INFLUENCE OF PLANTING DATES ON THE MORPHOLOGICAL AND YIELD ATTRIBUTES OF SOME HYBRID RICE (*Oryza sativa* L.) VARIETIES IN *AUS* SEASON

BY

MD. BAKI BILLAH

Registration No. : 05-01696

A Thesis

Submitted to the Department of Agricultural Botany
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (M. S.)
IN
AGRICULTURAL BOTANY

SEMESTER: JANUARY - JUNE, 2011

Approved by:

(Prof. Dr. Kamal Uddin Ahamed)
Supervisor

(Assoc. Prof. Md. Moinul Haque)
Co-Supervisor

(Prof. Asim Kumar Bhadra)
Chairman
Examination Committee

DEPARTMENT OF AGRICULTURAL BOTANY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

Ref: ------------------ Date: ----------------

CERTIFICATE

This is to certify that the thesis entitled "INFLUENCE OF PLANTING DATES ON THE MORPHOLOGICAL AND YIELD ATTRIBUTES OF SOME HYBRID RICE (Oryza sativa L.) VARIETIES IN AUS 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 in AGRICULTURAL BOTANY**, embodies the results of a piece of bona fide research work carried out by **MD. BAKI BILLAH**, Registration No. 05-01696 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.

Dated:
Place: Dhaka, Bangladesh

(Prof. Dr. Kamal Uddin Ahamed)
Supervisor

DEDICATED TO
MY
BELOVED PARENTS

ACKNOWLEDGEMENT

All praises to Almighty Allah, the Supreme Ruler of the universe Who enables the author to complete this thesis work successfully for MS degree.

The author wishes to express his sincere appreciation and immense indebtedness to his supervisor ***Prof. Dr. Kamal Uddin Ahamed,*** *Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, for his scholastic guidance, planning, valuable suggestions, continuous encouragements and all kinds of support and help throughout the period of research work and preparation of this manuscript of thesis.*

He deems it a proud privilege to acknowledge his gratefulness, boundless gratitude and best regards to my respectable co-supervisor ***Associate Prof. Md. Moinul Haque,*** *Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, for his valuable suggestions, kind co-operation and dynamic guidance throughout the study and research work.*

It is a great pleasure and privilege to express his profound gratitude and sincere regards to ***Associate Prof. Asim Kumar Bhadra,*** *Chairman, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh for his valuable advice and sympathetic consideration.*

Again the author would like to express his sincere appreciation and immense indebtedness to, ***Prof. A. M. M. Shamsuzzaman,*** *Department of Agricultural Botany, SAU, Dhaka, whose constant encouragement with co-operation in innumerable aspects made it possible to complete the study in a peaceful state of mind.*

Special appreciation and warmest gratitude are extended to his other course teachers Prof. Dr. Shahnaz Sarkar, Associate Prof. Dr. Mohammad Mahbub Islam, Assistant Prof. Nasima Akter, Assistant Prof. Md. Ashabul Haque, Assistant Prof. Hasan Mohammad

Zubair and Lecturer Kamrun Nahar, Department of Agricultural Botany, Sher-e- Bangla Agricultural University, Dhaka, for their co-operations and constant encouragement.

The author owes a lot to Prof. Md. Razzab Ali, Department of Entomology and Porf. Noor Md. Rahmatulla, Department of Agricultural Statistics, Sher-e- Bangla Agricultural University, Dhaka, for their co-operations during data analysis.

He also wishes to acknowledge my indebtedness to farm division of SAU and other staff of the Department of Agricultural Botany, for their co-operation in the implementation of research work.

The author wants to give thanks to his all friends for their active encouragement and inspiration; personal acknowledgement to Mohammad Shahjahan, S. M. Al Beruni, Kh. Ashraf-Uz-Zaman, Md. Torikul Islam, Md. Alam Hossain and Sharif Mohammad Titumeer.

The author expresses his unfathomable tributes, sincere gratitude and heartfelt indebtedness from his core of heart to his beloved parents Md. Raihan Uddin and Most. Nurjahan Begum and his brothers Abdur Razzak and Monirul Islam whose sacrifice, inspiration, encouragement and continuous blessings paved the way to his higher education. The Author is also grateful to other members of the family for their forbearance, inspirations, sacrifices and blessings.

Dated: December, 2010
Place: Dhaka, Bangladesh

The Author

INFLUENCE OF PLANTING DATES ON THE MORPHOLOGICAL AND YIELD ATTRIBUTES OF SOME HYBRID RICE (*Oryza sativa* L.) VARIETIES IN *AUS* SEASON

ABSTRACT

An experiment was conducted at the field of Agricultural Botany Department, Sher-e-Bangla Agricultural University (SAU), Dhaka during Aus season from March to July 2010, with a view to study the influence of planting dates on the morphological and yield attributes of hybrid rice varieties. The experiment consisted of two levels of treatments viz. A: Three varieties where two of them were hybrids and one was inbred: BRRI Hybrid dhan2, Tia and BRRI dhan48 (Inbred). B: Four transplanting dates: 16th March, 31st March, 15th April and 30th April. The experiment was laid out in factorial randomized complete block design with three replications. Experimental results indicated that transplanting dates and varieties individually had significant effect on the growth and yield parameters like plant height, number of total tiller hill^{-1}, leaf area hill^{-1}, total dry weight (g hill^{-1}), light interception percent, chlorophyll content at flag leaf stage, number of effective tiller hill^{-1}, panicle length, number of filled spikelet panicle^{-1}, number of unfilled spikelet panicle^{-1}, number of total spikelet panicle^{-1}, spikelet filling percent, grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%). The results revealed that 16th March transplanting gave the highest grain yield. Chlorophyll content was higher in BRRI Hybrid dhan2 followed by Tia. In contrast chlorophyll content was lower in BRRI dhan48. Among the varieties BRRI dhan48 gave the highest grain yield but both the hybrid varieties BRRI Hybrid dhan2 and Tia gave lower grain yield due to higher spikelet sterility because of more sensitiveness of hybrid rice varieties to high temperature and low sunshine hour at grain filling stage. The combined effect of transplanting dates and variety had also significant effect on yield and yield contributing characters. BRRI dhan48 transplanting on 16th March showed highest grain yield attaining good yield contributing characters.

