EFFECT OF DATE OF TRANSPLANTING ON GROWTH AND YIELD PERFORMANCE OF SELECTED HYBRID AND INBRED RICE VARIETIES IN *BORO* SEASON

A Thesis

By

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Examination Roll No.: 01390

Semester: January - June, 2010

Registration No.: 04-01390 (2003-04)

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This is to certify that the thesis entitled "EFFECT OF DATE OF TRANSPLANTING ON GROWTH AND YIELD PERFORMANCE OF SELECTED HYBRID AND INBRED RICE VARIETIES IN *BORO* SEASON" submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka-1207 in partial fulfillment of the requirements for the degree of Master of Science (M.S.) in Agricultural Botany embodies the result of a piece of *bonafide* research work carried out by **M. Towhid Hasan**, Registration No.: **04-01390** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: ....
Place: Dhaka, Bangladesh

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EFFECT OF DATE OF TRANSPLANTING ON GROWTH AND YIELD PERFORMANCE OF SELECTED HYBRID AND INBRED RICE VARIETIES IN *BORO* SEASON

ABSTRACT

A field experiment was conducted at the research field of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from November 2009 to June 2010 to investigate the effect of variety and date of transplanting on morpho-physiological characters, yield attributes and yields of hybrids and inbred rice varieties in *Boro* season. The experiment comprised of three hybrid varieties *viz*., Hira2, Aloron and Tia along with an inbred variety, BRRI dhan29, and four dates of transplanting *viz*., 01, 16 and 31 January and 15 February. The experiment was laid out in two factors randomized complete block design with three replications. The growth parameters such as leaf area, total dry matter production and absolute growth rate, morphological and phenological parameters, yield contributing characters and grain yield were significantly influenced by the date of transplanting. Results revealed that leaf area, total dry matter, absolute growth rate, plant height, straw yield, number of unfilled grains panicle^{-1}, days required to flowering and maturity were higher when transplanted on 01 January than those on 16, 31 January and 15 February. In contrast, the lowest values of the parameters were recorded when transplanted on 15 February. The maximum grain yield was recorded when transplanted in mid-January owing to increased grains panicle^{-1} and harvest index, where as the lowest grain yield was recorded when transplanted on 15 February due to inferiority in yield contributing characters. Among the varieties, Hira2 showed superiority in leaf area (LA), and total dry matter (TDM) production, straw yield and absolute growth rate which resulted the superior performance of yield attributes thereby increasing grain yield. In contrast, Tia produced the lowest grain yield for its inferior performance of yield attributes.

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CHAPTER 1

INTRODUCTION

Rice is extensively grown in Bangladesh in three seasons of Bangladesh viz., *Aus, Aman* and *Boro*, which covers 80% of the total cultivable area (AIS, 2011). *Aman* rice hold the major share of acreage but *Boro* rice hold major share of production. In Bangladesh, rice yield level is far below than that of many other countries like China, Japan, Korea and Egypt where yield is 7.5, 5.9, 7.3 and 7.5 t ha^{-1}, respectively (FAO, 2009). As there is very little scope of horizontal expansion of crop production in Bangladesh, farmers and agricultural scientists are diverting attention towards vertical expansion to increase crop production. Projected supply and demand balance show that the country will require 34-35 million tons of food grain by 2020 while the production would be 27-30 million tons under two alternative case-scenarios(BRRI, 2009). In such situation, there is no other alternative rather than development and adoption of yield enhancing technologies.

Yield is the cumulative effect of inherent characteristics of a variety as well as management practices under which it is grown. Variety is one of the important factors for increasing yield. In general, it is believed that there are differences in morpho-physiological characters among the traditional and modern varieties. Generally modern inbred rice varieties in Bangladesh have a longer growth duration of 150-160 days in *Boro* season with a low daily yield (lower than 30 kg ha^{-1} day^{-1}), while high daily yield in hybrid one because of its short duration of 120-130 days (Julfiquar *et al.*, 1998). If hybrid rice is introduced, crop duration can be reduced by 20-40 days. This may facilitate the accommodation of succeeding crop in the cropping systems.

Usually there is an optimum planting time to obtain higher yield of a crop (Bhuiya *et al.*, 1992). Generally, *Boro* rice is transplanted from early December to mid March (BBRI, 2004). Early transplanting of *Boro* rice prolongs field duration due to low temperature and involves high cost of production, particularly for management practices including irrigation, while delayed transplanting reduces the yield in some cases (BRRI, 2005). A compromise is therefore needed between sacrificing grain yield by adjusting transplanting date or incurring extra expenditure by irrigating the crop for a longer period in case of early planting.

Recently, several private seed traders are introducing hybrid rice varieties like Hira, Aloron, Tia, Jagoroni from China. But as introduced plant materials it need thorough evaluation under the prevailing climatic conditions of Bangladesh for morphological and physiological characteristics before they are handed over to the end users i.e., for large scale cultivation by the farmers. As per available information regarding the yield and yield contributing characters, both morphological and physiological characteristics of hybrid rice varieties are meager in Bangladesh. That is why, it is a prime need to conduct more research works to find out and develop sustainable technologies of hybrid rice cultivation under the prevailing local conditions.

The present study was, therefore, undertaken with the following objectives:

i. To determine the optimum date of transplanting of hybrid rice in *Boro* season ;

ii. To assess the varietal performance of hybrid rice over modern inbred varieties in *Boro* season and

iii. To find out the interaction between varieties and date of transplanting in respect of morpho-physiological characters, yields and yield attributes of hybrid rice in *Boro* season.

CHAPTER 2

REVIEW OF LITERATURE

Date of transplanting influences growth and yield of *Boro* rice. Extensive studies have been carried out by the researchers throughout the world on various cultural practices of rice. Some of the relevant findings have been reviewed and presented in this chapter.

2.1 Effect of variety

Pruneddu and Spanu (2001) conducted an experiment with 18 varieties to know the varietal performance of rice. They classified them into groups according to grain properties (round, medium, long A, long B and aromatic) and the highest yield was obtained from the long-grained varieties (9.1 t ha^{-1}), while the lowest was recorded in aromatic rice (3.15 t ha^{-1}). Mondal *et al.* (2005) conducted an experiment with 17 modern varieties of rice in the northern region of Bangladesh and reported that BRRI dhan36 produced the highest grain yield (5.30 t ha^{-1}) due to superior yield components. Further, Kamal *et al.* (1998) conducted an experiment to assess the yield of nine modern varieties and six local improved varieties and observed that modern varieties gave greater yield (4.89 t ha^{-1}) than the local cultivars (3.36 t ha^{-1}) due to production of greater number of effective tillers $hill^{-1}$, number of grains $panicle^{-1}$. Rahman (2002) studied seven fine grain rice (Ukunimadhu, Bullet, Hetkumra, Ghunshi, Bojromuri, Hoglapata and Binashail) to assess their yield and yield related traits and reported that Binashail produced the highest grain yield (5.36 t ha^{-1}) due to the production of higher number of effective tillers m^{-2}, filled grains panicle^{-1} and better partitioning (HI) while Hetkumra, a aromatic rice, produced the lowest (2.70 t ha^{-1}). An experiment was conducted by Yeasmin (2006) during the period from November to June to study the performance of hybrid rice varieties in *Boro* season as affected by the date of transplanting. The experiment comprised of four rice varieties viz., Hira2, Aftab, Jagorini and BRRI dhan29 and five dates of transplanting in *Boro* season viz., 17 December, 1, 16 and 31 January and February. The author reported that the highest grain yield (5.93 t ha-1), biological yield (13.02 t ha-1) and harvest index (45.55%) were produced by the variety, Jagoroni because of maximum number of effective tillers hill-1, number of grains panicle-1 and 1000-grain weight. On the other hand, BRRI dhan29 produced the lowest values for the aforesaid parameters. A field experiment was set by BINA (2006) with three promising rice mutants (TNBD-100, Y-1281 and RD-25-56) along with one check variety (BRRI dhan28) to know the performance under four dates of planting (01, 15 and 30 January and 15 February) during *Boro* season and reported that TNDB-100 produced the highest grain yield where BRRI dhan28 produced the lowest grain yield.

From the reviews cited above, it is clear that time of transplanting has considerable influence on grain yield of rice in *Boro* season.

2.2 Effect of date of transplanting

An experiment was conducted by BRRI (1994) with 40 days old seedlings of sixteen promising lines including one check variety of BR26 to know the optimum transplanting date for getting maximum grain yield in *Boro* rice. Seedlings were transplanted from 25

December 1993 to 12 March 1994 and reported that grain yield was the highest when transplanted both at 25 December and 9 January followed by 25 January planting. After 25 January planting, the grain yield declined significantly.

An experiment was conducted by BRRI (1995) to find out the optimum planting date of *Boro* rice which were planted at 15 days interval from 25 December to 12 March and found that all tested lines produced satisfactory yield up to 10 February and after that grain and straw yield reduced drastically and field duration of the tested lines decreased with delay transplanting.

