice variety: 3 rice varieties

i. V_1: BRRI dhan33

ii. V_2: BRRI dhan62

iii. V_3: Chamak

As such there were 12 treatments combinations viz. PG_1V_1, PG_1V_2, PG_1V_3, PG_1V_4, PG_1V_5, PG_1V_6, PG_2V_1, PG_2V_2, PG_2V_3, PG_2V_4, PG_2V_5 and PG_2V_1.

3.3.2 Experimental design and layout

The experiment was laid out in a randomized complete block design (RCBD) with three replications, where the experimental area was divided into three blocks representing the replications to reduce soil heterogenetic effects. Each block was divided into 12 unit plots as treatments demarked with raised bunds. Thus the total numbers of plots were 36. The unit plot size was 3.0 m × 2.0 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

3.3 Growing of crops

3.3.1 Seed collection and sprouting

Seeds were collected from BRRI (Bangladesh Rice Research Institute), Gazipur and local market just 20 days ahead of the sowing of seeds in seed bed. Seeds were immersed in water in a bucket for 24 hours. The imbibed seeds were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 72 hours.

3.3.2 Raising of seedlings

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown on beds as uniformly as possible. Irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed.

3.3.3 Land preparation

The plot selected for conducting the experiment was opened in the second week of July 2013 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. Weeds and stubbles were removed. The experimental plot was partitioned into unit plots in accordance with the experimental design. Organic and inorganic manures as indicated below were mixed with the soil of each unit plot.

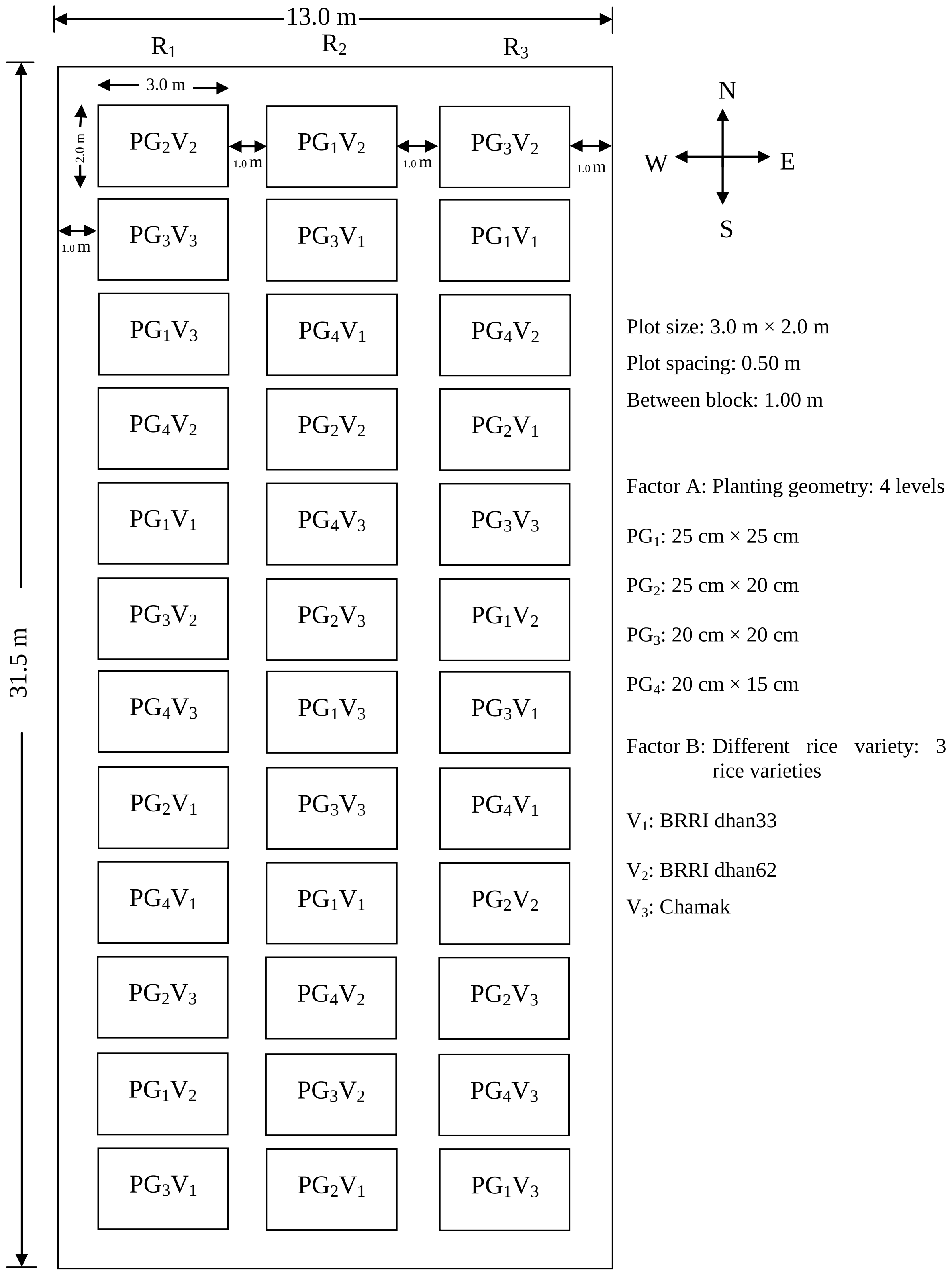


Figure 1. Layout of the experimental plot

3.3.4 Fertilizers and manure application

The fertilizers N, P, K, S, Zn and B in the form of USG, TSP, MoP, Gypsum, zinc sulphate and borax, respectively were applied @ 80 kg, 60 kg, 90 kg, 12 kg, 2.0 kg and 10 kg (BRRI, 2013). Urea was applied as urea super granule (USG). The entire amount of TSP, MoP, gypsum, zinc sulphate and borax were applied during the final preparation of land. USG was applied in two equal installments at tillering and panicle initiation stages.

3.3.5 Transplanting of seedling

Twenty five days old seedlings were carefully uprooted from the seedling nursery and transplanted on 25 July, 2013 in well puddled plot. Three seedlings $hill^{-1}$ were used following spacing as per treatment. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings of the same source whenever required.

3.3.6 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.3.6.1 Irrigation and drainage

Irrigation was provided to maintain a constant level of standing water upto 6 cm in the early stages to establishment of the seedlings and then maintained the amount drying and wetting system throughout the entire vegetative phase. No water stress was encountered in reproductive and ripening phase. The plot was finally dried out at 15 days before harvesting.

3.3.6.2 Weeding

Weedings were done to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at 30 DAT and 60 DAT by mechanical means.

3.3.6.3 Insect and pest control

There was no infection of diseases in the field but leaf roller (*Chaphalocrosis medinalis*) was found in the field and used Malathion @ 1.12 L ha^{-1} at 30 DAT with using a hand sprayer.

3.4 Harvesting, threshing and cleaning

The crop was harvested at full maturity at 26 November when 80-90% of the grains were turned into straw colored. The harvested crop was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during threshing and cleaning period of rice grain. Fresh weight of rice grain and straw were recorded plot wise from 1 m^2 area. The grains were dried, cleaned and weighed for individual plot. The weight was adjusted to a moisture content of 14%. Yields of rice grain and straw 1 m^{-2} were recorded from each plot and converted to t ha^{-1}.

3.5 Data recording

3.5.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 30, 50, 70, 90 days after transplanting and at harvesting stage. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the panicle or flag leaf.

3.5.2 Number of tillers $hill^{-1}$

Number of tillers $hill^{1}$ was recorded at 30, 50, 70 and 90 days after transplanting. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.5.3 Total dry matter $hill^{-1}$

Total dry matter $hill^{-1}$ was recorded at 30, 50, 70 and 90 days after transplanting by drying plant sample. Data were recorded as the average of 3 sample $hill^{-1}$ collected at random from the inner rows of each plot and expressed in gram.

3.5.4 Effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tiller during harvesting. Data on effective tillers hill^{-1} were counted from 10 selected hills and average value was recorded.

3.5.5 Non-effective tillers hill^{-1}

The total number of non-effective tiller hill^{-1} was counted as the number of non-panicle bearing tiller during harvesting. Data on non effective tiller hill^{-1} were counted from 10 selected hills and average value was recorded.

3.5.6 Total tillers hill^{-1}

The total number of tiller hill^{-1} was counted as the number of effective tillers hill^{-1} and non-effective tillers hill^{-1}. Data on total tillers hill^{-1} were counted from 10 selected hills and average value was recorded.