LIST OF ABBRIVIATIONS

ABBREVIATION	FULL WORD
AEZ	Agro-Ecological Zone
Anon.	Anonymous
@	At the rate of
BRRI	Bangladesh Rice Research Institute
cm	Centimeter
cm^2	Centimeter square
cv.	Cultivar(s)
CV	Coefficient of Variance
DMRT	Duncan's Multiple Range Test
DAT	Days after transplanting
e.g.	example
et al.	and others
g	Gram
G	Granular
i.e	that is
IRRI	International Rice Research Institute
kg	Kilogram
kg ha^{-1}	Kg per hectare
K_2O	Potassium Oxide
LSD	Least Significant Difference
TSP	Triple Super Phosphate
m	Meter
mg	Miligram
MP	Muriate of Potash
NS	Not Significant
OM	Organic matter
pH	Hydrogen ion concentration
P_2O_5	Phosphorus Penta Oxide
^0C	Degree Celsius
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
t ha^{-1}	Ton per hectare
TDM	Total Dry Matter

CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important cereal crop in Bangladesh and it is also our staple food. Approximately 75% of the total cultivated land covering about 11.58 million hectares (ha) produces approximate 30 million tons of rice annually BBS (2008). Rice is a cereal crop belongs to Gramineae family. It is one of the world's most widely consumed grains which play a unique role in combating global hunger (IRRI, 2004). It is the major and most extensively cultivated cereal of the world including Bangladesh that feeds half of the total population in the world. More than 90% of the world rice is produced and consumed in Asia, so it is the homeland of rice cultivation (Hossain and Pingali, 1998). At present, food production has been given the highest priority in the world to meet the demands of its ever-increasing population. Half of the world populations choose rice as their staple food as it alone supplies about 75 % of the calories and 5.5 % of the protein in the average daily diet (BRRI, 2001; Kenmore, 2003 and Bhuiyan *et al.*, 2004). Moreover, it provides vitamin and other nutrients for people (BRRI 1997a; Sattar, 1994).

Rice-growing countries in the world occupy about 146.5 million hectares (Anon, 2005). Bangladesh is the fourth largest producer and consumer of rice in the world. In Bangladesh majority of the food grains come from rice. About 80% of cropped area of this country is used for rice cultivation, with annual production of 25.18 million tons from 10.29 million ha of land (AIS, 2011). The average yield of rice in Bangladesh is 2.45 t ha^{-1} (BRRI, 2007). This average yield is almost less than 50% of the world average rice grain yield. Thus, rice plays a vital role in the livelihood of the people of Bangladesh (Hasanuzzaman *et al.*, 2007). The increased rice production has been possible largely due to the adoption of modern rice varieties on around 70.24% of the rice land which contributes to about 83.39% of the country's total rice production. However, there is no reason to be complacent. The population of Bangladesh is still increasing by 2.3 million every year to its total of 150 million and may increase by another 30 millions over the next 20 years (Momin and Husain, 2009). For the ever increasing population plus cropland reduction, the increasing demand for rice will have to be met with less land, less water, less labour and less pesticides. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020. During this time total rice area will also shrink to 10.28 million hectares. Rice (clean) yield therefore, needs to be increased from the present 2.45 to 3.74 t ha^{-1} (BRKB, 2007). Therefore, it is an urgent need of the time to increase the production of rice through increasing the yield ha^{-1}.

Based on growing seasons, three separate rice crops are recognized, the rainfed *Aus* crop with 10 percent of area, the rainfed *Aman* crop with about 51 percent area and the increasingly important irrigated *Boro* crop with about 39 percent of the cropped area. More specifically, rice production in *Aus*, *Aman* and *Boro* seasons are 150.04, 981.96 and 1383.70 million ton respectively (BBS, 2006). So among these three seasons, rice yield in the *Aus* season is the lowest and therefore, efforts should be made to increase the yield of *Aus* rice. In *Aus* season, rice cultivation area and the yield are less than other seasons due to the climatic condition. This yield may be due to high temperature and low solar radiation during the growing season (Nasiruddin, 1993). For successful rice production, timely planting, appropriate control of vegetative growth throughout the duration of the crop, suitable transplanting dates for optimum tillering and control of leaf growth by controlling water, fertilizer and chemical inputs are essential for improving the growth variables responsible for high yield (Ghosh and Singh, 1998).

Rice yield can be increased in many ways - of them developing new high yielding variety and by adopting proper agronomic management practices to the existing varieties to achieve their potential yield is important. So to develop the high yielding varieties, Japan initiated first breeding program in 1981 (Wang, 2001). In 1989, IRRI started super rice breeding program to give up to 30% more yield (13-15t ha^{-1}) than the current modern high yielding plant types (IRRI, 1993). Generally the yield of hybrid rice varieties is 10-15% more than the improved inbred varieties. It has great potentiality for food security of poor countries where arable land is scarce, population is expanding and labour is cheap. In our country BRRI has started breeding program for the development of hybrid rice varieties with large panicles and high yield potentialities. The recent yield level of high yielding inbred varieties has reached the plateau. Hybrid rice offers to break the yield ceiling of conventional semi-dwarf rice varieties. Since tropical rice-growing countries need an increased supply of rice because of their increasing population and decreasing land and water resources. Hybrid rice technology offers an opportunity to increase rice yield and thereby ensures a steady supply. Many hybrid rice varieties out yield the standard check variety with same growth duration by more than 1-1.5 t ha^{-1} (Julfiquar, 2009). In Bangladesh, hybrid rice technology has been introduced through IRRI, BRRI and commercial seed companies of India and China during last ten years and has already gained positive experience in *Boro* and early *Aman* seasons. None of the hybrid varieties has been tested so far in *Aus* season.

All the characteristics of hybrid rice are genetically governed and inherited; their expression under natural condition is very much dependent on environment, soil and management practices. Farmers sow seed in the bed and transfer to field. Delayed transplanting resulted in poor vegetative growth as well as yield. Planting date of a crop is an important factor for obtaining higher yields (Bhuiyan, 1992).

However, seeding and transplanting time can be influenced directly or indirectly, by weather condition during land and seedbed preparation, method of seeding or transplanting, irrigation facilities, times of maturity of rice in relation to the date of seeding or transplanting. Singh *et al.* (1997) described some factors which adversely affect growth and yield, such as transplanting date, hot weather during flowering and development, fertilizer management, poor soil, heavy soil, delayed harvesting after maturity and mechanical dehulling.