BRRI (1998) evaluated the performance of four promising lines under different dates of transplanting (25 December, 10 January, 25 January and 10 February) and reported that all the tested lines performed the best when transplanted on 10 January.

Chowdhury and Guha (2000) conducted an experiment to know the effect of date of tranplsnting on five short duration varieties (Calturel, IR50, Govind, China and Jagilu) and three medium duration (Joymati, Mala and Mahisur) varieties. The date of transplanting was 20 January, 5 and 20 February, 1998. Planting on 20 January produced the highest grain yield in all the cultivars except Mala. Mala performed better when planting on 5 February.

A field experiment was conducted during spring season of 1996, 1997 and 1998 to study the effect of sowing date on the productivity of rice varieties in low hills of Urunachal Prodesh. The authors reported that considering pooled data over three years, 15 March sowing recorded significantly higher values of yield attributes and grain yield of rice. (Singh and Singh, 2000)

An experiment was conducted by Yeasmin (2006) during the period from November to June to study the performance of *Boro* rice varieties as affected by date of transplanting. The experiment comprised of four *Boro* rice varieties viz., Hira1, Aftab, Jagorini and BRRI dhan29 and five dates of transplanting viz., 17 December, 1, 16 and 31 January and 15 February. The author reported that grain and biological yield gradually increased up to 16 January transplanting followed by declined in all the varieties and 17 December transplanting recorded the lowest grain and straw yield.

BRRI dhan29, a high yielding inbred variety was grown by Shaon (2006) in *Boro* season with five dates of transplanting viz., 1, 10, 20 and 30 January and 10 February in 2005-06 aimed at assessing the influence of date of transplanting on different crop characters and grain yield. The author reported that grain yield of rice planted on 20 January was the highest (4.99 t ha-1) followed by 30 January planting. The lowest grain yield was obtained from 10 February transplanting which was statistically similar to 01 January planting.

An experiment was conducted by Khalid (2006) to know the effect of date of transplanting (10, 20 and 30 January, and 10 and 20 February) of BRRI dhan28 during *Boro* season of 2005-06 and reported that the grain yield was the highest when transplanted on 10 January.

An experiment was conducted by Asaduzzaman (2006) at the field laboratory of Bangladesh Agricultural University, Mymensingh to study the effect of date of transplanting (5, 15 and 25 January, and 5 and 15 February) on the performance of *Boro* rice cv. BRRI dhan29 and reported that date of transplanting had tremendous effect on growth and yield of rice. The author observed that maximum yield was obtained when transplanted on 5 January while the lowest grain yield was observed on 15 February transplanting.

A field experiment was set by BINA (2006) with three promising rice mutants (TNBD-100, Y-1281 and RD-25-56) along with one check variety (BRRI dhan28) under four dates of planting (01, 15 and 30 January and 15 February) during *Boro* season and reported that pooled grain yield was the highest when planted on 15 January due to increased number of effective tillers $hill^{-1}$. The lowest grain yield was observed on 01 January transplanting.

CHAPTER 3
MATERIALS AND METHODS

In this chapter the details of different materials used and methodology followed for the experiment are presented under the following heads:

3.1 Experimental site

The experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka, during the period from November 2009 to June 2010. Geographically the experimental area is located at $24^0 75'$ N latitude and $90^0 50'$ E longitudes at the elevation of 18 m above the sea level. The experimental field was medium high land belonging to the Brahmaputra Alluvium Floodplain soil. The soil was silty loam. Fertility status of the soil is shown in the Appendix I.

3.2 Weather and climate

The experimental field was under subtropical monsoon climate characterized by a heavy rainfall during the month of April to September and a scanty rainfall during October to March. The monthly means of daily maximum, minimum and average temperature, relative humidity, total rainfall, and sunshine hours received at the experimental site during the period November 2009 to June 2010 are presented in Appendix II.

3.3 Plant material

Four varieties of *Boro* rice viz., BRRI dhan29, Hera 2, Aloron and Tia were used as test crops in the experiment. The salient features of rice varieties are given below.

BRRI dhan29

BRRI dhan29, a high yielding variety of *Boro* rice was developed by the Bangladesh Rice Research Institute and was released in 1994. It is a photo-insensitive late maturing variety. This variety takes 150-160 days to mature. It can give a grain yield of 7.0 t ha^{-1}. The cooked rice is very good for consumption.

Hira2

Hira2 is a hybrid variety and was imported from China and approved by the National Seed Board of Bangladesh. The variety is well adapted with the climatic condition of Bangladesh. Supreme Seed Company Pvt. Ltd. is the importer of this rice in Bangladesh. The plant type is semi dwarf (95-105 cm), growth duration is 145-150 days, and average grain yield ranges from 9-10 t ha^{-1}.

Aloron

It is hybrid rice developed in China and marketed in Bangladesh by ACI Ltd and BRAC. Aloron has an ability to produce grain yield 8.5-9.5 t ha^{-1}, growth duration 104-130 days, plant type is semi dwarf (100-120 cm), and suitable for irrigated soils.

Tia

Tia is a hybrid rice variety developed in China. It is well adapted with the climatic condition of Bangladesh. BRAC is its sole distributing agent in Bangladesh. The average plant height is 90-100 cm. The plant duration is 103-140 days. This variety has the yield potentiality up to 10 t ha^{-1}.

3.4 Treatments

Two factors were included in the study as mentioned below:

A. Four varieties were taken as test crop viz., BRRI dhan29, Hira2, Aloron and Tia

B. Four dates of transplanting viz., 01, 16 and 31 January, and 15 February.

3.5 Design and lay out

The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. There were 48 unit plots in the experiment. Each replication was divided into 16 unit plots where the treatment combinations were allocated at random. The size of each unit plot was 4.0 m × 3.0 m. The spacing between block to block and plot to plot was 1.0 m and 0.5 m, respectively.

3.6 Seed collection

Seeds of Hira2, Aloron and Tia were collected from local markets. The seeds of BRRI dhan29 were collected from the Plant Breeding Division, Bangladesh Rice Research Institute, Gazipur.

3.7 Nursery preparation and raising of seedlings

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

A piece of high land was ploughed well with country plough followed by cleaning and leveling with a ladder. Sprouted seeds were sown in the wet nursery bed on 20 November, 05 and 20 December 2009 and 05 January 2010. Proper care was taken to raise healthy seedlings in the seedbed. Weeds were removed and irrigation was given in the nursery as and when necessary.

3.8 Preparation of experimental land

The land of the experimental plot was opened on 20 December 2009 with a power tiller. Later on, the land was ploughed and cross-ploughed three times followed by laddering to level the field. The corners of the land were spaded and weeds and stubbles were removed from the field. The land was thus ready for transplanting. The layout of the experimental field was done on 31 December 2009 according to the design adopted. Individual plots were leveled with wooden plank.

3.9 Fertilization

A fertilizer dose of 75-60-34-5.0 kg ha^{-1} of TSP, MP, gypsum and zinc sulphate, respectively, was applied at the time of final land preparation. Urea was applied @ 300 kg ha^{-1} at three times in equal splits at 15, 35 and 50 days after transplanting (DAT).

3.10 Uprooting and transplanting of seedlings

Forty day-old seedlings were uprooted carefully from the nursery bed without causing any mechanical injury to the roots. Seedlings were transplanted on the experimental plots on 01, 15, 30 January, 2010 and 15 February 2010 at the rate of 2 seedlings per hill maintaining spacing of 25 cm × 20 cm.

3.11 Gap filling

Gap filling was done after one week of transplanting.

3.12 Irrigation

Irrigation was done regularly with 7-10 days interval. The crop was provided with flood irrigation and steps were taken to maintain constant level of standing water of 4-5 cm in the field. The field was finally drained out before 10 days of harvesting.

3.13 Weeding

Two hand weeding were done at 25 and 50 DAT .

3.14 Plant protection measures

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

3.15 Growth parameters

To study the growth characteristics, a total of six harvests were made at 10, 20, 30, 40, 50 and 60 DAT. For each sampling, five hills were randomly selected from each plot and uprooted for collecting data on necessary parameters. The plants were separated into leaves, stems and roots and the corresponding dry weight were recorded after oven drying at 80 ± 2 ^{0}C for 72 hours. The leaf area of each sample was measured by an automatic leaf area meter (Model: LICOR 3000 USA). The growth analysis was carried out following the formula of Hunt (1978), e.g.

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

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

Where, W_2 and W_1 are the dry matter at time T_2 and T_1, respectively.

3.16 Sampling, harvesting, threshing, cleaning and processing

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

3.17 Data collection

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

Leaf area hill^{-1}

Leaf area hill^{-1}was measured by automatic leaf area meter (Model: LICOR 3000, USA) at 10, 20, 30, 40, 50 and 60 DAT.

Plant height (cm)

Length between the bases of the plant to the tip of the panicle was taken at harvest.