3.5.7 Panicle length

The length of panicle was measured with a meter scale from 10 selected panicle and the average length was recorded as per panicle in cm.

3.5.8 Filled grains panicle^{-1}

The total numbers of filled grain were collected randomly from selected 10 panicle of a plot on the basis of grain in the spikelet and then average numbers of filled grains panicle^{-1} was recorded.

3.5.9 Unfilled grains panicle^{-1}

The total numbers of unfilled grain was collected randomly from selected 10 plants of a plot on the basis of not grain in the spikelet and then average numbers of unfilled grains panicle^{-1} was recorded.

3.5.10 Total grains panicle^{-1}

The total numbers of grain was collected randomly from selected 10 plants of a plot by adding filled and unfilled grain and then average numbers of grains panicle^{-1} was recorded.

3.5.11 Weight of 1000-grain

One thousand grains were counted randomly from the total cleaned harvested grains and then weighed in grams and recorded.

3.5.12 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central 1 m^2 area in each plot were taken the final grain yield $plot^{-1}$ and finally converted to ton $hectare^{-1}$ (t ha^{-1}).

3.5.13 Straw yield

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of central 1 m^2 area was taken from each plot and finally converted to ton $hectare^{-1}$ (t ha^{-1}).

3.5.14 Biological yield

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

Biological yield = Grain yield + Straw yield.

3.5.15 Harvest index

Harvest index was calculated from the grain and straw yield of rice for each plot and expressed in percentage.

$$HI = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (total dry weight)}} \times 100$$

3.6 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatments. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

Chapter IV

Results and Discussion

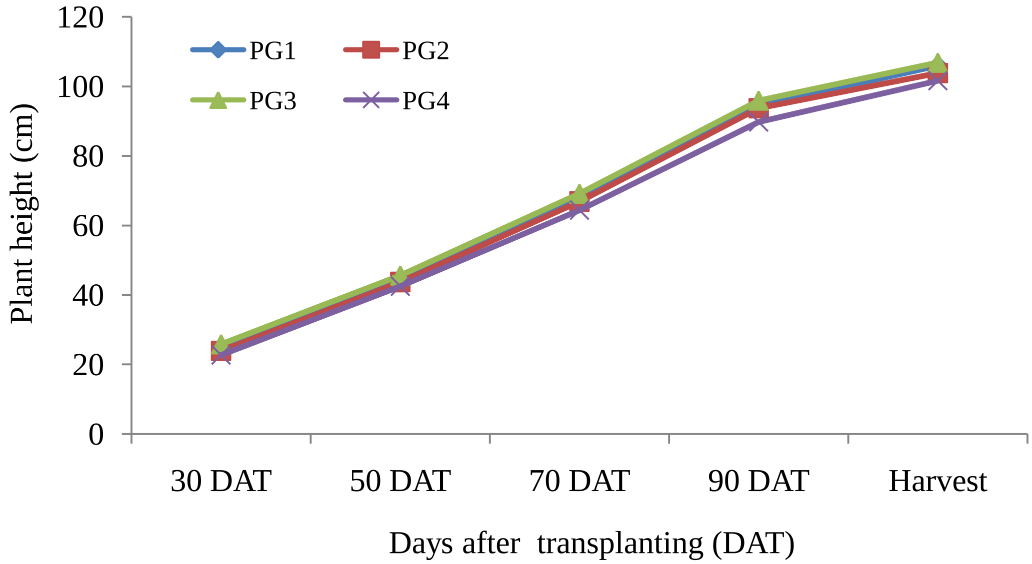
CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted in transplanted aman season to evaluate the yield and yield components of transplanted aman rice grown under different planting geometries. Data on different yield contributing characters and yield were recorded. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix III-VII. The results have been presented with the help of table and graphs and possible interpretations have been given under the following headings:

4.1 Plant height

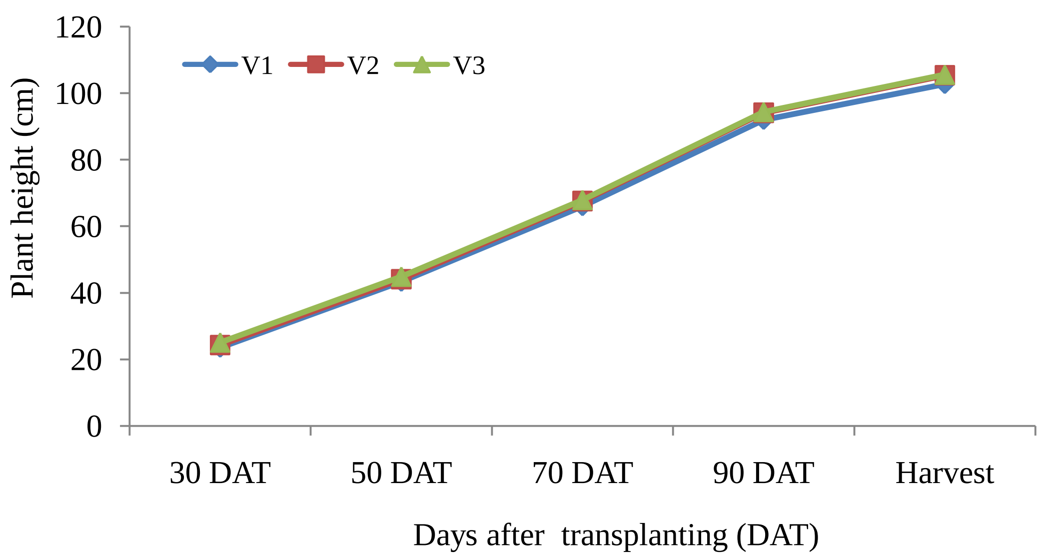
Plant height showed statistically significant variation due to different planting geometry at 30, 50, 70, 90 days after transplanting (DAT) and at harvest (Figure 2). Data revealed that at 30, 50, 70, 90 DAT and harvest, the tallest plant (25.86, 45.66, 69.20, 95.99 and 106.91 cm, respectively) was recorded from PG_3 (20 cm × 20 cm) which was statistically similar (24.74, 44.54, 68.25, 94.47 and 105.96 cm, respectively) with PG_1 and followed (23.95, 43.75, 66.93, 93.74 and 103.85 cm, respectively) by PG_2 (25 cm × 20 cm), whereas the shortest plant (22.73, 42.53, 64.41, 89.76 and 101.60 cm, respectively) was found from PG_4 (20 cm × 15 cm). Krishna *et al.* (2008) reported that wider spacing of 40 × 40 cm found to have significant influence on growth parameters. Data revealed that at different days after transplanting of rice seedling produced different plant height due to different rice variety that used in the present experiment. Varieties produced different plant height on the basis of their varietal characters and also genetical influences but environmental and different management practices also influences different growth parameters as well as plant height. Khalifa (2009) reported earlier that H_1 hybrid rice variety surpassed other varieties in terms of plant height. Bhuiyan *et al*. (2014) reported earlier significant effects on plant height at maturity for different rice variety.



PG_1: 25 cm × 25 cm PG_2: 25 cm × 20 cm

PG_3: 20 cm × 20 cm PG_4: 20 cm × 15 cm

Figure 2. Effect of planting geometry on plant height of rice (LSD$_{(0.05)}$ = 1.320, 1.326, 1.711, 2.254 and 2 .181 for 30, 50, 70, 90 DAT and at harvest, respectively)



V_1: BRRI dhan33 V_2: BRRI dhan62

V_3: Chamak

Figure 3. Effect of rice varieties on plant height of rice (LSD$_{(0.05)}$ = 1.143, 1.149, 1.482, 1.952 and 1.888 for 30, 50, 70, 90 DAT and at harvest, respectively

Different rice varieties varied significantly in terms of plant height at 30, 50, 70, 90 DAT and at harvest (Figure 3). At 30, 50, 70, 90 DAT and harvest, the tallest plant (25.05, 44.85, 67.93, 94.38 and 105.60 cm, respectively) was observed from V_3 (Chamak), which was statistically similar (24.33, 44.13, 67.58, 94.09 and 105.60 cm, respectively) with V_2 (BRRI dhan62), while the shortest plant (23.58, 43.38, 66.08, 92.01 and 102.78 cm, respectively) from V_1 (BRRI dhan33). Varieties produced different plant height on the basis of their varietal characters and also genetical influences but environmental and different management practices also influences different growth parameters as well as plant height. Khalifa (2009) reported earlier that H_1 hybrid rice variety surpassed other varieties in terms of plant height. Bhuiyan *et al*. (2014) reported earlier significant effects on plant height at maturity for different rice variety.