Under the above circumstances, it was felt necessary to examine the performance of hybrid rice in *Aus* season in comparison with an inbred variety which is cultivated in *Aus* season. Considering the above facts the present experiment was conducted to achieve the following objectives.

OBJECTIVES

i. To find out the response of some hybrid rice varieties to different dates of planting in *Aus* season.

ii. To study the morpho-physiological characters, yield and yield attributes of some hybrid rice varieties and compare them with standard inbred check variety (BRRI dhan48).

CHAPTER 2

REVIEW OF LITERATURE

The interactions of genetic potential with its environment to which it is grown actually determine the performance of rice (BRRI, 1990). The genetic potential (yield) is influenced by cultural practices. The cultural practices such as transplanting of rice in optimum time and the use of good varieties have considerable role on the growth and yield of rice. A number of experiments have been conducted in Bangladesh and also elsewhere in the world with these aspects to evaluate the performance of hybrid rice in *Aus* season. In this chapter, an attempt has been made to review some of the remarkable findings of various researches at home and abroad related to the influence of optimum time and variety on the performance of hybrid rice in *Aus* season.

2.1 Effect of transplanting dates

BRRI (1992) reported that among the tested promising lines in Aus season, IR7165-J20-3-2-1 yielded higher followed by S818-B-10-2 and BR4490-B-69. Most of the lines yielded more than 3 t ha^{-1} up to 15 April transplanting.

From an experiment Islam *et al.* (1999b) showed that agronomic characters such as plant height, panicle $hill^{-1}$ and panicle length were significantly affected by planting dates.

BRRI (2009) reported that hybrid rice varieties ACI1, Aloron, Hira2 compared with BRRI hybrid 2, BRRI dhan28 and BRRI dhan29. Results revealed that all the hybrid rice produced higher grain yield than BRRI dhan28 and BRRI dhan29 up to 15 January planting and after that BRRI dhan29 produced the highest grain yield compared to hybrid rice.

Muthukrishnan *et al.* (2000) determined the optimum time of planting (5, 15 and 25 July) for four rice hybrids. Grain yield of rice decreased progressively with delay in transplanting. The crop transplanted on 5 July and 15 July was comparable. The decrease in grain yield with delayed transplanting was accompanied by fewer panicles and filled grains panicle^{-1} and lowered 1000-grain weight. Grain yield was reduced by 9%, from 5.14 t ha^{-1} on 5 July to 4.69 t ha^{-1} on 25 July.

Hundle *et al.* (1999) conducted a research work to the effect of various date of transplanting. The reported that earlier transplanted (1 June) rice performs better.

Rao *et al.* (1996) reported from an experiment with 4 Basmati type varieties of rice transplanted during 15-25 July gave the highest yield. While delay in transplanting up to 4 August reduced the grain yield by 38.9%

Gohain and Saikai (1996) concluded that different transplanting dates significantly influenced the grain yield of transplant *Aman* rice. They said that the reduction in yield was about 50% when planting was delayed from 20 July to 5 September.

In Bangladesh, BRRI evaluated that most of the hybrid rice varieties are grown in the *Boro* season. However, hybrid rice varieties can also be grown in *Aus* and *Aman* season with the manipulation of planting date, application of manures and fertilizer and other agronomic practices.

Swain *et al.* (2007) conducted an experiment to increase the rice production during the wet season in Asia by the use of a suitable combination of a medium or long duration varieties. The crop growth stimulation model ORYZA 1N was used for variety selection. Selection was made from 12 released rice varieties of 115 to 150 day duration. ORYZA 1N model was used to stimulate the effect of planting dates on rice yield and yield was decline with late planting.

Singh *et al.* (1997) conducted experiment and showed that the rice seedlings planted early or late influence the growth and yield due to change in the climatic conditions. Thus, the growth and grain yields of rice depended on the genetic potentials of cultivars, environmental conditions and management practices.

Ghosh and Ganguly (1994) observed in a trial that modern variety in late planting caused reduction of grain yield, while, early planting of traditional variety failed to increase grain yield due to premature lodging of the crop prior to flowering.

Dhiman *et al.* (1997) showed that when transplanting became late the crop was attacked by insect or disease severely.

Babu (1987) and AICRIP (1992) reported that the yield and quantity of scanted rice was achieved by planting the crop at the optimum time at any specific location, which may vary from variety to variety.

Haque (1997) observed that delayed transplanting led to increase in vegetative growth index, where as duration of vegetative growth based on number of days until heading decreased. Changed in growth duration to various stages due to delayed transplanting were more pronounced for flowering and 80% panicle ripe indicating that these stages could be optimal for studying the response of rice plant to delayed transplanting.

Chandra and Manna (1988) reported that the delay length of the vegetative phase determines the growth and ultimate grain yield. It has been found that the vegetative phase shorter by delayed planting and ultimately decreases the yield.

BRRI (1994) observed that 40 days old seedlings of sixteen promising lines including one check variety of BR-26 to know the optimum transplanting date for getting maximum grain yield in *Boro* rice. Seedling were transplanted from 25 December 1993 to 12 March 1994 and reported that grain yield was highest when transplanted both at 25 December and 9 January followed by 25 January planting. After 25 January planting, the grain yield declined significantly.

Ali *et al.* (1995) transplanting *Boro* rice (BR-1, BR-3, BR-14) at first week of January, February and March and reported that February transplanting is the best for yield attributes and grain yield in all the varieties.

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.

Krishnan and Nayak (1998) stated that pollen grains were desiccated by high temperature was significantly reduced by delayed transplanting.

Yoshida (1981) observed that the flowering response to photoperiod sensitive varieties was markedly affected by the changes in day length. Rice growing in short day is sensitive to photoperiod thus long day can prevent or considerably delay flowering. However, photoperiod of most varieties is about 9-10 hours.

Chowdhury and Guha (2000) wants to know the effect of date of transplanting on five short duration varieties (Calturel, IR50, Govind, China and Jagilu) and three medium duration (Joymati, Mala and Mahsuri) 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.

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

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 grainy yield was 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.

Zaman (1980) revealed that transplanting time in *Aman* season was very important to control the vegetative phase of a variety. In other words, early transplanting beyond the optimum enhanced excessive vegetative growth and late planting shortening the vegetative phase.