Total tillers

Number of tillers was counted from each hill.

Effective tillers

The tiller, which had at least one grain, was considered as effective tiller.

Non-effective tillers

The tiller, which had no grain or panicle, was regarded as non effective tiller.

Panicle length (cm)

Panicle length was recorded from the basal node of the rachis to the apex of each panicle.

Grains panicle^{-1}

Grains of 10 randomly selected panicles of each plot were counted and then the average number of grains for each panicle was determined.

Unfilled grains panicle^{-1}

Spikelet lacking any food material inside was considered as unfilled grain.

Weight of 1000 grain (gm)

One thousand clean and sun-dried grains were counted from the seed stock and weighed by an electronic balance.

Grain yield

The grains per plot were sun-dried and weighed. The grain weight was finally converted to t ha^{-1}.

Straw yield

Straw obtained from each unit plot was sun dried and weighed and then converted to t ha^{-1}.

Harvest index (%)

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

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

3.18 Statistical analysis

The collected data were analyzed statistically following the analysis of variance technique and the mean differences were adjudged with Duncan's Multiple Range Test using the statistical computer package program, MSTAT –C.

CHAPTER 4

RESULTS AND DISCUSSION

The results of the study regarding the performance of *Boro* rice as affected by date of transplanting on various morpho-physiological and yield contributing characters have been presented and possible interpretations have been made in this chapter.

4.1 Growth parameters

4.1.1 Leaf area

Effect of variety

The development of leaf area (LA) over time in rice varieties has been presented in Fig. 1. Results revealed that LA increased till 60 days after transplanting (DAT). The increasing of leaf area (LA) varied significantly due to variety at all growth stages. At 60 DAT, the leaf area (LA) production by Hera2 and Tia was significantly higher than other two varieties. In contrast, the variety Aloron produced the lowest LA. The variation in leaf area might occur due to the variation in number of leaves and the expansion of leaf. The results obtained from the present study are consistent with the results of BINA (2006) in rice where it was stated that the variation in LA could be attributed to the changes in number of leaves. The results are also supported by the result of Yeasmin (2005) reported in case of rice.

Effect of date of transplanting

Date of transplanting had significant influence on leaf area (LA) development hill^{-1} at all growth stages (Fig. 2). It was observed that leaf area increased progressively with the advancement of time and growth stages till 60 DAT. The highest LA at all growth stages was observed when transplanted on 16 January followed by 01 January transplanting. In contrast, the lower LA was recorded at 31 January and 15 February transplanting at most

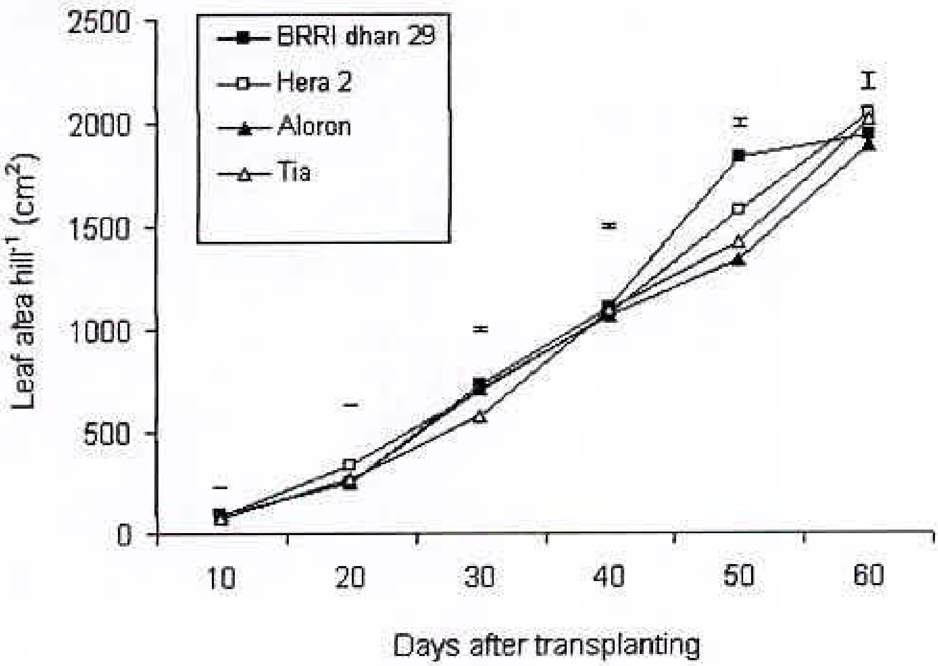

Fig. 1. Effect of variety oin leaf area development at different age.
[Vertical bars represent LSD (0.05)]

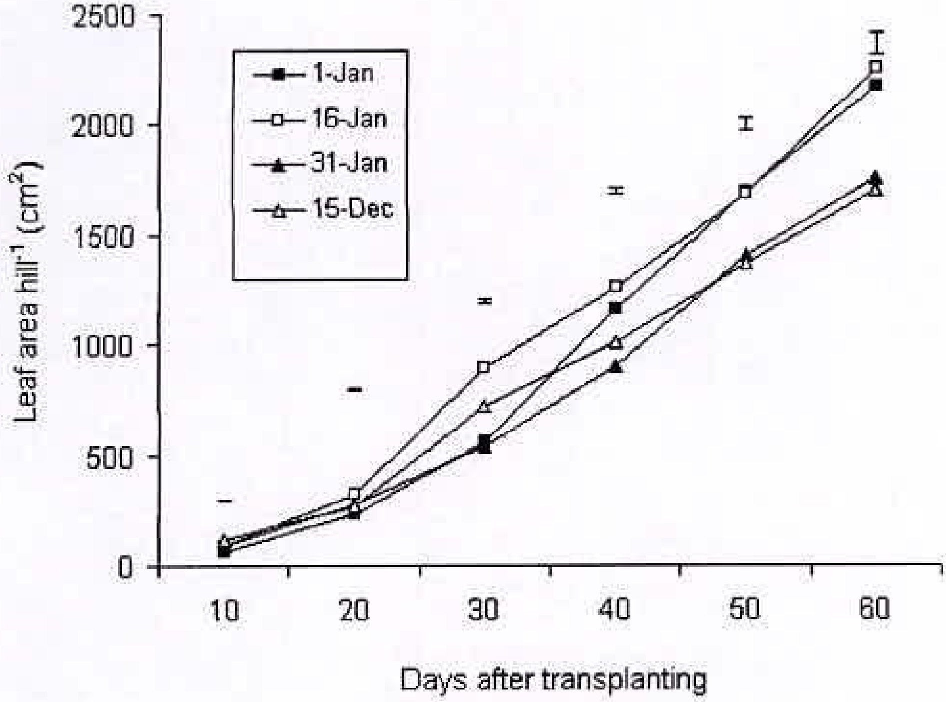

Fig.2. Effect of transplantingtime on leaf area development at different days after transplanting

of the growth stages. The LA was greater at 16 January transplanting because of increased production of tillers hill^{-1} (Table 5). Similar result was also reported by BINA (2006) in *Boro* rice where two field experiments were conducted in consecutive two years to know the effect of transplanting date on leaf area development of *Boro* rice and reported that leaf area increased when rice was transplanted at mid January.

Interaction effect of variety and date of transplanting

LA was significantly varied due to interaction effect of variety and date of transplanting at all growth stages (Table1). The highest LA was recorded in the treatment combination of Tia when transplanted on 01 January (2571 cm^2 $hill^{-1}$). In contrast the lowest LA was recorded in Tia when transplanted on 15 February (1436 cm^2 $hill^{-1}$).

4.1.2 Total dry matter production

Effect of variety

Variety had significant influence on total dry matter production (TDM) $hill^{-1}$ at all growth stages (Fig. 3). The TDM production gradually increased at all sampling dates from 10 to 60 DAT. The highest TDM was recorded in Hira2 at all growth stages followed by Aloron. The higher TDM was recorded in Hira2 due to increased LA. In contrast, the lowest TDM $hill^{-1}$ was recorded in BRRI dhan29. Genotypic variation in TDM production in rice was also observed by Rahman (2002) that supported the present experimental results.