Interaction effect of different planting geometry and rice varieties showed significant variation on plant height of at 30, 50, 70, 90 DAT and at harvest (Table 1). At 30, 50, 70, 90 DAT and harvest, the tallest plant (27.72, 47.52, 72.71, 98.83 and 111.06 cm, respectively) was observed from treatment combination of PG_3V_3 (20 cm × 20 cm + Chamak) and the shortest plant (22.25, 42.05, 64.23, 88.35 and 100.68 cm, respectively) was recorded from treatment combination of PG_4V_1 (20 cm × 15 cm + BRRI dhan33).

4.2 Number of tillers hill^{-1}

Statistically significant variation was recorded for number of tillers hill^{-1} due to different planting geometry at 30, 50, 70 and 90 DAT (Table 2). At 30, 50, 70 and 90 DAT, the maximum number of tillers hill^{-1} (5.47, 13.04, 16.56 and 19.78, respectively) was found from PG_3 which was followed (5.40, 12.36, 16.07 and 1833, respectively) with PG_1, whereas the minimum number (4.49, 11.09, 14.67 and 15.93, respectively) from PG_4. Karmakar *et al*. (2004) reported that number of tillers and panicles per unit area were higher in closer spacing. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all agronomic parameters including number of tillers hill^{-1} in SRI system.

Table 1. Interaction effect of planting geometry and variety of T. aman rice on plant height at different days after transplanting (DAT)

Treatments combination	Plant height (cm)				
	30 DAT	50 DAT	70 DAT	90 DAT	Harvest
PG_1V_1	25.08 bc	44.88 bc	68.18 bc	95.14 abc	105.96 bc
PG_1V_2	24.82 bcd	44.62 bcd	69.21 b	94.20 bcd	106.63 bc
PG_1V_3	24.33 bcd	44.13 bcd	67.36 bcd	94.05 bcd	105.31 bcd
PG_2V_1	23.90 cd	43.70 cd	66.94 bcd	93.34 cd	103.44 cde
PG_2V_2	23.50 cd	43.30 cd	66.60 bcd	94.12 bcd	104.60 bcde
PG_2V_3	24.44 bcd	44.24 bcd	67.27 bcd	93.77 bcd	103.52 cde
PG_3V_1	23.08 cd	42.88 cd	64.98 cd	91.19 cde	101.03 de
PG_3V_2	26.77 ab	46.57 ab	69.91 ab	97.95 ab	108.64 ab
PG_3V_3	27.72 a	47.52 a	72.71 a	98.83 a	111.06 a
PG_4V_1	22.25 d	42.05 d	64.23 d	88.35 e	100.68 e
PG_4V_2	22.24 d	42.04 d	64.60 d	90.10 de	101.62 de
PG_4V_3	23.70 cd	43.50 cd	64.39 d	90.84 cde	102.50 cde
$LSD_{(0.05)}$	2.286	2.298	2.963	3.903	3.777
CV(%)	5.55	6.06	4.60	5.47	6.13

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

PG_1: 25 cm × 25 cm
PG_2: 25 cm × 20 cm
PG_3: 20 cm × 20 cm
PG_4: 20 cm × 15 cm

V_1: BRRIdhan33
V_2: BRRIdhan62
V_3: Chamak

Table 2. Effect of planting geometry and variety of T. aman rice on number of tillers hill^{-1} at different days after transplanting (DAT)

Treatments	Number of tillers hill^{-1}			
	30 DAT	50 DAT	70 DAT	90 DAT
Planting Geometry				
PG_1	5.40 a	12.36 b	16.07 a	18.33 b
PG_2	4.93 b	12.27 b	15.71 ab	16.89 c
PG_3	5.47 a	13.04 a	16.56 a	19.78 a
PG_4	4.49 c	11.09 c	14.67 b	15.93 c
$LSD_{(0.05)}$	0.172	0.500	1.072	1.072
Variety				
V_1	4.47 b	11.48 c	14.83 b	16.20 c
V_2	5.32 a	12.30 b	15.42 b	17.22 b
V_3	5.43 a	12.78 a	17.00 a	19.78 a
$LSD_{(0.05)}$	0.149	0.433	0.929	0.929
CV(%)	5.49	4.19	6.96	6.19

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

PG_1: 25 cm × 25 cm

PG_2: 25 cm × 20 cm

PG_3: 20 cm × 20 cm

PG_4: 20 cm × 15 cm

V_1: BRRIdhan33

V_2: BRRIdhan62

V_3: Chamak

Number of tillers hill^{-1} varied significantly due to different rice varieties at 30, 50, 70 and 90 DAT (Table 2). At 30, 50, 70 and 90 DAT, the maximum number of tillers hill^{-1} (5.43, 12.78, 17.00 and 19.78, respectively) was recorded from V_3, which was followed (5.32, 12.30, 15.42 and 17.22, respectively) with V_2, while the minimum number (4.47, 11.48, 14.83 and 16.20, respectively) from V_1.

Different planting geometry and rice varieties showed significant variation due to interaction effect on number of tillers hill^{-1} at 30, 50, 70 and 90 DAT (Table 3). At 30, 50, 70 and 90 DAT, the maximum number of tillers hill^{-1} (5.93, 14.40, 18.93 and 23.13, respectively) was obtained from treatment combination of PG_3V_3 and the minimum number (4.13, 10.60, 13.47 and 14.93, respectively) was found from treatment combination of PG_4V_1.

4.3 Dry matter content hill^{-1}

Dry matter content hill^{-1} showed statistically significant variation due to different planting geometry at 30, 50, 70 and 90 DAT (Table 4). At 30, 50, 70 and 90 DAT, the highest dry matter content hill^{-1} (4.51, 5.59, 8.12 and 9.30 g, respectively) was recorded from PG_3 which was statistically similar (4.29, 5.45, 7.83 and 9.06 g, respectively) with PG_2, while the lowest (3.61, 5.29, 7.10 and 8.05 g, respectively) from PG_4. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all agronomic parameters including dry matter hill^{-1} in SRI system. Sridhara *et al*. (2011) reported that significantly higher dry matter accumulation was recorded in BI-43 with 30 cm × 30 cm spacing under direct seeding.

Different rice varieties varied significantly in terms of dry matter content hill^{-1} at 30, 50, 70 and 90 DAT (Table 4). At 30, 50, 70 and 90 DAT, the highest dry matter content hill^{-1} (4.52, 5.68, 8.13 and 9.53 g, respectively) was observed from V_3, which was followed (4.14, 5.58, 7.97 and 8.88 g, respectively) by V_1, whereas the lowest (3.80, 5.09, 6.95 and 8.20 g, respectively) from V_2. Similar results also reported by Amin *et al*. (2006), Son *et al*. (1998) and Shaloie *et al*. (2014) from their earlier experiment.

Table 3. Interaction effect of planting geometry and variety of T. aman rice on number of tillers hill^{-1} at different days after transplanting (DAT)

Treatments combination	Number of tillers hill^{-1}			
	30 DAT	50 DAT	70 DAT	90 DAT
PG_1V_1	4.67 cd	12.00 cde	15.47 bcd	17.27 cd
PG_1V_2	5.73 a	12.27 cd	15.60 bc	18.00 bcd
PG_1V_3	5.80 a	12.80 bc	17.13 ab	19.73 b
PG_2V_1	4.40 de	12.13 cde	15.67 bc	16.07 de
PG_2V_2	5.20 b	12.47 cd	15.40 bcd	16.60 cde
PG_2V_3	5.20 b	12.20 cd	16.07 bc	18.00 bcd
PG_3V_1	4.67 cd	11.20 efg	14.73 cd	16.53 cde
PG_3V_2	5.80 a	13.53 b	16.00 bc	19.67 b
PG_3V_3	5.93 a	14.40 a	18.93 a	23.13 a
PG_4V_1	4.13 e	10.60 g	13.47 d	14.93 e
PG_4V_2	4.53 cd	10.93 fg	14.67 cd	14.60 e
PG_4V_3	4.80 c	11.73 def	15.87 bc	18.27 bc
$LSD_{(0.05)}$	0.298	0.865	1.857	1.857
CV(%)	5.49	4.19	6.96	6.19

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

PG_1: 25 cm × 25 cm
PG_2: 25 cm × 20 cm
PG_3: 20 cm × 20 cm
PG_4: 20 cm × 15 cm

V_1: BRRIdhan33
V_2: BRRIdhan62
V_3: Chamak

Table 4. Effect of planting geometry and variety of T. aman rice on dry matter content hill^{-1} at different days after transplanting (DAT)