Islam *et al.* (1999a) observed that the grain yield of transplanting *Aman* rice decreased gradually with the delay of planting dates beyond August, because low temperature increase the sterility in late planted rice.

Miah *et al.* (1990) and *Islam et al.* (1999b) reported that transplanting time influences the vegetative phase of a variety in *Aman* season. Rice seedling when planted late it will get short period for its vegetative growth and thus its yield decreased.

Asaduzzaman (2006) studied the effect of date of transplanting (5, 15 and 25 January, and 5and 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.

Joseph and Havanagi (1987) reported that consideration of planting time of rice was the most important to obtain higher yield. The early or late planting of rice in the *Aman* season influences the growth and yield due to change in climatic condition.

2.2 Effect of variety

The successful production of any crop depends on manipulation of basic ingredients of crop culture. The variety of crop is one of the important basic ingredients. High yielding varieties of rice play an important role in achieving higher yield. Some of the works related to different rice varieties are cited below.

BINA (1998) found that the hybrid rice Alok 6201 showed 20-93% higher grain yield over the modern variety IRATOM 24 number of tillers hill^{-1}, effective tillers hill^{-1}, spikelets panicle^{-1} and panicle length were maximum in Alok 6201 while the 1000-grain weight was maximum in IRATOM 24.

BINA (1998b) in a field trial with seven hybrid rice varieties found that hybrid rice 93024 gave the highest grain yield of 6.04 t ha^{-1} and the lowest grain yield was given by hybrid rice 92017, Alok 6201 produced a grain yield of 5.71 t ha^{-1}.

Khisha (2002) observed that plant height was significantly influenced by variety. He found the highest plant height (129.94 cm) in BINA dhan 5, which was significantly higher than those of Sonar Bangla 1 and BRRI dhan 29.

The characters responsible for high yielding hybrid lines were the higher panicle length, higher effective tiller and higher number of grain panicle^{-1}. Some high yielding hybrid lines such as 94024, 93027 and BINA dhan5 showed significantly higher HI (46-50%) thus transplanting more assimilate towards grain. The normal varieties BRRI dhan28 and BINA dhan5 possessed also higher HI (46-53%) as compare to many hybrid lines (36-44%) including the highest yielding line 92007 (43.7%) but except the hybrid line 95045 (57.3%) (BINA, 2001).

Patel (2000) reported the varietal performance of Kanti and IR 36. He observed that Kranti produced significantly higher grain and straw yield than IR 36. The mean yield increases with Kranti over IR 36 was 7.1 and 10.0% for grain and straw, respectively. Variety Kranti showed superiority over IR 36 due to production of taller plants.

Singh *et al.* (1998) evaluated the productivity of two rice hybrids TNH-1 and TNH-2 using Rasi and Jaya as standard checks during Kharif-1 and found that Jaya produced significantly highest grain yield (5.12 t ha^{-1}). Superior, Rasi and TNH-1 were at par in grain yield but TNH-2 recorded the lowest grain yield of 3.06 t ha^{-1}.

Kim-Jong Gun *et al.* (2007) studied to determine the effect of growth stage and cultivar on the yield and quality of whole crop rice (WCR) at National Livestock Research Institute, RDA [Korea Republic] from 2003 to 2005. Two types of rice "Chucheong and Hamasan" were harvested at six different growth stages (heading, flowering, milk, dough, yellow ripening and fully ripening stage). The highest dry matter (TDM) production was at the ripening stage and "Chucheong" gave higher yields than "Hamasan". The dry matter yield of all cultivars was low.

Naher *et al.* (2000) conducted an experiment in the net house of the Department of Agronomy, Bangladesh Agricultural University, Mymensingh during June 1994 to October 1995 to evaluate the growth duration and yield performance of BR11 and BR14 rice varieties as affected by year round transplanting. Two varieties had 12 transplanting dates at 30-day intervals. Transplanting date also affected these durations. Yield and yield contributing characters varied significantly due to variety, transplanting date and their interactions. Planting of BR14 on 29 September produce 100% sterility and with BR11 it was 90%. The BR14 rice cultivar produced the highest grain yield of 9023 kg ha^{-1} on 27 January planting and no grain was formed on 27 September planting. The overall performance of BR14 rice was better than BR11.

Prabagara and Ponnuswamy (1998) found that the A lines were found late for first flowering and 50% flowering and to have higher duration of flowering in a panicle and productive tillers than their respective maintainers.

Rajendra *et al*. (1998) tested the performance of various hybrids rice during 1998 and observed that IR58025A x IR9761-1R was superior to inbred variety Mangala. The hybrid recorded and average yield of 5.6 and 4.9 ton ha^{-1} respectively, at Honnaville and Kathalagere, while Mangala yielded 3.8 ton ha^{-1} and 3.6 ton ha^{-1}.

Julfiqure *et al*. (1997) concluded that tiller number varied widely among the varieties and the number of tillers $plant^{-1}$ at the maximum tiller number stage ranged between 14.3 and 9.5 in 1995 and 12.2 and 34.6 in 1996.

Kulkarni *et al*. (1989) stated that late sown crops showed reduction in plant height and panicle length.

Radhakrishna *et al*. (1996) in 5 trials at Mandya, Karnataka from 1992-95 found that hybrid rice cv. KRH-2 gave an average yield of 9.31 ton ha^{-1}. Over the best check variety Jaya.

Alam *et al*. (1996) conducted an experiment to evaluate the performance of different rice varieties. Among the varieties, Kalijira produced the tallest plant, which was followed by Pajam.

Liu Xinhua (1995) conducted field trials with new indica hybrid rice II-You92 and found an average yield of 7.5 t ha^{-1} which was 10% higher than that of standard hybrid Shanyou 64.

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

From the results of an experiment, BRRI (1995) showed that the average plant height of BRRI dhan30, BR22, BR23, were 120, 125 and 120 cm, respectively. In another study, BRRI (1995) again revealed that the average plant height of BR3, BR7 and BRRI dhan29 were 95, 125 and 95 cm respectively.

Hossain and Alim (1991) reported that the growth character like plant height, number of total tillers hill^{-1} and the number of grains panicle^{-1} differed significantly among BR3, BR14 and Pajam varieties in *Boro* season.