Table 1. Interaction effect of variety and transplanting time on leaf area development at different growth stages

Interaction	Leaf area ($cm^2\ hill^{-1}$) at different days after transplanting					
	10	20	30	40	50	60
V_1D_1	58.58 h	218.2 ef	536.3 g	943 g	1814 b	2049 c-f
V_1D_2	104.7 d	200.4 f	831.6 c	1547 a	2064 a	2227 bcd
V_1D_3	118.3 c	313.3 c	718.1 e	1095 ef	1682 b	1717 gh
V_1D_4	103.8 d	284.4 d	823.3 cd	826 h	1778 b	1784 fgh
V_2D_1	58.33 h	200.4 f	615.6 f	1075 f	1661 b	1962 d-g
V_2D_2	110.7 d	554.2 a	932.9 b	1111 ef	1703 b	2363 ab
V_2D_3	83.10 e	315.7 c	418.3 i	1040 f	1513 c	1893 e-h
V_2D_4	75.10 f	288.0 cd	840.0 c	1082 ef	1421 c	1970 d-g
V_3D_1	68.10 g	205.0 ef	626.4 f	1206 d	1508 c	2121 b-e
V_3D_2	84.00 e	344.2 b	1002 a	1294 c	1485 c	2166 bcd
V_3D_3	76.80 ef	200.4 f	423.4 i	825 h	1217 d	1625 hi
V_3D_4	152.2 a	231.3 e	778.7 d	950 g	1117 d	1650 hi
V_4D_1	59.48 h	303.6 cd	475.7 h	1450 b	1792 b	2571 a
V_4D_2	45.65 i	197.3 f	800.3 cd	1116 ef	1500 c	2279 bc
V_4D_3	79.50 ef	303.3 cd	591.3 f	654 i	1220 d	1794 fgh
V_4D_4	134.4 b	291.7 cd	442.8 hi	1172 de	1183 d	1436 i
LSD(0.05)	6.77	25.22	45.46	83.83	138.9	240.8
CV (%)	4.60	5.44	4.02	4.63	5.41	7.31

V_1 = BRRI dhan29; V_2 = Hera2; V_3 = Aloron; V_4 = Tia; D_1 = Transplanting on 01 January; D_2 = Transplanting on 16 January; D_3 = Transplanting on 31 January; D_4 = Transplanting on 15 February;

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

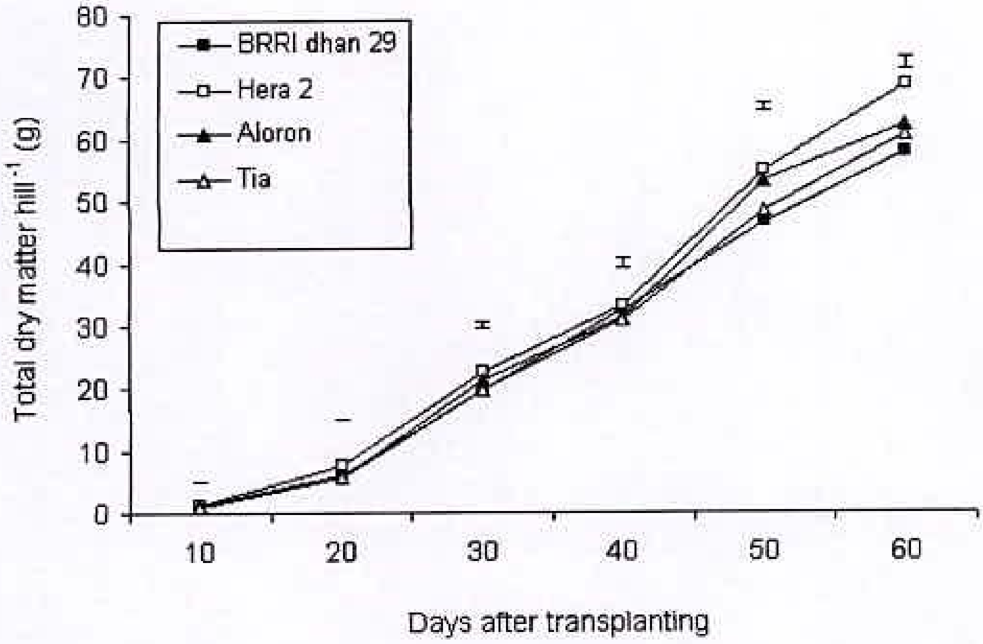

Fig. 3. Effect of variety on dry matter production at different days after transplanting. [Vertical bars represent LSD (0.05)]

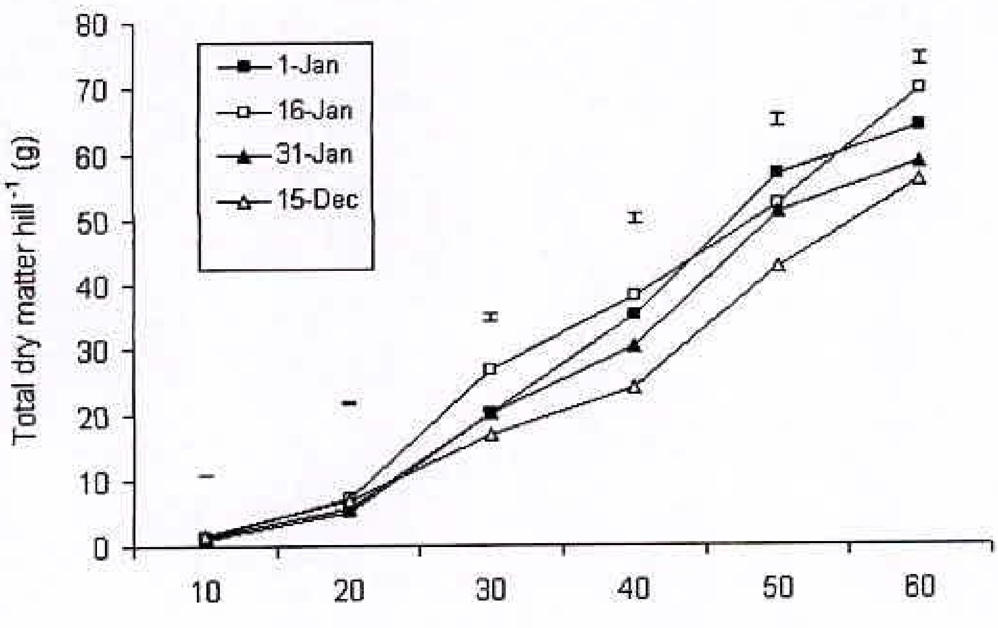

Fig. 4. Effect of transplanting time on dry matter production at different days after transplanting. [Vertical bars represent LSD (0.05)]

Effect of date of transplanting

The effect of different dates of transplanting on total dry matter (TDM) $hill^{-1}$ at all growth stages was significant (Fig. 4). Results revealed that TDM increased with age. The highest TDM $hill^{-1}$ was observed in 16 January transplanting at most of the growth stages followed by 01 January transplanting. The TDM was greater in 16 January transplanting because of increased LA which accumulated more assimilates than the other dates of sowing. In contrast, the lowest production of TDM $hill^{-1}$ was recorded when transplanted on 15 February. The plant took less time for growth and development when transplanted on 15 February. That is why, TDM was less in 15 February transplanting of *Boro* rice.

Interaction effect of variety and date of transplanting

The interaction effect of variety and date of transplanting on TDM production at all growth stages was significant (Table2). The highest TDM $hill^{-1}$ was recorded in Hira2 when transplanted on 16 January at most of the growth stages. In contrast, the lowest TDM production was recorded in BRRI dhan29 when transplanted on 15 February (49.11 g $hill^{-1}$).

4.1.3 Absolute growth rate

Effect of variety

The effect of variety on AGR at all growth stages was significant (Fig. 5).The AGR increased from 10-20 DAT to 20-360 DAT followed by decline to 30-40 DAT and then increased from 40-50 DAT followed by decline at 50-60 DAT. Aloron and Hira2 showed higher AGR at 20-30 and 40-50 DAT whereas BRRI dhan29 showed lower AGR at most of the growth stages.

Table 2. Interaction effect of variety and transplanting time on total dry matter production at different growth stages

Interaction	Total dry matter (g $hill^{-1}$) at different days after transplanting					
	10	20	30	40	50	60
V_1D_1	1.11 ef	4.69 gh	19.02 de	36.57 bc	52.98 cd	56.04 fg
V_1D_2	1.52 bc	4.97 g	22.95 bc	42.20 a	52.30 cde	68.58 bcd
V_1D_3	1.42 cd	6.61 e	19.33 de	30.29 def	43.53 fg	56.44 fg
V_1D_4	1.23 de	7.36 bc	17.69 ef	20.59 h	37.59 h	49.11 h
V_2D_1	0.91 fgh	4.83 gh	17.02 efg	34.44 bcd	63.04 a	71.34 ab
V_2D_2	1.65 b	11.69 a	31.39 a	38.96 ab	54.71 cd	75.46 a
V_2D_3	1.07 efg	7.05 cde	17.93 ef	32.19 cde	55.86 bc	61.05 ef
V_2D_4	1.06 efg	6.88 de	24.68 b	27.52 ef	45.08 f	65.88 b-e
V_3D_1	1.01 e-h	4.47 h	21.39 cd	34.49 bcd	59.96 ab	64.67 cde
V_3D_2	1.43 cd	7.57 b	29.15 a	36.17 bc	51.01 de	65.35 cde
V_3D_3	1.05 efg	4.83 gh	15.54 fg	28.78 ef	53.71 cd	60.17 ef
V_3D_4	1.96 a	6.01 f	18.85 de	25.62 fg	47.85 ef	57.79 f
V_4D_1	0.99 fgh	6.10 f	22.65 bc	35.44 bc	51.19 cde	63.82 de
V_4D_2	0.81 h	4.47 h	23.77 bc	35.67 bc	51.33 cde	70.24 abc
V_4D_3	0.84 gh	4.94 gh	14.18 g	29.95 def	51.03 de	57.22 f
V_4D_4	1.47 bc	7.12 bcd	18.88 de	22.27 gh	39.78 gh	51.09 gh
LSD(0.05)	0.20	0.43	2.94	4.26	4.12	5.16
CV (%)	10.04	4.16	8.42	8.00	4.88	4.98

V_1 = BRRI dhan29; V_2 = Hera2; V_3 = Aloron; V_4 = Tia; D_1 = Transplanting on 01 January; D_2 = Transplanting on 16 January; D_3 = Transplanting on 31 January; D_4 = Transplanting on 15 February;
In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT;
* and ** indicate significance at 5% and 1% level of probability, respectively.