Treatments	Dry matter content (g) hill^{-1}			
	30 DAT	50 DAT	70 DAT	90 DAT
Planting Geometry				
PG_1	4.21 a	5.47 a	7.69 b	9.07 a
PG_2	4.29 a	5.45 a	7.83 ab	9.06 a
PG_3	4.51 a	5.59 a	8.12 a	9.30 a
PG_4	3.61 b	5.29 b	7.10 c	8.05 b
$LSD_{(0.05)}$	0.380	0.148	0.329	0.376
Variety				
V_1	4.15 b	5.58 a	7.97 a	8.88 b
V_2	3.80 c	5.09 b	6.95 b	8.20 c
V_3	4.52 a	5.68 a	8.13 a	9.53 a
$LSD_{(0.05)}$	0.329	0.128	0.285	0.326
CV(%)	9.36	5.79	4.37	5.34

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

PG_1: 25 cm × 25 cm

PG_2: 25 cm × 20 cm

PG_3: 20 cm × 20 cm

PG_4: 20 cm × 15 cm

V_1: BRRIdhan33

V_2: BRRIdhan62

V_3: Chamak

Interaction effect of different planting geometry and rice varieties showed significant variation on dry matter content hill^{-1} at 30, 50, 70 and 90 DAT (Table 5). At 30, 50, 70 and 90 DAT, the highest dry matter content hill^{-1} (5.07, 5.97, 9.14 and 9.92 g, respectively) was observed from treatment combination of PG_3V_3, while the lowest (3.12, 5.02, 6.61 and 7.15 g, respectively) was recorded from treatment combination of PG_4V_2.

4.4 Effective tillers hill^{-1}

Effective tillers hill^{-1} showed statistically significant variation due to different planting geometry (Table 6). The maximum number of effective tillers hill^{-1} (20.20) was recorded from PG_3 which was statistically similar with PG_1 (19.40) and followed by PG_2 (18.96) whereas the minimum number from PG_4 (16.58). Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all agronomic parameters including number of effective tillers hill^{-1} in SRI system.

Different rice varieties varied significantly in terms of number of effective tillers hill^{-1} (Table 6). The maximum number of effective tillers hill^{-1} (20.65) was observed from V_3, which was followed by V_2 (18.80), whereas the minimum number from V_1 (16.90).

Interaction effect of different planting geometry and rice varieties showed significant variation on number of effective tillers hill^{-1} (Table 7). The maximum number of effective tillers hill^{-1} (22.80) was observed from treatment combination of PG_3V_3 and the minimum number (15.40) was recorded from treatment combination of PG_4V_1.

4.5 Non-effective tillers hill^{-1}

Non-effective tillers hill^{-1} varied significantly due to different planting geometry (Table 6). The maximum number of non-effective tillers hill^{-1} (2.82) was recorded from PG_1 which was followed (2.64 and 2.56) by PG_4 and PG_2, respectively, whereas the minimum number (2.33) from PG_3. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all agronomic parameters including number of ineffective tillers hill^{-1}.

Table 5. Interaction effect of planting geometry and variety of T. aman rice on dry matter content hill^{-1} at different days after transplanting (DAT)

Treatments combination	Dry matter content (g) hill^{-1}			
	30 DAT	50 DAT	70 DAT	90 DAT
PG_1V_1	4.44 abc	5.64 b	8.19 b	9.55 ab
PG_1V_2	3.74 cd	5.06 e	7.03 de	8.30 de
PG_1V_3	4.44 abc	5.72 ab	7.86 bc	9.36 abc
PG_2V_1	4.19 bc	5.65 b	8.23 b	9.23 abc
PG_2V_2	4.03 bc	5.05 e	7.03 de	8.05 e
PG_2V_3	4.66 ab	5.67 b	8.23 b	9.90 a
PG_3V_1	4.17 bc	5.55 bc	8.07 b	8.67 cde
PG_3V_2	4.30 bc	5.24 de	7.15 de	9.30 abc
PG_3V_3	5.07 a	5.97 a	9.14 a	9.92 a
PG_4V_1	3.81 cd	5.49 bcd	7.39 cd	8.08 e
PG_4V_2	3.12 d	5.02 e	6.61 e	7.15 f
PG_4V_3	3.90 c	5.36 cd	7.31 cd	8.93 bcd
$LSD_{(0.05)}$	0.658	0.257	0.569	0.651
CV(%)	9.36	5.79	4.37	5.34

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

PG_1: 25 cm × 25 cm V_1: BRRIdhan33

PG_2: 25 cm × 20 cm V_2: BRRIdhan62

PG_3: 20 cm × 20 cm V_3: Chamak

PG_4: 20 cm × 15 cm

Table 6. Effect of planting geometry and variety on yield contributing characters of T. aman rice

Treatments	Effective tillers $hill^{-1}$ (No.)	Non-effective tillers $hill^{-1}$ (No.)	Panicle length (cm)	Filled grain $panicle^{-1}$ (No.)	Unfilled grains $panicle^{-1}$ (No.)
Planting Geometry					
PG_1	19.40 ab	2.82 a	24.66 ab	82.47 a	7.98 b
PG_2	18.96 b	2.56 b	23.36 b	80.71 a	7.60 c
PG_3	20.20 a	2.33 c	24.87 a	83.80 a	7.40 c
PG_4	16.58 c	2.64 b	20.64 c	75.52 b	9.27 a
$LSD_{(0.05)}$	0.902	0.131	1.390	3.239	0.288
Variety					
V_1	16.90 c	2.68 a	20.99 c	73.93 b	7.87 b
V_2	18.80 b	2.53 b	23.89 b	82.64 a	8.13 a
V_3	20.65 a	2.55 b	25.26 a	85.30 a	8.18 a
$LSD_{(0.05)}$	0.781	0.114	1.204	2.805	0.250
CV(%)	4.91	5.19	6.08	4.11	5.65

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

PG_1: 25 cm × 25 cm

PG_2: 25 cm × 20 cm

PG_3: 20 cm × 20 cm

PG_4: 20 cm × 15 cm

V_1: BRRIdhan33

V_2: BRRIdhan62

V_3: Chamak

Table 7. Interaction effect of planting geometry and variety on yield contributing characters of T. aman rice

Treatments combination	Effective tillers $hill^{-1}$ (No.)	Non-effective tillers $hill^{-1}$ (No.)	Panicle length (cm)	Filled grain $panicle^{-1}$ (No.)	Unfilled grains $panicle^{-1}$ (No.)
PG_1V_1	18.27 de	2.87 a	22.30 b	76.33 cd	8.07 b
PG_1V_2	19.40 bcd	2.87 a	25.77 a	85.60 ab	8.00 b
PG_1V_3	20.53 bc	2.73 ab	25.90 a	85.47 ab	7.87 b
PG_2V_1	17.00 ef	2.73 ab	21.90 bc	75.20 cd	7.73 b
PG_2V_2	19.13 cd	2.53 bc	22.87 b	80.67 bc	7.53 b
PG_2V_3	20.73 bc	2.40 c	25.30 a	86.27 ab	7.53 b
PG_3V_1	16.93 ef	2.33 c	20.27 bc	72.60 d	6.67 c
PG_3V_2	20.87 b	2.33 c	26.63 a	88.20 a	7.67 b
PG_3V_3	22.80 a	2.33 c	27.70 a	90.60 a	7.87 b
PG_4V_1	15.40 f	2.80 a	19.50 c	71.60 d	9.00 a
PG_4V_2	15.80 f	2.40 c	20.30 bc	76.10 cd	9.33 a
PG_4V_3	18.53 de	2.73 ab	22.13 bc	78.87 c	9.47 a
$LSD_{(0.05)}$	1.562	0.227	2.407	5.610	0.500
CV(%)	4.91	5.19	6.08	4.11	5.65

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

PG_1: 25 cm × 25 cm
PG_2: 25 cm × 20 cm
PG_3: 20 cm × 20 cm
PG_4: 20 cm × 15 cm

V_1: BRRIdhan33
V_2: BRRIdhan62
V_3: Chamak

Different rice varieties varied significantly in terms of number of non-effective tillers $hill^{-1}$ (Table 6). The maximum number of non-effective tillers $hill^{-1}$ (2.68) was observed from V_1, while the minimum number (2.53) from V_2 which was statistically similar with V_3 (2.55).