Hossain and Alim (1991) reported that the growth character like plant height, number of total tillers hill^{-1} and the number of grains panicle^{-1} differed significantly among BR3, BR14 and Pajam varieties in *Boro* season.

Devaraju *et al.* (1998) in a study with two rice hybrids such as Karnataka Rice Hybrid1 (KRH1) and Karnataka Rice Hybrid2 (KRI42) using HYV IR20 as the check variety and found that KRH2 out yielded IR20. In IR20, number productive tiller plant^{-1} was higher than that of KRH2.

BRRI (1997) reported that the weight of 1000-grain of Halio, Tilockachari, Nizershail and Latishail was 26.5g, 27.7g, 25.2g, and 25g respectively.

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 lowest number was produced by the cultivar BR10.

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

Roy (1999) reported that in Nizershail, leaf area index peaked around panicle initiation stage and in BRRI dhan31, although maximum leaf area index from panicle initiation stage to heading stage was only small.

Rao *et al.* (1996) found that the highest grain yield was obtained in the wet seasons by local variety Badshabhog (3.2 t ha^{-1}) than the other ones (cv. Kastui, Ranbir, Basmati and IET 8579) and mean yields varied from 2.22-2.58 t ha^{-1}.

Singh and Gangwer (1989) recorded from an experiment with four rice cultivars C-14-8, CR-1009, IET-5656 and IET-6314 that grain number $panicle^{-1}$, 1000-grian weight and biological yielded were the highest for C-14-8 among the three varieties.

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

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.

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

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

BRRI (1991) reported that the number of effective tillers/hill was produced by transplant *Aman* rice varieties which ranged from 7-14. Number of effective tillers $hill^{-1}$ significantly differed among the varieties.

Idris and Matin (1990) found that panicle length differed among the varieties and it was greater in IR20 than that of any of the indigenous and high yielding varieties.

Kamal *et al.* (1988) reported that produced the number of grains panicle^{-1} in BR3, IR20 and Pajam were 107.6, 123.0 and 170.9 respectively.

BAU (1998) reported that the hybrid variety 93024 gave the highest grain yield (7.58 t/ha) followed by Alok 6201 (7.33 t/ha) and the check one (BR22) gave the lowest yield (4.75 t/ha).

In a trial, varietal differences in harvest index and yield examined using 60 Japanese varieties and 20 high yielding varieties bred in Asian countries. It was reported that harvest index varied from 36.8% to 53.4%. Mean values of harvest index were 43.5% in the Japanese group and 48.8% in high yielding group. Yield ranged from 22.6 g plant^{-1} to 40.0 g plant^{-1}. The mean value of yield in Japanese group was 22.8 g plant^{-1}, and that in the high yielding group was 34.1 g plant^{-1}. They also reported that a positive correlation was found between harvest index and yield in the high yielding group (Cui *et al.*, 2000).

Ahmed *et al.* (1998) worked in Bangladesh during *Aman* season when natural disaster like flood and cyclone were more prevalent, when crop was planted late; the photosensitive varieties were reported to play a major role for boosting yield rice.

BRRI (2007) reported that the BRRI dhan28 produced the highest number of tiller and panicle per unit area than that BRRI dhan29 but higher grain yield was observed in BRRI dhan29 than BRRI dhan28.

CHAPTER 3

MATERIALS AND METHODS

Different materials used and methodologies followed in this experiment have been presented in this chapter in detail. This chapter deals with a brief description of experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and analysis etc.

3.1 Experimental site and time

The experiment was conducted from March, 2010 to July, 2010 (*Aus* season) which comprised of seed collection, growing and experimentation, data collection and compilation etc. at the Sher-e-Bangla Agricultural University farm, Sher-e-Bangla Nagar, Dhaka-1207. It is located under the Agro-ecological zone of Madhupur Tract, AEZ-28 ($23^0 41'$ N latitude and $90^0 22'$) at an elevation of 8 m above the sea level (Appendix-I).

3.2 Climate

The area under experiment was situated under subtropical zone. During Aus season in general there was sufficient rainfall for growing the crop. However, sometimes due of undesirable behavior of climate crop suffered from inadequate water and then irrigation was applied. On the other hand, the temperature increased in the *Aus* season and reached highest in April and gradually deceased with the advance of time during *Aman* and *Boro* season. The bright sunshine hour comparatively became lower in *Aus* season than *Aman* and *Boro* season respectively. Thus the climatic factors were agreeable to grow the hybrid rice. Climatic data is presented in Appendix – II.

3.3 Soil

The soil of the experimental field belongs to Joydebpur series of Shallow Red-Brown Terrace soil type with silty clay in surface and silt clay loam in sub-surface region. As per USDA soil classification, the experimental soil was under Ochrept sub-order of Inceptisol order. The land was above flood level. Soil samples from 0-15 cm depth were collected from experimental filed. The analysis was done at Soil Resources and Development Institute (SRDI), Dhaka. The physio-chemical properties of the soil are presented in Appendix-III

3.4 Planting material

The three rice varieties (BRRI Hybrid dhan2, Tia and BRRI dhan48) were used. Among them two were hybrid and one BRRI released high yielding variety. BRRI Hybrid dhan2 and BRRI dhan48 were collected from Bangladesh Rice Research Institute (BRRI), Tia was collected from ACI Seed Enterprise Limited. Varieties were transplanted in different dates in the same season to find out the optimum time of planting and to select suitable variety. Finally potential variety was selected from the tested varieties based on the yield performance.

3.5 Raising of seedlings

The seedlings of different varieties were raised in the separate seedbed in traditional way with initial seed soaking in water for 24 hours and incubated for a period until radicles came out. No fertilizer was applied in seedbed. Sprouted seeds were sown in beds by broadcast method. Nursery beds were irrigated as and when necessary.

3.6 Land preparation

The experimental land was prepared with the help of power tiller by three successive ploughing and cross-ploughing followed by laddering. The experimental field was puddled by stagnant water. Weeds and crop residues of previous crop were removed from the field. The experimental area was laid out according to the design of the experiment. The unit plot was leveled before transplanting.

3.7 Fertilizer management

At the time of first ploughing, cowdung was applied at the rate of 10 t ha^{-1}. The experimental area was fertilized with 120, 80, 80, 20 and 5 kg ha^{-1} N, P_2O_5, K_2O, S and Zn applied in the form of urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate respectively. The full amounts of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied at final land preparation as a basal dose. Urea was applied in three installments. The first one-third of urea was top dressed after seedling recovery, second one- at 15 days after first top dressing and rest at the time of panicle initiation.