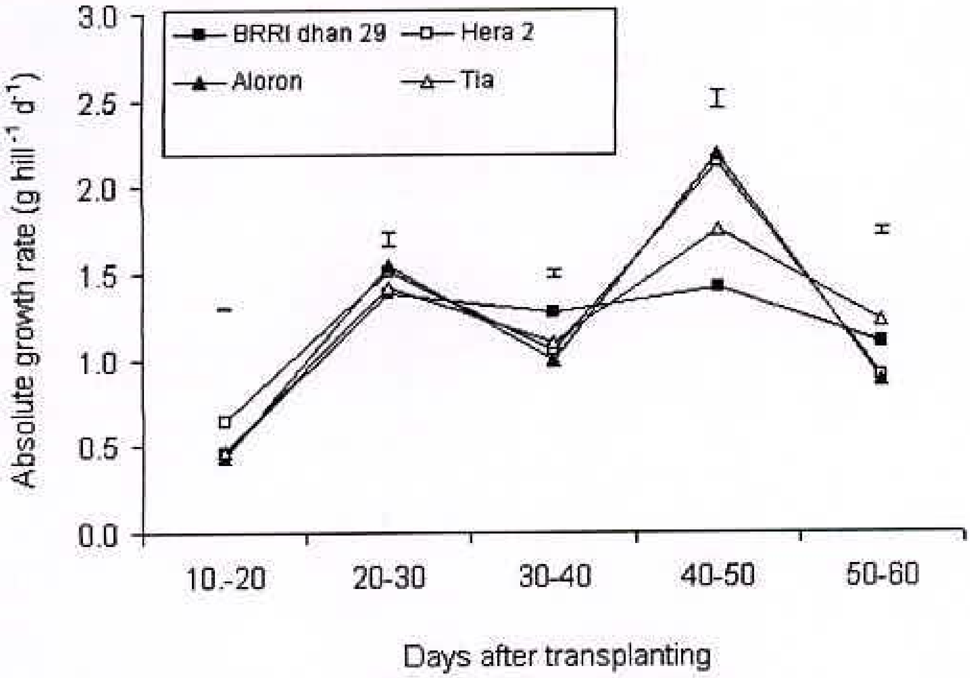

Fig. 5 Effect of variety on absolute growth rate at different age.
[Vertical bars represent LSD (0.05)]

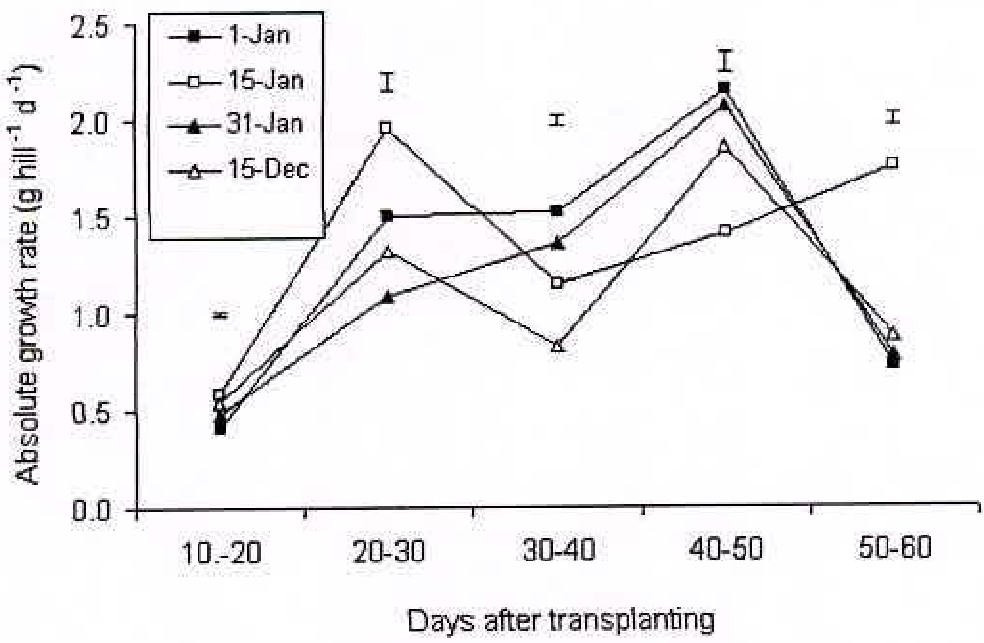

Fig. 6. Effect of transplanting time on absolute growth rate at different days after transplanting. [Vertical bars represent LSD (0.05)]

Effect of date of transplanting

Absolute growth rate (AGR) was significantly influenced by date of transplanting at all growth stages (Fig. 6). Results revealed that AGR increased from 10-20 DAT to 20-30 DAT followed by a decline till 30-40 DAT and then increased for 40-50 DAT and thereafter declined in three dates of transplanting out of four. In 15 January transplanting, the AGR increased from 10-20 DAT to 20-30 DAT followed by declined to 30-40 DAT and thereafter increased gradually till 60 DAT. At 20-30 and 50-60 DAT, the AGR was recorded in 15 January transplanting due to increased TDM hill^{-1} (Fig. 3). At 30-40 DAT, the lowest AGR was recorded in 15 February transplanting because lesser TDM production when transplanted on 15 February. Assaduzzam (2006) reported that TDM production as well as AGR was lower in February transplanting that supported the present experimental results.

Interaction effect of variety and date of transplanting

The interaction effect of variety and date of transplanting on AGR at all growth stages was significant (Table 3). At 10-20 and 50-60 DAT, the highest AGR was recorded in Hira2 when transplanted on 16 January. In contrast, the lowest AGR was recorded in Hira2 when transplanted on 15 February (0.21 g hill^{-1} day^{-1}).

4.2 Some morphological and phenological characters

4.2.1 Plant height

Effect of variety

Plant height differed significantly in case of different varieties (Table4). Plant height was statistically similar in three varieties out of four varieties. The shortest plant height was recorded in Tia (98.20 cm). Genotypic variation in plant height was also observed by BRRI (1998) in rice that supported the present experimental results.

Table 3. Interaction effect of variety and transplanting time on absolute growth rate at different growth stages

Interaction	Absolute growth rate (g hill^{-1} day^{-1}) at different days after transplanting				
	10-20	20-30	30-40	40-50	50-60
V_1D_1	0.36 ef	1.43 de	1.76 b	1.64 e	0.31 j
V_1D_2	0.34 f	1.80 bc	1.93 a	1.01 g	1.64 c
V_1D_3	0.52 cd	1.27 ef	1.10 f	1.32 f	1.29 de
V_1D_4	0.61 b	1.03 fg	0.29 h	1.70 e	1.15 e
V_2D_1	0.39 ef	1.22 ef	1.74 b	2.86 a	0.83 g
V_2D_2	1.00 a	1.97 ab	0.76 g	1.58 ef	2.08 a
V_2D_3	0.60 b	1.09 fg	1.43 d	2.37 bcd	0.52 hi
V_2D_4	0.58 b	1.78 bc	0.28 h	1.76 e	0.21 j
V_3D_1	0.35 ef	1.69 bcd	1.3 de	2.55 b	0.47 i
V_3D_2	0.61 b	2.16 a	0.70 g	1.48 ef	1.43 d
V_3D_3	0.38 ef	1.06 fg	1.32 de	2.49 bc	0.65 h
V_3D_4	0.41 e	1.28 ef	0.67 g	2.22 cd	0.99 f
V_4D_1	0.51 d	1.66 cd	1.28 e	1.58 ef	1.26 e
V_4D_2	0.37 ef	1.93 abc	1.19 ef	1.57 ef	1.89 b
V_4D_3	0.41 e	0.92 g	1.58 c	2.11 d	0.62 hi
V_4D_4	0.57 bc	1.18 efg	0.34 h	1.75 e	1.13 ef
LSD(0.05)	0.05	0.26	0.13	0.26	0.15
CV (%)	4.61	10.47	7.22	8.36	8.76

V_1 = BRRI dhan29; V_2 = Hera2; V_3 = Aloron; V_4 = Tia; D_1 = Transplanting on 01 January; D_2 = Transplanting on 16 January; D_3 = Transplanting on 31 January; D_4 = Transplanting on 15 February;
In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT;
** indicate significance at 1% level of probability.