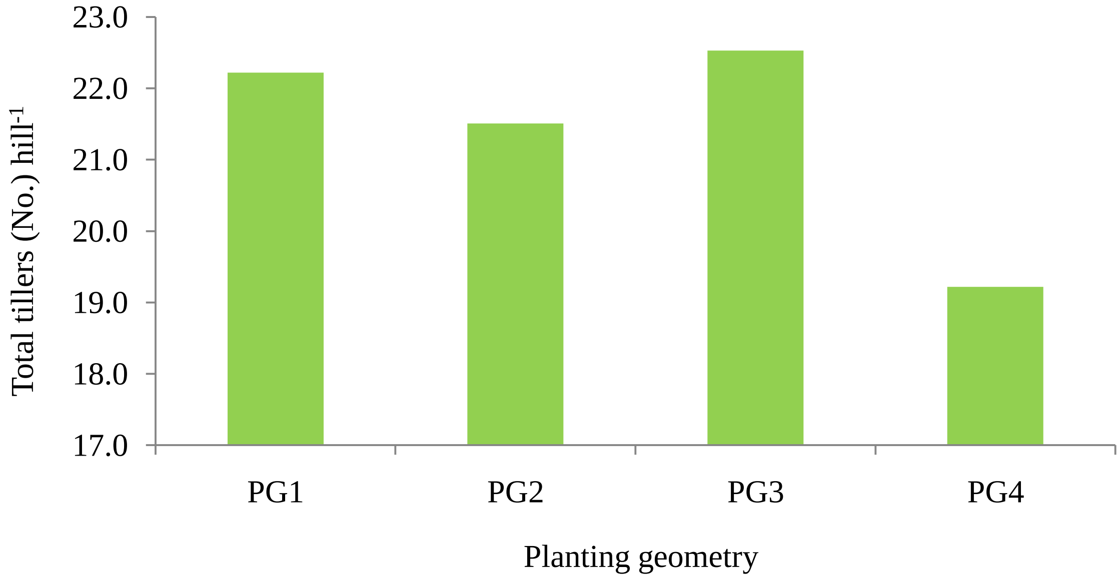
Interaction effect of different planting geometry and rice varieties showed significant variation on number of non-effective tillers $hill^{-1}$ (Table 7). The maximum number of non-effective tillers $hill^{-1}$ (2.87) was observed from treatment combination of PG_1V_1 and PG_1V_2, while the minimum number (2.33) was recorded from treatment combination of PG_3V_1, PG_3V_2 and PG_3V_3.

4.6 Total tillers $hill^{-1}$

Number of total tillers $hill^{-1}$ showed statistically significant variation due to different planting geometry (Figure 4). The maximum number of total tillers $hill^{-1}$ (22.53) was recorded from PG_3 which was statistically similar (22.22) with PG_1 and followed (21.51) by PG_2 whereas the minimum number (19.22) from PG_4. Bhuiyan *et al*. (2014) recommended hybrid rice varieties because it produced more productive tillers.

Different rice varieties varied significantly in terms of number of total tillers $hill^{-1}$ (Figure 5). The maximum number of total tillers $hill^{-1}$ (23.20) was observed from V_3, which was followed (21.33) by V_2, whereas the minimum number (19.58) was recorded from V_1. Devaraju *et al*. (1998) also reported Rice Hybrid-2 (KRH2) produced highest tiller number than the others variety.

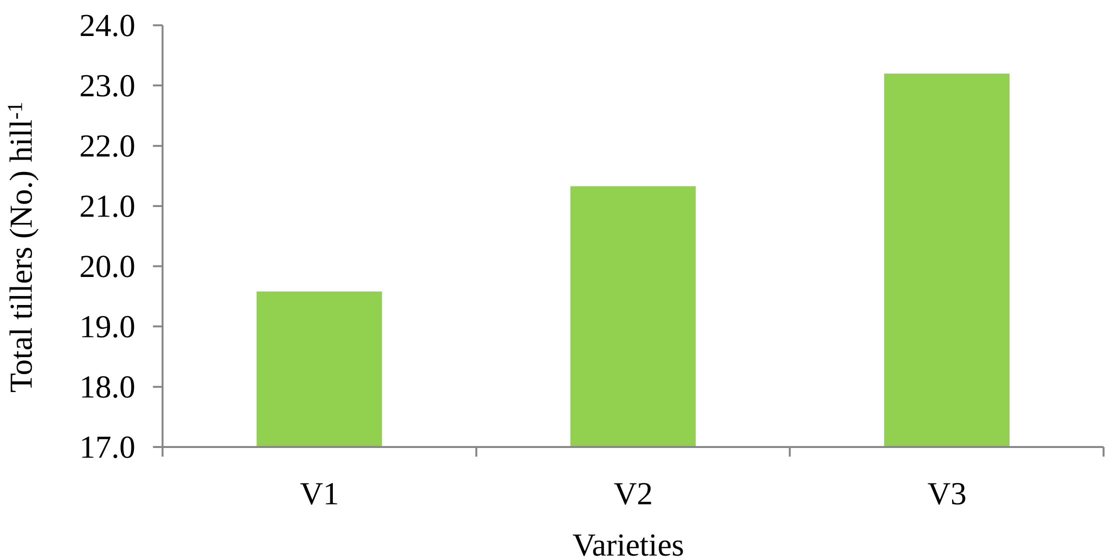
Interaction effect of different planting geometry and rice varieties showed significant variation on number of total tillers $hill^{-1}$ (Figure 6). The maximum number of total tillers $hill^{-1}$ (25.13) was observed from treatment combination of PG_3V_3, while the minimum number (18.20) was recorded from treatment combination of both PG_4V_1 and PG_4V_2.



PG_1: 25 cm × 25 cm PG_2: 25 cm × 20 cm

PG_3: 20 cm × 20 cm PG_4: 20 cm × 15 cm

Figure 4. Effect of planting geometry on number of total tillers hill^{-1} of rice (LSD $_{(0.05)}$ = 0.900)



V_1: BRRI dhan33 V_2: BRRI dhan62

V_3: Chamak

Figure 5. Effect of rice varieties on number of total tillers hill^{-1} of rice (LSD$_{(0.05)}$= 0.780)

4.7 Panicle length (cm)

Panicle length showed statistically significant variation due to different planting geometry (Table 6). The longest panicle (24.87 cm) was recorded from PG_3 which was statistically similar (24.66 cm) with PG_1 and followed (23.36 cm) by PG_2 whereas the shortest panicle (20.64 cm) from PG_4. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all yield parameters including panicle length in SRI system.

Different rice varieties varied significantly in terms of panicle length (Table 6). The longest panicle (25.26 cm) was observed from V_3, which was followed (23.89 cm) by V_2, while the shortest panicle (20.99 cm) from V_1. Devaraju *et al.* (1998) in a study with hybrid rice cultivar KRH2 and 1R20 as a check variety and reported that the increased grain yield of KRH2 was mainly attributed to the tallest panicle length. Idris and Matin (1990) conducted an experiment with six varieties and observed that panicle length differed among varieties and it was greater in IR 20 than in indigenous and high yielding varieties.

Interaction effect of different planting geometry and rice varieties showed significant variation on panicle length (Table 7). The longest panicle (27.70 cm) was observed from treatment combination of PG_3V_3 and the shortest panicle (19.50 cm) was recorded from treatment combination of PG_4V_1.

4.8 Filled grains panicle^{-1}

Filled grains panicle^{-1} showed statistically significant variation due to different planting geometry (Table 6). The maximum number of filled grains panicle^{-1} (83.80) was recorded from PG_3 which was statistically similar (82.47 and 80.71) with PG_1 and PG_2, while the minimum number (75.52) from PG_4. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference in filled grains panicle^{-1} in SRI system.

Different rice varieties varied significantly in terms of number of filled grains panicle^{-1} (Table 6). The maximum number of filled grains panicle^{-1} (85.30) was observed from V_3, which was statistically similar (82.64) with V_2, whereas the minimum number (73.93) from V_1. Murthy *et al.* (2004) recorded different number of filled spikelets for different variety.

Interaction effect of different planting geometry and rice varieties showed significant variation on number of filled grains panicle^{-1} (Table 7). The maximum number of filled grains panicle^{-1} (90.60) was observed from treatment combination of PG_3V_3 and the minimum number (71.60) was recorded from treatment combination of PG_4V_1.

4.9 Unfilled grains panicle^{-1}

Unfilled grains panicle^{-1} showed statistically significant variation due to different planting geometry (Table 6). The maximum number of unfilled grains panicle^{-1} (9.27) was recorded from PG_4 which was followed (7.98) by PG_1, whereas the minimum number (7.40) from PG_3. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference for unfilled grains in SRI system.