3.8 Experimental treatments

Treatment factors included in the experiment were as follows:

A. Varieties

i) BRRI Hybrid dhan2
ii) Tia
iii) BRRI Dhan48

B. Transplanting times

i) 16^{th} March
ii) 31^{st} March
iii) 15^{th} April
iv) 30^{th} April

C. Treatments combinations:

BRRI Hybrid dhan2	X	16th March 31st March 15th April 30th April
Tia	X	16th March 31st March 15th April 30th April
BRRI dhan48	X	16th March 31st March 15th April 30th April

3.9 Experimental Design

The unit plots were arranged in randomized complete block design. The experiment was replicated thrice. The unit plot size was 4m x 3m. The spacing between block was 1 m and between plots 0.5 m. The layout of the experiment has been shown in Appendix-IV.

3.10 Uprooting and Transplanting of seedlings

Twenty five days old seedlings were uprooted carefully for the transplantation and were kept in soft mud in shade. The seed beds were made wet by application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots. A 25 days old seedlings were uprooted and transplanted on the well puddled plots on 16th march, 31st march, 15th April, 30th April, 2010 maintaining the standard spacing of 25 cm x 15cm with one seedlings $hill^{-1}$.

3.11 Intercultural operations

3.11.1 Gap filling

Gap filling was done after one week of transplanting using the seedlings from the same source.

3.11.2 Weeding

Two hand weedings were done at 20 DAT and second weeding at 35 DAT to keep the crop weed free.

3.11.3 Application of irrigation water

Irrigation was applied during transplanting and crop establishment period. The field was saturated with 2-3 cm water and water level was increased with the advance of growth stages. However, at maturity no standing water was allowed.

3.11.4 Plant protection measures

Crop was infested with nemic disease which was controlled by Furadan 5 G 10 Kg/ ha. Crop was protected from birds and rats during the grain filling period. Field trap and Fostoxin bait were used to control rat.

3.11.5 General observation of the experimental field

The field was investigated time to time to detect visual differences among the treatments and any kind of infestation by weeds, insects and diseases so that considerable losses by pest could be minimized. The field looked nice with normal green color plants. Incidence of stem borer, green leaf hopper, leaf roller and rice hispa were observed during tillering stage those were controlled properly. No bacterial and fungal disease was observed in the field.

3.11.6 Harvesting and post harvest operation

Crop was harvested at maturity when 80% grains were matured. Harvesting was done in different dates due to the variation of planting dates and variation of life cycle of rice variety. Five hills were randomly select from middle portion of each plot for different morphological data collection and hills of 3 m^2 areas were separately harvested and bundle, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done by using paddle thresher. The grains were cleaned and sun dried to moisture content of 14%. Straw was also sun dried properly.

3.12 Recording of data

The following data were recorded at harvest.

A. Morphophysiological characters

i. Plant height (cm)
ii. Number of tillers $hill^{-1}$
iii. Leaf area (cm^2)
iv. Stem dry weight (g)
v. Leaf dry weight (g)
vi. Panicle dry weight (g)
vii. Total dry weight (g)
viii. Days to panicle initiation, flowering and maturity
ix. Light interception (%) at top, middle and bottom portion of plant
x. Chlorophyll content at flag leaf stage (mg g^{-1} fresh weight of leaf)

B. Yield and yield components and other crop characters

i. Number of effective tillers $hill^{-1}$
ii. Panicle length (cm)

iii. Number of filled spikelets panicle^{-1}

iv. Number of unfilled spikelets panicle^{-1}

v. Number of total spikelets panicle^{-1}

vi. Spikelets filling percent

vii. Weight of 1000-grain (g)

viii. Grain yield (t ha^{-1})

ix. Straw yield (t ha^{-1})

x. Biological yield (t ha^{-1})

xi. Harvest index (%)

3.13 Detailed procedures of data recording

3.13.1 Crop growth characters

i) Plant height (cm)

Plant height was measured at 20 days interval starting from 40 days after transplantation and continued up to harvest from randomly preselected ten hills plot^{-1}. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading and to the tip of panicle after heading.

ii) Total number of tillers hill^{-1}

Number of tillers hill^{-1} were counted at 20 days interval starting from 40 day after transplantation and up to harvest from preselected ten hills plot^{-1} and finally the mean value was calculated as their number hill^{-1}. Only those tillers having three or more leaves were considered for counting.

iii) Leaf area (cm^2)

Leaf area was estimated measuring the length and width of leaf and multiplying by a factor of 0.75 followed by Yoshida (1981).

iv) Stem dry weight (g hill^{-1})

The sub-samples of 5 hills plot^{-1} uprooting the plant with root from 2nd line were oven dried until a constant level of weight was attained from which the weight of stem dry weight were recorded at 20 days interval up to harvest. All plant samples were kept 72 hours in the oven at a temperature of 70^{0} c to count dry weight.

vii) Leaf dry weight (g hill^{-1})

The sub-samples of 5 hills plot^{-1} uprooting the plant with root from 2nd line were oven dried until a constant level of weight was attained from which the weight of leaf dry weight were recorded at 20 days interval up to harvest.

viii) Panicle dry weight (g hill^{-1})

The sub-samples of 5 hills plot^{-1} uprooting the plant with root from 2nd line were oven dried until a constant level of weight was attained from which the weight of panicle dry weight were recorded at 20 days interval up to harvest.

v) Total dry weight (g hill^{-1})

The sub-samples of 5 hills plot^{-1} uprooting the plant with root from 2nd line were oven dried until a constant level of weight was attained from which the weight of total dry weight were recorded at 20 days interval up to harvest.

iv) Days to panicle initiation, flowering and maturity

Panicle initiation was checked starting from 25 days after transplanting. Time of flowering was recorded when about 100 % of the plants flowered in a plot. The number of days for flowering was recorded. Maturity of crop was determined when 90 % of the grains became golden yellow in color. The number of days for maturity was recorded.

ix) Light interception (%) at top, middle and bottom portion of plant

Light interception (%) was recorded from top, middle and bottom portion of the plant before and after flowering stage. Difference of light ratio at top, middle and bottom portion of plant was measured in both the stages (Mid tillering and mid flowering stages).