Table 4. Effect of variety and transplanting time on plant characters

Treatments	Plant height (cm)	Straw yield ($t\ ha^{-1}$)	Unfilled grains $panicle^{-1}$ (no.)	Days to flowering	Days to maturity
Variety					
BRRI dhan29	111.6 a	6.96 b	48.00 a	62.08 a	90.67 a
Hera2	114.5 a	7.58 a	41.33 b	58.08 b	86.58 b
Aloron	113.3 a	6.96 b	37.96 b	53.50 d	84.33 c
Tia	98.20 b	4.92 c	42.22 b	55.08 c	85.00 c
LSD(0.05)	5.63	0.43	9.94	1.84	2.14
Transplanting time					
01 January	110.2 ab	8.58 a	54.87 a	78.33 a	107.8 a
16 January	108.4 bc	6.26 b	35.85 c	53.33 b	82.25 b
31 January	107.2 c	5.96 c	31.36 c	51.42 c	80.75 c
15 February	111.8 a	5.62 d	47.44 b	45.67 d	75.75 d
LSD(0.05)	5.63	0.43	9.94	1.84	2.14
CV (%)	3.09	4.88	14.07	1.93	1.48

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

Effect of date of transplanting

Date of transplanting exerted significant effect on plant height (Table4). The tallest plant was recorded on 15 February transplanting (111.8 cm) and the shortest plant was recorded on 31 January transplanting (107.2 cm). This result is partial supported by BINA (2006) where it was reported that plant height increased with delayed transplanting.

Interaction effect of variety and date of transplanting

The interaction between date of transplanting and variety had significant effect on plant height in rice (Table5). The taller plants of BRRI dhan29 and Tia were recorded when transplanted on 31 January and the taller plants of Hira2 and Aloron were recorded when transplanted on 16 January. In contrast, the shortest plants in all the varieties were recorded when transplanted on 15 February.

4.2.2 Straw yield

Effect of variety

In varieties, straw yield varied significantly (Table4). The variety, Hira2 produced the highest straw yield (7.58 t ha^{-1}) and the variety, Tia produced the lowest (4.92 t ha^{-1}).

Effect of date of transplanting

The effect of transplanting date on straw yield was significant (Table4). Results revealed that straw yield decreased with delayed transplanting. The highest straw yield was observed when transplanted on 01 January (8.58 t ha^{-1}) and the lowest was recorded when transplanted on 15 February (5.62 t ha^{-1}). BRRI (2005) reported that straw yield decreased with delayed transplanting which supports the present experimental results.

Table 5. Interaction effect of variety and transplanting time on plant characters

Interaction	Plant height (cm)	Straw yield (t ha^{-1})	Unfilled grains $panicle^{-1}$ (no.)	Days to flowering	Days to maturity
V_1D_1	108.0 bc	8.86 c	51.23 bc	97.00 a	127.7 a
V_1D_2	110.0 bc	10.4 a	36.20 def	82.33 b	112.7 b
V_1D_3	117.4 a	9.64 b	54.57 b	69.67 c	97.00 c
V_1D_4	105.5 c	5.42 g	77.47 a	64.33 d	94.00 d
V_2D_1	113.0 ab	6.32 e	39.53 d	53.67 e	80.33 ghi
V_2D_2	113.8 ab	6.97 d	38.57 de	53.33 ef	81.00 fgh
V_2D_3	112.5 ab	6.81 d	37.27 def	51.33 gh	82.67 f
V_2D_4	94.30 d	4.97 h	28.03 efg	55.00 e	85.00 e
V_3D_1	108.9 bc	6.51 de	40.77 d	51.67 fg	79.33 hij
V_3D_2	116.9 a	6.77 d	35.50 def	51.00 gh	78.67 ij
V_3D_3	105.9 c	5.83 fg	27.20 fg	49.67 h	82.00 fg
V_3D_4	97.20 d	4.75 h	21.97 g	53.33 ef	83.00 ef
V_1D_1	116.6 a	6.17 ef	60.47 b	46.00 ij	75.33 k
V_1D_2	117.2 a	6.18 ef	55.07 b	45.67 j	74.00 k
V_1D_3	117.4 a	5.57 g	32.80 def	43.33 k	75.67 k
V_1D_4	95.80 d	4.57 h	41.43 cd	47.67 i	78.00 j
LSD(0.05)	5.63	0.43	9.94	1.84	2.14
CV (%)	3.09	4.88	14.07	1.93	1.48

V_1 = BRRI dhan29; V_2 = Hera2; V_3 = Aloron; V_4 = Tia; D_1 = Transplanting on 01 January; D_2 = Transplanting on 16 January; D_3 = Transplanting on 31 January; D_4 = Transplanting on 15 February;
In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; ** indicate significance at 1% level of probability.

Interaction effect of variety and date of transplanting

The interaction between date of transplanting and variety had significant effect on straw yield in rice (Table5). BRRI dhan29 produced the highest straw yield when transplanted on 16 January (10.4 t ha^{-1}). Tia produced the lowest straw yield when transplanted on 15 February (4.57 t ha^{-1}).

4.2.3 Unfilled grains $panicle^{-1}$

Effect of variety

Variety had significant effect on the number of unfilled grains $panicle^{-1}$ (Table4). The variety Aloron produced the fewest unfilled grains $panicle^{-1}$ (37.96) while the highest unfilled grains $panicle^{-1}$ was recorded in BRRI dhan29 (48.00). Genotypic variation in unfilled grains $panicle^{-1}$ was observed by Mandol *et al.* (2005) in rice which also supports the present experimental results.

Effect of date of transplanting

The effect of date of transplanting on unfilled grain numbers $panicle^{-1}$ was statistically significant at $P \leq 0.05$ (Table4). Result revealed that the number of unfilled grains $panicle^{-1}$ was greater at early transplanting of 01 January (54.87 $panicle^{-1}$) followed by 15 February transplanting (47.44 $panicle^{-1}$). The lowest number of unfilled grains $panicle^{-1}$ was recorded on 31 January transplanting (31.36 $panicle^{-1}$).

Interaction effect of variety and date of transplanting

The interaction effect of variety and date of transplanting on number of unfilled grains $panicle^{-1}$ was significant at $P \leq 0.05$ (Table5). The highest unfilled grains $panicle^{-1}$ was recorded in BRRI dhan29 when transplanted on 15 February (77.47 panicle^{-1}) and the lowest was recorded in Aloron when transplanted on 15 February (21.97 panicle^{-1}).

4.2.4 Days to flowering and maturity

Effect of variety

There was significant variation in days to flowering and maturity among the varieties (Table4). BRRI dhan29 took the longest period for flowering (62.08 DAT) and for maturity (90.67 DAT). Aloron took the shortest period for flowering (53.50 DAT) and for maturity (84.33 DAT) which was statistically identical to Tia. Genotypic variation in days to flowering and maturity was also observed by BRRI (1998) in rice that also supports the present experimental results.

Effect of date of transplanting

Days to flowering and maturity were significantly influenced by the date of transplanting (Table4). Results revealed that days to flowering and maturity decreased with delayed planting. Results also showed that early flowering plants also matured earlier. The longest period for flowering (78.33 DAT) and for maturity (107.8 DAT) were observed when planted on 01 January and the shortest period for flowering (45.67 DAT) and for maturity (75.75 DAT) was observed when transplanting on 15 February. This result is consistent with Yeasmin (2005) who reported that days to maturity decreased with delayed transplanting in *Boro* rice.

Interaction effect of variety and date of transplanting

The interaction effect of variety and date of transplanting on days to flowering and maturity was significant at $P \leq 0.05$ (Table5). The highest days to flowering (97.0 DAT) and maturity (127.7 DAT) was observed in BRRI dhan29 when transplanted on 01 January. The lowest days to flowering and maturity was observed in Tia when transplanted on 16 January.

4.3 Yield attributes and yields

4.3.1 Effective tillers hill^{-1}

Effect of variety

Number of effective tillers hill^{-1} differed significantly due to variety (Table6). The higher number of effective tillers hill^{-1} was recorded in BRRI dhan29 and Hira2 with being the highest in Hira2 (8.98 hill^{-1}). The lowest number of effective tillers hill^{-1} was observed in Tia (7.48 hill^{-1}). Genotypic variation in effective tiller number hill^{-1} was also observed by BRRI (1998) in rice that supported the present experimental result.