Different rice varieties varied significantly in terms of number of unfilled grains panicle^{-1} (Table 6). The maximum number of unfilled grains panicle^{-1} (8.18) was observed from V_3, which was statistically similar (8.13) with V_2, while the minimum number (7.87) from V_1.). BINA (1993) conducted an experiment with four varieties/advance lines and reported significant variation in unfilled spikelets panicle^{-1}.

Interaction effect of different planting geometry and rice varieties showed significant variation on number of unfilled grains panicle^{-1} (Table 7). The maximum number of unfilled grains panicle^{-1} (9.47) was observed from treatment combination of PG_4V_4 and the minimum number (6.67) was recorded from treatment combination of PG_3V_1.

4.10 Total grains panicle^{-1}

Total grains panicle^{-1} showed statistically significant variation due to different planting geometry (Figure 7). The maximum number of total grains panicle^{-1} (91.20) was recorded from PG_3 which was statistically similar (90.44 and 88.31) with PG_1 and PG_2 whereas the minimum number (84.79) from PG_4.

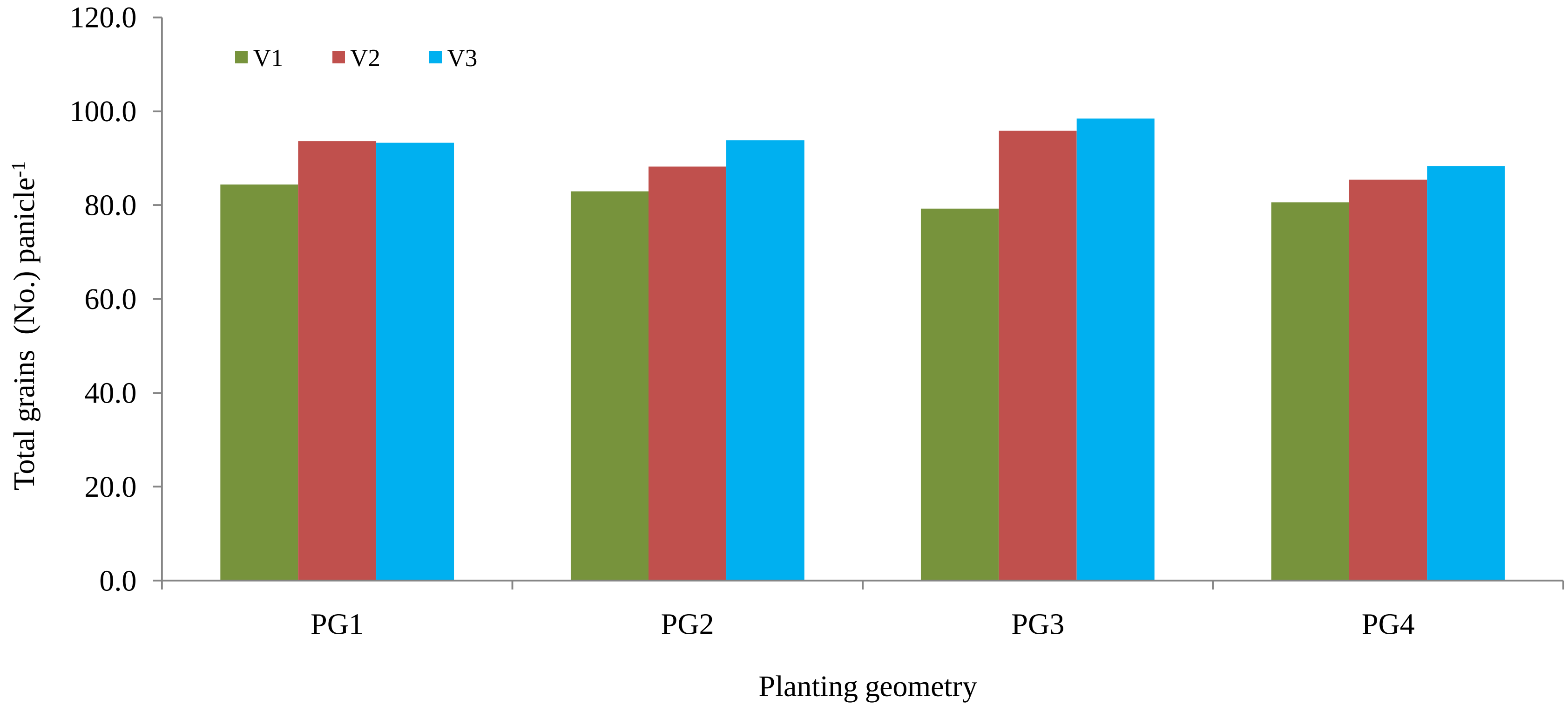
Different rice varieties varied significantly in terms of number of total grains panicle^{-1} (Figure 8). The maximum number of total grains panicle^{-1} (93.48) was observed from V_3, which was statistically similar (90.77) with V_2, while the minimum number (81.80) from V_1. Xu and Wang (2001) observed that the restorer lines showed more spikelet than maintainer lines.

Interaction effect of different planting geometry and rice varieties showed significant variation on number of total grains panicle^{-1} (Figure 9). The maximum number of total grains panicle^{-1} (98.47) was observed from treatment combination of PG_3V_3 and the minimum number (79.27) was recorded from treatment combination of PG_3V_1.

4.11 Weight of 1000 seeds (g)

Weight of 1000 seeds showed statistically significant variation due to different planting geometry (Table 8). The highest weight of 1000 seeds (25.91 g) was recorded from PG_1 which was statistically similar (25.71 g and 24.40 g) with PG_3 and PG_2 whereas the lowest weight (23.91 g) from PG_4.

Different rice varieties varied significantly in terms of weight of 1000 seeds (Table 8). The highest weight of 1000 seeds (26.02 g) was observed from V_3, which was statistically similar (25.05 g) with V_1, while the minimum weight (23.88 g) recorded from V_2. Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers and observed that IR36 gave the highest 1000-grain weight (21.07g).



PG_1: 25 cm × 25 cm PG_2: 25 cm × 20 cm V_1: BRRI dhan33 V_2: BRRI dhan62

PG_3: 20 cm × 20 cm PG_4: 20 cm × 15 cm V_3: Chamak

Figure 9. Interaction effect of planting geometry and varieties on number of total grains panicle^{-1} of rice ($LSD_{(0.05)}$ = 5.731)

Table 8. Effect of planting geometry and variety on yield contributing characters, yield and harvest index of T. aman rice

Treatments	Weight of 1000 seeds (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Planting Geometry					
PG_1	25.91 a	4.48 b	5.38 a	9.86 b	45.38
PG_2	24.40 ab	4.58 b	5.55 a	10.13 b	45.25
PG_3	25.71 a	4.86 a	5.70 a	10.56 a	46.02
PG_4	23.91 b	3.70 c	4.56 b	8.26 c	44.82
$LSD_{(0.05)}$	1.480	0.169	0.366	0.407	--
Variety					
V_1	25.05 ab	4.30 b	5.47 a	9.77 b	44.04 b
V_2	23.88 b	3.76 c	4.68 b	8.44 c	44,66 b
V_3	26.02 a	5.16 a	5.73 a	10.89 a	47.40 a
$LSD_{(0.05)}$	1.282	0.147	0.317	0.352	1.548
CV(%)	6.06	5.91	7.05	4.28	4.03

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

PG_1: 25 cm × 25 cm

PG_2: 25 cm × 20 cm

PG_3: 20 cm × 20 cm

PG_4: 20 cm × 15 cm

V_1: BRRIdhan33

V_2: BRRIdhan62

V_3: Chamak

Interaction effect of different planting geometry and rice varieties showed significant variation in terms of weight of 1000 seeds (Table 9). The highest weight of 1000 seeds (28.90 g) was observed from treatment combination of PG_3V_3 and the lowest weight (22.38 g) was recorded from treatment combination of PG_3V_1.

4.12 Grain yield

Grain yield showed statistically significant variation due to different planting geometry (Table 8). The highest grain yield (4.86 t ha^{-1}) was recorded from PG_3 which was followed (4.58 t ha^{-1} and 4.48 t ha^{-1}) by PG_2 and PG_1, while the lowest yield (3.70 t ha^{-1}) from PG_4. Probably, in case of PG_3 USG may available in optimum amount and easily available to the plants in optimum amount that is why most of the growth and yield parameter response greatly in this spacing. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all yield parameters including grain yield in SRI system.

Different rice varieties varied significantly in terms of grain yield (Table 8). The highest grain yield (5.16 t ha^{-1}) was observed from V_3, which was followed (4.30 t ha^{-1}) by V_1, while the lowest yield (3.76 t ha^{-1}) from V_2. Swain *et al*. (2006) reported that the control cultivar IR64, with high 1000-grain weight and lowest spikelet sterility recorded a grain yield of 5.6 t ha^{-1} that was statistically similar to the hybrid line PA6201. Xie *et al.* (2007) reported different yield for different variety.