x) Chlorophyll content at flag leaf stage (mg g^{-1} fresh weight of leaf)

Chlorophyll content was recorded at flag leaf stage. Hundred milligram of rice leaf sample was broken into small pieces and dipped into 80% acetone in twenty five milliliter vial. The vial was made up to the volume with 80% acetone. Then the sample was kept over forty eight hours in a dark place. Finally the absorbance of the filtrate was taken by spectrophotometer at 663 nm and 645 nm, respectively. Coombs *et al.* (1985). Amount of chlorophyll were calculated using the following equations/ formula (Witham, 1986):

Chlorophyll a (mg/g) = $[12.7\ (OD_{663}) - 2.69\ (OD_{645})]\ V/1000W$

Chlorophyll b (mg/g) = $[22.9\ (OD_{645}) - 4.68\ (OD_{663})]\ V/1000W$

Chlorophyll a+b (mg/g) = $[20.2(OD_{645}) - 8.02\ (OD_{663})]\ V/1000W$

Where,

OD = Optical density regarding of the chlorophyll extract at the specific indicated wavelength (645 and 663nm)

V = Final volume of the 80% acetone chlorophyll extract (ml)

W = Fresh weight in gram of the tissue extracted

3.13.2 Yield and yield contributing characters

i) Number of effective tillers hill^{-1}

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

ii) Panicle length (cm)

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 10 panicles.

iii) Number of filled spikelet panicle^{-1}

Number of filled spikelet panicle^{-1} was considered to be fertile if any kernel was present there in. The numbers of total filled grains present in each ten panicles was recorded and mean value was calculated.

iv) Number of unfilled spikelet panicle^{-1}

Number of unfilled spikelet panicle^{-1}means the absence of any kernel inside the floret after fertilization and such grains present in each panicle were counted.

v) Total number of spikelet panicle^{-1}

The number of filled spikelet panicle^{-1} plus the number of unfilled spikelet panicle^{-1} gave the total number of grain panicle^{-1}.

vi) Spikelet filling percent

$$\text{Filled spikelet percent} = \frac{\text{Filled spikelet number}}{\text{Total spikelet number}} \times 100$$

vii) Weight of 1000-grain (g)

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained 12% moisture and the mean weight were expressed in gram.

viii) Grain yield (t ha^{-1})

Grain yield was recorded from the central 6 m^2 undisturbed area of each plot was used to calculate grain yield m^{-2} and then it was expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

ix) Straw yield (t ha^{-1})

Straw yield was recorded from the central 6 m^2 undisturbed area of each plot was used to calculate straw yield m^{-2}. After threshing, the sub-sample was oven to a constant wt. and finally converted to t ha^{-1}.

x) Biological yield

Biological yield was calculated by using the following formula:

Biological yield= Grain yield + straw yield

xi) Harvest index (%)

It denotes the ratio of economic yield to biological yield and was calculated with following formula (Gardner *et al.*, 1985).

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

3.14 Statistical analysis

The data collected on different parameters were statistically analyzed to obtain the level of significance using the MSTATC (Russell, 1986) computer package program. Analysis of variance was done following two factors randomized complete block design. The mean differences among the treatments were compared by Duncan's Multiple Range Test (DMRT) test at 5% level of significance.

CHAPTER 4

RESULTS AND DISCUSSION

The results of the study regarding the morphological and yield contributing performances of some hybrid rice varieties with an inbred rice in *Aus* season as affected by different times of transplanting have been presented with possible interpretations under the following headings:

4.1 Morphophysiological parameters of rice in *Aus* season

4.1.1 Plant height at different days after transplanting

4.1.1.1 Effect of varieties on the plant height

Plant height of the varieties were measured at 40, 60, 80 DAT and at maturity. Result revealed that varieties had significant influence on plant height at all growth stages (Figure 1). It was observed from figure 1 that plant height increased rapidly at the early stages and rate of increase in height was slow at the later stages. The highest plant height at all the growth stages was recorded from Tia. In contrast, the lowest plant height was recorded from BRRI Hybrid dhan2 followed by BRRI dhan48. Probably the genetic makeup of varieties was responsible for the variation in plant height. This confirms the reports of BINA (1992), BRRI (1991) and Shamsuddin *et al.* (1988) that plant height differed due to varietal variation.

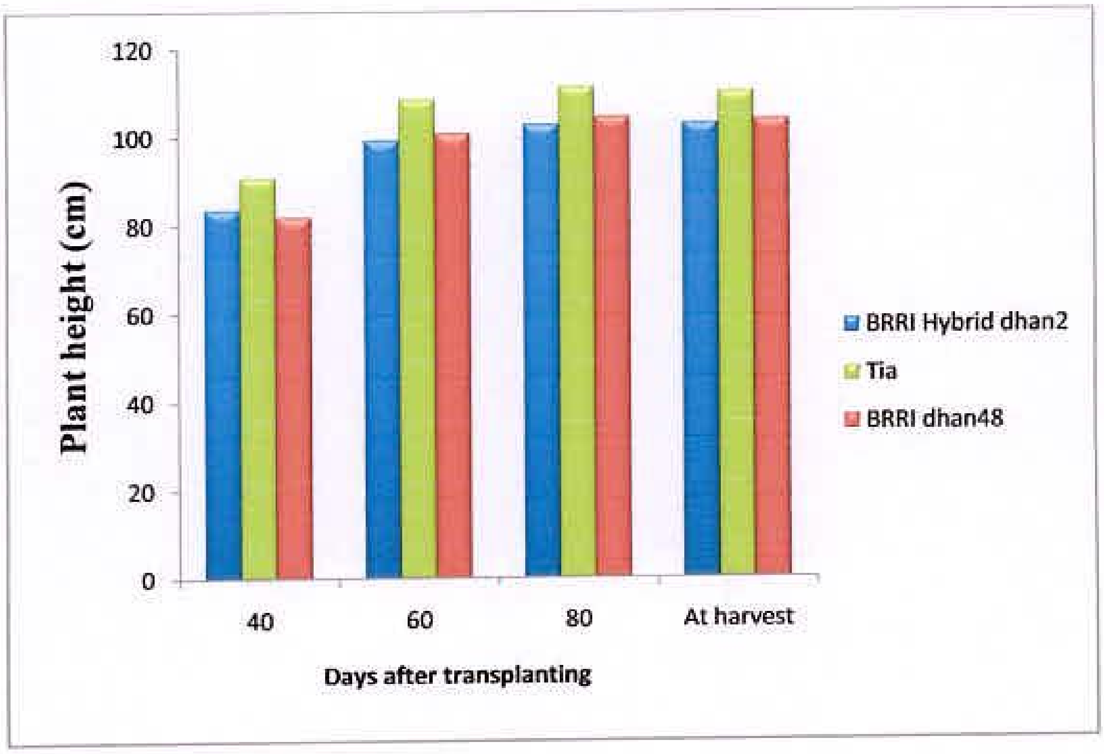

Figure 1. Effect of varieties on plant height (cm) of rice at different days after transplanting during *Aus* season