Effect of date of transplanting

Date of transplanting exerted significant effect on number of effective tillers hill^{-1} (Table6). Result showed that number of effective tillers hill^{-1} decreased with delayed transplanting in *Boro* rice. The highest number of effective tillers hill^{-1} was recorded in 01 January planting (9.10 hill^{-1}) followed by 16 January planting (8.82 hill^{-1}) with same statistical rank. In contrast, the lowest number of effective tillers hill^{-1} was recorded in 15 February planting. This result is supported by Khalid (2006) who reported that effective tiller number decreased with delayed transplanting that supported the present experimental results.

Interaction Effect of Variety and Date of Transplanting

The interaction between date of transplanting and variety had significant effect on the number of effective tillers hill^{-1} in *Boro* rice (Table5). Results showed that higher number of effective tillers hill^{-1} was observed in all the varieties when transplanted on 16 January. The lower number of effective tillers hill^{-1} was recorded in all the varieties when transplanted on 15 February.

Table 6. Effect of variety and transplanting time on yield attributes and yields

Treatments	Effective tillers hill^{-1} (no.)	Grains panicle^{-1} (no.)	1000-grain weight (g)	Grain yield (t ha^{-1})	Harvest index (%)
Variety					
BRRI dhan29	8.88 a	124.8 a	23.14	6.03 b	46.67 a
Hera2	8.98 a	129.4 a	23.23	6.40 a	46.58 a
Aloron	7.70 b	116.9 b	23.18	5.42 c	43.52 b
Tia	7.48 b	90.82 c	22.85	4.12 d	45.40 ab
LSD(0.05)	0.61	5.47	0.65	0.19	1.83
Transplanting time					
01 January	9.10 a	111.9 b	22.26 c	5.45 b	39.03 c
16 January	8.82 a	123.9 a	24.01 b	6.07 a	48.45 a
31 January	7.88 b	112.2 b	25.35 a	5.62 b	48.56 a
15 February	7.25 c	113.8 b	20.78 d	4.82 c	46.14 b
LSD(0.05)	0.61	5.47	0.65	0.19	1.83
CV (%)	4.42	5.68	3.37	4.14	4.84

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

4.3.2 Grains panicle $^{-1}$

Effect of variety

Variety had significant effect on the number of grains panicle^{-1} (Table6). The grains panicle^{-1} was significantly higher in Hira2 (129.4) and BRRI dhan29 (124.8) with being the highest in Hira2. The lowest number of grains panicle^{-1} was recorded in Tia (90.82). Genotypic variations in grains panicle^{-1} was observed by BRRI (2004) in rice also supported the present experimental result.

Effect of date of transplanting

The effect of date of transplanting on number of grains panicle $^{-1}$ was statistically significant at $P \leq 0.05$ (Table6). Results revealed that the number of grains panicle $^{-1}$ increased till 16 January transplanting followed by a decline. The highest number of grains panicle^{-1} (123.9) was observed when transplanted on 16 January and the lowest number of grains panicle^{-1} (111.9) was recorded when transplanted on 01 January. Reduction in the number of grains panicle^{-1} at early transplanting might be due to unfavorable assimilate translocation to the grain i.e. lower harvest index (Table 6). Similar result was also reported by Chowdhury and Guha (2000) who observed that grains panicle $^{-1}$ was higher in *Boro* rice when transplanted in January.

Table 7. Interaction effect of variety and transplanting time on yield attributes and yields

Interaction	Effective tillers $hill^{-1}$ (no.)	Grains $panicle^{-1}$ (no.)	1000-grain weight (g)	Grain yield ($t\ ha^{-1}$)	Harvest index (%)
V_1D_1	9.47 a	126.2 a-d	22.23	5.75 ef	39.36 e
V_1D_2	9.60 a	130.5 abc	22.44	6.55 ab	38.64 e
V_1D_3	8.83 bc	120.4 cde	22.30	5.84 def	37.73 e
V_1D_4	8.50 cde	70.57 i	22.06	3.67 i	40.37 de
V_2D_1	9.40 ab	134.0 ab	24.10	6.73 a	51.57 a
V_2D_2	9.50 a	135.2 a	24.00	6.71 a	49.05 ab
V_2D_3	8.40 cde	123.1 a-d	24.15	6.23 bcd	45.01 bc
V_2D_4	8.00 e	103.4 fg	23.78	4.62 h	48.18 ab
V_3D_1	8.70 cd	116.3 de	25.41	6.11 cde	48.42 ab
V_3D_2	8.75 c	120.0 cde	25.48	6.48 abc	48.91 ab
V_3D_3	7.07 f	114.2 def	25.37	5.25 g	47.38 abc
V_3D_4	7.00 f	98.40 gh	25.16	4.66 h	49.52 a
V_1D_1	7.97 e	122.6 bcd	20.80	5.55 fg	47.35 abc
V_1D_2	8.07 de	131.8 abc	21.00	5.86 def	49.74 a
V_1D_3	6.53 f	109.9 ef	20.92	4.37 h	43.96 cd
V_1D_4	6.43 f	90.90 h	20.41	3.52 i	43.51 cd
LSD(0.05)	0.61	10.94	1.30	0.38	3.68
CV (%)	4.42	5.68	3.37	4.14	4.84

V_1 = BRRI dhan 29; V_2 = Hera 2; V_3 = Aloron; V_4 = Tia; D_1 = Transplanting on 01 January; D_2 = Transplanting on 16 January; D_3 = Transplanting on 31 January; D_4 = Transplanting on 15 February;
In a column, figures bearing same letter (s) do not differ significantly at $P \leq 0.05$ by DMRT; NS = Not significant; ** indicate significance at 1% level of probability.

Interaction effect of variety and date of transplanting

The interaction effect of variety and date of transplanting for grains panicle^{-1} was also significant at $P \leq 0.05$ (Table7). Results revealed that higher number of grains panicle^{-1} was observed when transplanted on 16 January in all the varieties and the lower number of grains panicle^{-1} was observed when transplanted on 15 February in all the varieties.

4.3.3 1000 grain weight

Effect of variety

A non-significant difference in 1000 grain weight was also observed in studied varieties of rice (Table6).

Effect of date of transplanting

1000 grain weight was significantly influenced by the date of transplanting (Table6). Results revealed that 1000 grain weight increased with delayed transplanting till 31 January followed by a decline. The highest 1000 grain weight (25.35 g) was recorded when transplanted on 31 January. The lowest 1000 grain weight (20.78 g) was observed when transplanted on 15 February. This result indicates that grain size is controlled by genes not by environment. This result is consistent with Shaon (2006) who reported early transplanted rice had greater grain size than latter ones.

Interaction effect of variety and date of transplanting

The interaction effect of seed rate and variety for 1000 grain weight was statistically non-significant at $P \leq 0.05$ (Table7).

4.3.4 Grain yield

Effect of variety

Variety had significant effect on grain yield in *Boro* rice (Table6). The highest grain yield (6.40 t ha^{-1}) was recorded in Hira2 due to increased number of effective tillers $hill^{-1}$ and grains $panicle^{-1}$. The variety Tia showed the lowest grain yield (4.12 t ha^{-1}) due to inferiority in yield attributes. Genotypic variation in grain yield was also observed by many workers (Kamal et al., 1998; Singh and Singh, 2000; Rahman, 2002; Mondal et al., 2005; Yeasmin, 2005).

Effect of date of transplanting

Date of transplanting had significant effect on grain yieldin *Boro* rice (Table6). Result revealed that grain yield increased from 01 January transplanting to 16 January transplanting followed by a decline. The highest grain yield (6.07 t ha^{-1}) was recorded when transplanted on 16 January followed by 31 January transplanting (5.62 t ha^{-1}). Grain yield increased during January transplanting was due to greater number of effective tillers $hill^{-1}$, increased number of grains $panicle^{-1}$ and increased grain size. This result indicates that optimum time for transplanting of *Boro* rice is Mid January. The lowest grain yield (4.82 t ha^{-1}) was observed when transplanted on 15 February. The lower grain yield under delay transplanting was might be due to lesser amount of assimilate produced by the plants through lesser photosynthetic area $plant^{-1}$ (Fig. 1-4). Similar result was also reported by many workers (Ali et al., 1995; BRRI, 1998; Chowdhury and Guha, 2000; Assaduzzaman, 2006; BINA, 2006). They observed that grain yield of *Boro* rice was maximum when transplanted during First to Mid February.

Interaction effect of variety and date of transplanting

The interaction effect of variety and date of transplanting on grain yield was significant at $P \leq 0.05$ (Table7). Results showed that three varieties of BRRI dhan29, Aloron and Tia performed the best when transplanted on 16 January whereas Aloron performed the best when transplanted on 01 and 16 January. In contrast, all the varieties performed the lowest when transplanted on 15 February. These results indicate that transplanting of *Boro* rice during mid January is the optimum for getting maximum grain yield in those four varieties.