Interaction effect of different planting geometry and rice varieties showed significant variation in terms of grain yield (Table 9). The highest grain yield (5.72 t ha^{-1}) was observed from treatment combination of PG_3V_3 and the lowest yield (3.04 t ha^{-1}) was recorded from treatment combination of PG_4V_2.

Table 9. Interaction effect of planting geometry and variety on yield contributing characters, yield and harvest index of T. aman rice

Treatments combination	Weight of 1000 seeds (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
PG_1V_1	26.83 ab	4.50 c	5.63 bc	10.14 cd	44.44 abc
PG_1V_2	24.62 bcd	3.75 d	4.76 d	8.51 fg	44.17 abc
PG_1V_3	26.29 abc	5.19 b	5.74 abc	10.93 b	47.52 a
PG_2V_1	25.52 bc	4.46 c	6.24 ab	10.70 bc	41.62 c
PG_2V_2	22.45 d	3.89 d	4.48 d	8.37 g	46.44 ab
PG_2V_3	25.23 bcd	5.39 b	5.94 ab	11.33 b	47.70 a
PG_3V_1	22.38 d	4.50 c	4.94 d	9.44 de	47.69 a
PG_3V_2	25.85 bc	4.36 c	5.76 abc	10.12 cd	43.07 bc
PG_3V_3	28.90 a	5.72 a	6.40 a	12.12 a	47.32 a
PG_4V_1	25.45 bc	3.74 d	5.08 cd	8.82 efg	42.41 c
PG_4V_2	22.61 d	3.04 e	3.73 e	6.77 h	44.98 abc
PG_4V_3	23.65 cd	4.32 c	4.86 d	9.18 ef	47.06 a
$LSD_{(0.05)}$	2.563	0.293	0.634	0.704	3.095
CV(%)	6.06	5.91	7.05	4.28	4.03

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

PG_1: 25 cm × 25 cm	V_1: BRRIdhan33
PG_2: 25 cm × 20 cm	V_2: BRRIdhan62
PG_3: 20 cm × 20 cm	V_3: Chamak
PG_4: 20 cm × 15 cm	

4.13 Straw yield

Straw yield showed statistically significant variation due to different planting geometry (Table 8). The highest straw yield (5.70 t ha^{-1}) was recorded from PG_3 which statistically similar (5.55 t ha^{-1} and 5.38 t ha^{-1}) by PG_2 and PG_1, while the lowest (4.56 t ha^{-1}) from PG_4. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all yield parameters including straw yield in SRI system.

Different rice varieties varied significantly in terms of straw yield (Table 8). The highest straw yield (5.73 t ha^{-1}) was observed from V_3, which was followed (5.47 t ha^{-1}) by V_1, while the lowest (4.68 t ha^{-1}) recorded from V_2.

Interaction effect of different planting geometry and rice varieties showed significant variation in terms of straw yield (Table 9). The highest straw yield (6.40 t ha^{-1}) was observed from treatment combination of PG_3V_3 and the lowest straw yield (3.73 t ha^{-1}) was recorded from treatment combination of PG_4V_2.

4.14 Biological yield

Biological yield showed statistically significant variation due to different planting geometry (Table 8). The highest biological yield (10.56 t ha^{-1}) was recorded from PG_3 which was followed (10.13 t ha^{-1} and 9.86 t ha^{-1}) by PG_2 and PG_1, while the lowest (8.26 t ha^{-1}) from PG_4. Tohiduzzaman (2011) cultivated sixteen varieties in *boro* season and reported significant difference among them in all yield parameters including biological yield in SRI system.

Different rice varieties varied significantly in terms of biological yield (Table 8). The highest biological yield (10.89 t ha^{-1}) was observed from V_3, which was followed (9.77 t ha^{-1}) by V_1, while the lowest biological yield (8.44 t ha^{-1}) was recorded from V_2.

Interaction effect of different planting geometry and rice varieties showed significant variation in terms of biological yield (Table 9). The highest biological yield (12.12 t ha^{-1}) was observed from treatment combination of PG_3V_3 and the lowest (6.77 t ha^{-1}) was recorded from treatment combination of PG_4V_2.

4.15 Harvest index

Harvest index showed statistically non-significant variation due to different planting geometry (Table 8). The highest harvest index (46.02%) was recorded from PG_3, while the lowest (44.82%) from PG_4.

Different rice varieties varied significantly in terms of harvest index (Table 8). The highest harvest index (47.40%) was observed from V_3, whereas the lowest (44.04%) recorded from V_1 which was statistically similar (44.66%) with V_2.

Interaction effect of different planting geometry and rice varieties showed significant variation in terms of harvest index (Table 9). The highest harvest index (47.70%) was observed from treatment combination of PG_2V_3 and the lowest (41.62%) was recorded from treatment combination of PG_2V_1.

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from June to November 2013 in transplanted aman season to evaluate the yield and yield components of T. Aman rice grown under different planting geometries. The experiment comprised of two factors- Factor A: Planting geometry: 4 levels; PG_1: 25 cm × 25 cm, PG_2: 25 cm × 20 cm, PG_3: 20 cm × 20 cm and PG_4: 20 cm × 15 cm and Factor B: rice variety: 3 varieties- V_1: BRRI dhan33, V_2: BRRI dhan62 and V_3: Chamak. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Data on different yield contributing characters and yield were recorded and significant variation was observed for different treatments.

In case of planting geometry, at 30, 50, 70, 90 DAT and harvest, the tallest plant (25.86, 45.66, 69.20, 95.99 and 106.91 cm, respectively) was recorded from PG_3, whereas the shortest plant (22.73, 42.53, 64.41, 89.76 and 101.60 cm, respectively) from PG_4. At 30, 50, 70 and 90 DAT, the maximum number of tillers hill^{-1} (5.47, 13.04, 16.56 and 19.78, respectively) was found from PG_3, whereas the minimum number (4.49, 11.09, 14.67 and 15.93, respectively) from PG_4. At 30, 50, 70 and 90 DAT, the highest dry matter content hill^{-1} (4.51, 5.59, 8.12 and 9.30 g, respectively) was recorded from PG_3, while the lowest (3.61, 5.29, 7.10 and 8.05 g, respectively) from PG_4. The maximum number of effective tillers hill^{-1} (20.20) was recorded from PG_3 whereas the minimum number (16.58) from PG_4. The maximum number of non-effective tillers hill^{-1} (2.82) was recorded from PG_1 whereas the minimum number (2.33) from PG_3. The maximum number of total tillers hill^{-1} (22.53) was recorded from PG_3 whereas the minimum number (19.22) from PG_4. The longest panicle (24.87 cm) was recorded from PG_3 whereas the shortest panicle (20.64 cm) from PG_4. The maximum number of filled grain panicle^{-1} (83.80) was recorded from PG_3, while the minimum number (75.52) from PG_4. The maximum number of unfilled grain panicle^{-1} (9.27) was recorded from PG_4, whereas the minimum number (7.40) from PG_3. The maximum number of total grain panicle^{-1} (91.20) was recorded from PG_3 whereas the minimum number (84.79) from PG_4. The highest weight of 1000 seeds (25.91 g) was recorded from PG_1 whereas the lowest weight (23.91 g) from PG_4. The highest grain yield (4.86 t ha^{-1}) was recorded from, while the lowest yield (3.70 t ha^{-1}) from PG_4. The highest straw yield (5.70 t ha^{-1}) was recorded from PG_3, while the lowest (4.56 t ha^{-1}) from PG_4. The highest biological yield (10.56 t ha^{-1}) was recorded from PG_3, while the lowest (8.26 t ha^{-1}) from PG_4. The highest harvest index (46.02%) was recorded from PG_3, while the lowest (44.82%) from PG_4.