4.3.5 Harvest index

Effect of variety

Variation in harvest index among the studied varieties was statistically significant (Table6). The higher harvest index was observed in BRRI dhan29 (46.67%) and Hira2 (46.58%). The lowest harvest index was observed in Aloron (43.52%) indicating dry matter partitioning to economic yield is poor in Aloron than the other varieties. This result indicates that assimilate partitioning towards grains is better in BRRI dhan29 and Hira2 compared to Aloron. Genotypic variation in harvest index was also observed by many workers (Bhuiya*et al.*, 1992; BRRI, 1998; Chowdhury and Guha, 2000; BINA, 2006).

Effect of date of transplanting

The effect of date of transplanting of *Boro* rice on harvest index was statistically significant (Table6). Result showed that dry matter partitioning to economic was better when transplanted on 16 and 31 January. The lowest harvest index was observed when transplanted on 15 February (46.14%). It means dry matter partitioning was not favourable when transplanted of *Boro* rice after January.

Interaction effect of variety and date of transplanting

The interaction effect of variety and date of transplanting in relation to harvest index (HI) was also statistically significant (Table6). Results showed that different varieties response to different date of transplanting. BRRI dhan29 and Aloron showed the highest HI when transplanted on 15 February. Hira2 showed the highest HI when transplanted on 01 January. The (HI) of Tia was the best when transplanted on 16 January.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at the field laboratory of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from November 2009 to June 2010 to investigate the effect of variety and date of transplanting on morpho-physiological characters, yield attributes and yields of hybrid and inbred *Boro* rice varieties. The experiment comprised of three hybrid varieties *viz*., Hira2, Alron and Tia along with an inbred variety, BRRI dhan29, and four dates of transplanting *viz*., 01, 16 and 31 January and 15 February. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The collected data were analyzed statistically and the means were adjudged by DMRT at 5% and 1% level of probability.

The growth parameters such as leaf area, total dry matter production and absolute growth rate were significantly influenced by date of transplanting in *Boro* rice. Results revealed that leaf area, total dry matter and absolute growth rate were higher when transplanted on 01 and 16 January than those of 31 January and 15 February transplanting at most of the growth stages. In contrast, the lowest leaf area, total dry matter production and absolute growth rate were recorded when transplanted on 15 February.

The effect of date of transplanting on morphological and phenological characters such as plant height, straw yield, number of unfilled grains panicle^{-1}, days to flowering and maturity was significant. The highest straw yield, number of unfilled grains panicle^{-1}, days required to flowering and maturity were recorded when transplanted on 01 January. The lowest straw yield, days required to flowering and maturity was recorded on 15 February transplanting.

The effect of date of transplanting on yield attributes and grain yield was significant. Results revealed that number of effective tillers hill^{-1} decreased with delay transplanting. The highest grain weight was recorded when transplanted on 16 January due to increased number of grains panicle^{-1} and higher harvest index. However, 1000 grain weight increased with delay transplanting till 31 January followed by a decline. The lowest grain yield was recorded when transplanted on 15 February due to inferior yield attributes.

The effect of variety on growth, yield attributes and yields was significant. Results revealed that the variety Hira2 was superior in relation to plant height, tiller number, LA, TDM, AGR, grain number, 1000-grain weight and biological yield which resulting the higher grain yield t ha^{-1}. In contrast, the lowest yield attributing characters were observed in Tia and resulting the lowest grain yield.

The interaction effect of variety and date of transplanting on all the studied parameters such as growth, yield attributes and yields was significant. Results showed that the three varieties BRRI dhan29, Aloron and Tia performed the best when transplanted on 16 January where as HIra2 performed the best when transplanted on 01 and 16 January. In contrast, all the varieties performed the lowest when transplanted on 15 February. These results indicate that transplanting of *Boro* rice during mid January is the optimum for getting maximum grain yield in those four varieties.

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

i) The effect of date of transplanting was tremendous on morphological and growth characters, yield attributes and yields in *Boro* season and transplanting during mid January is the optimum time for getting maximum grain yield;

ii) The variety Hira2 showed the best regarding yield performance; and

iii) BRRI dhan29, Aloron and Tia performed the best when transplanted on 16 January where as Hira2 performed the best when transplanted on 01 and 16 January.

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APPENDICES

Appendix I. Physical and chemical properties of soil of the experimental plots

A. Physical properties of soil	
% Sand (0.2-.02 mm)	21.75
% Silt (0.02-.002 mm)	66.60
% Clay (< 0.002 mm)	11.65
Textural class	Silt loam
Consistency	Granular
B. Chemical properties of soil	
Soil pH	6.53
Organic carbon (%)	1.68
Organic matter (%)	1.28
Total nitrogen (%)	0.17
Available phosphorus (ppm)	8.05
Exchangeable potassium (me/100 g soil)	0.16
Available sulphur (ppm)	11.43

Appendix II. Average monthly rainfall, air temperature and relative humidity during the experimental period between November 2009 to June, 2010 at the SAU area, Dhaka

Month	Monthly average air temperature (^{0}C)			Average rainfall (mm)	Average relative humidity (%)	Average daily sunshine (hrs)
	Maximum	Minimum	Average			
October	31.27	24.14	27.71	18.0	86.2	8.65
November	29.49	19.55	24.52	00.0	84.3	8.45
December	26.52	13.19	19.85	00.0	80.8	6.67
January	23.43	12.93	18.18	00.0	78.0	7.20
February	27.34	16.41	21.87	06.6	73.9	8.18
March	29.61	20.57	25.09	13.6	80.6	7.66
April	30.56	22.14	26.35	96.6	78.57	7.42
May	32.80	23.34	28.07	266	82.50	5.66
June	31.27	26.46	29.09	153.4	86.29	6.20

Source: Weather Yard, SAU, Dhaka

Appendix III. Analysis of variance (mean square) on leaf area hill^{-1} of rice at different days after planting

Source of variation	df	Leaf area (cm^2 hill^{-1}) at days after transplanting					
		10	20	30	40	50	60
Replication	2	27.56	163.08	473.06	2678.0	29981.0	12488.0
Date of transplanting (A)	3	913.9**	21818**	55883*	3240**	579057**	61192*
Variety (B)	3	6128**	17189**	321318**	315745**	360728**	954112**
A×B	9	2115**	27206**	51064**	151808**	41511**	123868**
Error	30	16.49	228.81	743.19	2527.6	6938.2	20859.8

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

Appendix IV. Analysis of variance (mean square) on total dry matter $hill^{-1}$ of rice at different days after planting

Source of variation	df	Total dry matter (g $hill^{-1}$) at days after transplanting					
		10	20	30	40	50	60
Replication	2	0.001	0.001	0.893	3.063	0.250	2.908
Date of transplanting (A)	3	0.28**	10.4**	23.7**	14.7*	176.4**	252.5**
Variety (B)	3	0.49**	11.4**	215.1**	465.5**	423.7**	453.8**
A×B	9	0.26**	9.61**	30.5**	16.98*	26.8**	35.32**
Error	30	0.015	0.067	3.10	6.529	6.11	9.561

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

Appendix V. Analysis of variance (mean square) on absolute growth rate of rice at different days after planting

Source of variation	df	Absolute growth rate (g $hill^{-1}day^{-1}$) at days after transplanting				
		10-20	20-30	30-40	40-50	50-60
Replication	2	0.003	0.003	0.038	0.001	0.014
Date of transplanting (A)	3	0.109**	0.072**	0.164**	1.568**	0.312**
Variety (B)	3	0.073**	1.669**	2.975**	1.341**	2.895**
A×B	9	0.080**	0.173**	0.411**	0.303**	0.477**
Error	30	0.001	0.024	0.006	0.025	0.008

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

Appendix VI. Analysis of variance (mean square) on morphological and phenological characters

Source of variation	df	Plant height (cm)	Straw yield ($t\ ha^{-1}$)	Unfilled grains $panicle^{-1}$ (no.)	Days to flowering	Days to maturity
Replication	2	0.063	0.002	43.00	0.750	1.021
Date of transplanting (A)	3	47.73*	21.55**	1382.6**	2512.1**	2486.8**
Variety (B)	3	685.42**	16.08**	209.0**	171.1**	96.91**
A×B	9	65.84**	1.682**	478.9**	162.5**	220.9**
Error	30	11.396	0.066	35.53	1.217	1.643

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

Appendix VII. Analysis of variance (mean square) on yield attributes and grain yields

Source of variation	df	Effective tillers $hill^{-1}$ (no.)	Grains $panicle^{-1}$ (no.)	1000-grain weight (g)	Grain yield ($t\ ha^{-1}$)	Harvest index (%)
Replication	2	0.297	18.169	1.404	0.013	1.000
Date of transplanting (A)	3	8.750**	389.7**	47.95**	3.20**	241.5**
Variety (B)	3	7.270**	3559.0**	0.346 ^{ns}	12.05**	25.92**
A×B	9	0.145**	211.9**	0.024 ^{ns}	0.362**	9.457*
Error	30	0.133	43.022	0.607	0.052	4.867

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