For different rice varieties, at 30, 50, 70, 90 DAT and harvest, the tallest plant (25.05, 44.85, 67.93, 94.38 and 105.60 cm, respectively) was observed from V_3, while the shortest plant (23.58, 43.38, 66.08, 92.01 and 102.78 cm, respectively) from V_1. At 30, 50, 70 and 90 DAT, the maximum number of tillers hill^{-1} (5.43, 12.78, 17.00 and 19.78, respectively) was recorded from V_3, while the minimum number (4.47, 11.48, 14.83 and 16.20, respectively from V_1. At 30, 50, 70 and 90 DAT, the highest dry matter content hill^{-1} (4.52, 5.68, 8.13 and 9.53 g, respectively) was observed from V_3, whereas the lowest (3.80, 5.09, 6.95 and 8.20 g, respectively) from V_2. The maximum number of effective tillers hill^{-1} (20.65) was observed from V_3, whereas the minimum number (16.90) from V_1. The maximum number of non-effective tillers hill^{-1} (2.68) was observed from V_1, while the minimum number (2.53) from V_2. The maximum number of total tillers hill^{-1} (23.20) was observed from V_3, whereas the minimum number (19.58) was recorded from V_1. The longest panicle (25.26 cm) was observed from V_3, while the shortest panicle (20.99 cm) from V_1. The maximum number of filled grain panicle^{-1} (85.30) was observed from V_3, whereas the minimum number (73.93) from V_1. The maximum number of unfilled grain panicle^{-1} (8.18) was observed from V_3, while the minimum number (7.87) from V_1. The maximum number of total grain panicle^{-1} (93.48) was observed from V_3, while the minimum number (81.80) from V_1. The highest weight of 1000 seeds (26.02 g) was observed from

V_3, while the minimum weight (23.88 g) recorded from V_2. The highest grain yield (5.16 t ha^{-1}) was observed from V_3, while the lowest yield (3.76 t ha^{-1}) recorded from V_2. The highest straw yield (5.73 t ha^{-1}) was observed from V_3, while the lowest (4.68 t ha^{-1}) recorded from V_2. The highest biological yield (10.89 t ha^{-1}) was observed from V_3, while the lowest (8.44 t ha^{-1}) recorded from V_2. The highest harvest index (47.40%) was observed from V_3, whereas the lowest (44.04%) recorded from V_1.

Due to the interaction effect of different planting geometry and rice varieties at 30, 50, 70, 90 DAT and harvest, the tallest plant (27.72, 47.52, 72.71, 98.83 and 111.06 cm, respectively) was observed from treatment combination of PG_3V_3 and the shortest plant (22.25, 42.05, 64.23, 88.35 and 100.68 cm, respectively) from PG_4V_1. At 30, 50, 70 and 90 DAT, the maximum number of tillers $hill^{-1}$ (5.93, 14.40, 18.93 and 23.13, respectively) was obtained from treatment combination of PG_3V_3 and the minimum number (4.13, 10.60, 13.47 and 14.93, respectively) from PG_4V_1. At 30, 50, 70 and 90 DAT, the highest dry matter content $hill^{-1}$ (5.07, 5.97, 9.14 and 9.92 g, respectively) was observed from treatment combination of PG_3V_3, while the lowest (3.12, 5.02, 6.61 and 7.15 g, respectively) from PG_4V_2. The maximum number of effective tillers $hill^{-1}$ (22.80) was observed from treatment combination of PG_3V_3 and the minimum number (15.40) from PG_4V_1. The maximum number of non-effective tillers $hill^{-1}$ (2.87) was observed from treatment combination of PG_1V_1 and PG_1V_2, while the minimum number (2.33) from PG_3V_1, PG_3V_2 and PG_3V_3. The maximum number of total tillers $hill^{-1}$ (25.13) was observed from treatment combination of PG_3V_3, while the minimum number (18.20) from PG_4V_1 and PG_4V_2. The longest panicle (27.70 cm) was observed from treatment combination of PG_3V_3 and the shortest panicle (19.50 cm) from PG_4V_1. The maximum number of filled grain $panicle^{-1}$ (90.60) was observed from treatment combination of PG_3V_3 and the minimum number (71.60) from PG_4V_1. The maximum number of unfilled grain $panicle^{-1}$ (9.47) was observed from treatment combination of PG_4V_4 and the minimum number (6.67) from PG_3V_1. The maximum number of total grain $panicle^{-1}$ (98.47) was observed from treatment combination of PG_3V_3 and the minimum number (79.27) from PG_3V_1. The highest weight of 1000 seeds (28.90 g) was observed from treatment combination of PG_3V_3 and the lowest weight (22.38 g) from PG_3V_1. The highest grain yield (5.72 t ha^{-1}) was observed from treatment combination of PG_3V_3 and the lowest yield (3.04 t ha^{-1}) from PG_4V_2. The highest straw yield (6.40 t ha^{-1}) was observed from treatment combination of PG_3V_3 and the lowest yield (3.73 t ha^{-1}) from PG_4V_2. The highest biological yield (12.12 t ha^{-1}) was observed from of PG_3V_3 and the lowest (6.77 t ha^{-1}) from PG_4V_2. The highest harvest index (47.70%) was observed from of PG_2V_3 and the lowest (41.62%) from PG_2V_1.

From the above results it can be concluded that 20 cm × 20 cm planting geometry provided best yield for most of the varieties and the variety Chamak provided better yield than the other varieties.

Considering the results obtained from the present experiment, further studies in the following areas may be suggested:

- Other planting geometry with different management practices may be included in future study for more accurate results,
- Future study may be carried out with more varieties/genotypes, and
- Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional compliance and other performances.

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Appendices

APPENDICES

Appendix I. Monthly record of air temperature, relative humidity, rainfall, and sunshine (average) of the experimental site during the period from June to November 2013

Month (2013)	Air temperature (^{0}c)		Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
June	35.7	23.2	78	312	5.4
July	36.0	24.6	83	563	5.1
August	36.0	23.6	81	319	5.0
September	34.8	24.4	81	279	4.4
October	26.5	19.4	81	22	6.9
November	25.8	16.0	78	00	6.8

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka–1212*

Appendix II. Characteristics of the soil of experimental field analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the soil of experimental field

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

B. Physical and chemical properties of the initial soil

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

Source: SRDI, Khamarbari, Farmgate, Dhaka

Appendix III. Analysis of variance of the data on plant height of T. aman rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm)				
		30 DAT	50 DAT	70 DAT	90 DAT	Harvest
Replication	2	1.565	1.565	0.805	0.068	0.835
Planting geometry (A)	3	15.614**	15.614**	38.877**	63.439**	50.273**
Rice variety (B)	2	6.491**	6.491**	11.575**	20.115**	29.510**
Interaction (A×B)	6	4.921*	4.921*	12.464*	12.933*	19.245*
Error	22	1.823	1.841	3.062	5.314	4.975

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on number of tillers hill^{-1} of T. aman rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square			
		Number of tillers hill^{-1}			
		30 DAT	50 DAT	70 DAT	90 DAT
Replication	2	0.014	0.084	0.970	0.670
Planting geometry (A)	3	1.868**	5.927**	5.773**	25.479**
Rice variety (B)	2	3.341**	5.181**	15.083**	40.923**
Interaction (A×B)	6	0.101*	1.549**	2.024*	3.971*
Error	22	0.031	0.261	1.203	1.203

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Appendix V. Analysis of variance of the data on dry matter content hill^{-1} of T. aman rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square			
		Dry matter content hill^{-1}			
		30 DAT	50 DAT	70 DAT	90 DAT
Replication	2	0.006	0.022	0.022	0.076
Planting geometry (A)	3	1.341**	0.135**	1.651**	2.782**
Rice variety (B)	2	1.543**	1.190**	4.909**	5.293**
Interaction (A×B)	6	0.501*	0.051*	0.378**	0.756**
Error	22	0.151	0.023	0.113	0.148

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on number of tillers hill^{-1} of T. aman rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square						
		Effective tillers hill^{-1}	Non-effective tillers hill^{-1}	Total tillers hill^{-1}	Panicle length (cm)	Filled grains	Unfilled grains	Total grains
Replication	2	0.250	0.001	0.234	1.721	8.067	0.021	8.899
Planting geometry (A)	3	21.844**	0.372**	20.137**	33.963**	118.581**	6.333**	74.236**
Rice variety (B)	2	42.190**	0.081**	39.254**	56.956**	424.190**	0.348*	448.764**
Interaction (A×B)	6	2.575*	0.053*	3.035*	6.225*	26.410*	0.378**	31.119*
Error	22	0.851	0.018	0.848	2.021	10.976	0.087	11.453

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on yield contributing characters and yield of T. aman rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square				
		Weight of 1000 seeds (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.796	0.009	0.069	0.115	0.734
Planting geometry (A)	3	8.677*	2.221**	2.350**	9.110**	2.243
Rice variety (B)	2	13.721**	5.954**	3.592**	18.017**	38.284**
Interaction (A×B)	6	12.341**	0.083*	1.033**	1.577**	12.998**
Error	22	2.291	0.030	0.140	0.173	3.341

**: Significant at 0.01 level of probability: *: Significant at 0.05 level of probability