4.1.1.2 Effect of transplanting dates on plant height

Significant effect was shown by different transplanting dates on plant height at most of the growth stages (Figure 2). It was recorded that, with delayed transplanting (starting from 16th March to 30th Apri)l plant height showed a decreasing trend. It was observed that plant height increased progressively with advancement of time and growth stages till some days before harvest. The highest plant height at all growth stages was recorded when transplanted on 16th March followed by 31st March. On the other hand, the lowest plant height was recorded from 30th April transplanted plant followed by 15th April transplanting at all growth stages. The results agree with the results of Majos and Pave (1980) who reported that plant height reduced with delayed transplanting. This might be due to the premature flowering because of high temperature sensitiveness of the variety which forced the plants to switch from vegetative stage to reproductive stage. The results also agree with Islam *et al.* (1999b) who reported that plant height significantly affected by planting dates.

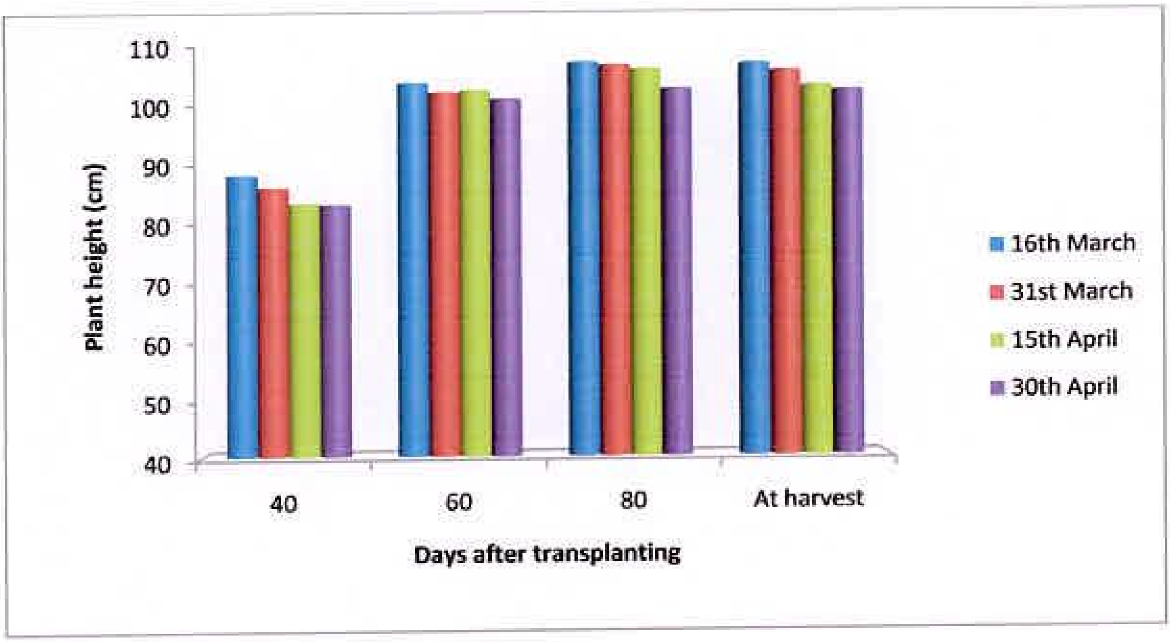

Figure 2. Effect of transplanting dates on plant height of rice at different days after transplanting during *Aus* season

4.1.1.3 Interaction effect of varieties and transplanting dates on plant height

Due to interaction effect of variety and transplanting dates, plant height was significantly varied at all growth stages (Table 1). The highest plant height at all growth stages was recorded from treatment combinations with Tia followed by BRRI dhan48 when transplanted on 16th March. In contrast the lowest plant height was recorded from the treatment combinations with BRRI dhan48 when transplanted on 30th April at all growth stages.

Table 1. Interaction effect of varieties and transplanting dates on plant height (cm) of rice at different days after transplanting during *Aus* season

Interaction		Plant height (cm)			
		40 days	60 days	80 days	At harvest
BRRI Hybrid dhan2 X	16th March	85.57 d	100.9 cd	102.6 fg	107.0 cd
	31st March	84.33 de	98.50 e	102.8 fg	103.8 ef
	15th April	82.23 f	99.30 de	104.9 ef	99.52 g
	30th April	82.33 ef	98.30 e	100.6 g	101.7 fg
Tia X	16th March	96.33 a	110.7 a	114.4 a	113.3 a
	31st March	90.43 b	109.7 a	110.8 bc	110.0 b
	15th April	88.43 bc	107.3 b	111.1 b	109.7 bc
	30th April	88.23 c	106.0 b	108.4 cd	107.3 bcd
BRRI dhan48 X	16th March	83.55 def	101.2 cd	104.7 ef	102.1 efg
	31st March	84.33 de	99.70 de	105.9 de	104.8 de
	15th April	80.00 g	102.1 c	107.1 de	101.5 fg
	30th April	79.50 g	99.80 de	100.4 g	99.35 g
$LSD_{0.05}$		2.033	2.290	2.573	2.770
CV (%)		1.24	1.31	1.60	1.87

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significance.

4.1.2 Number of tillers hill^{-1} at different days after transplanting

4.1.2.1 Effect of varieties on number of tillers hill^{-1}

Different varieties significantly influenced number of tillers hill^{-1} , at all growth stages (Figure 3). It was observed from figure 3 that number of tillers hill^{-1} increased progressively with the advancement of time and growth stages till 60 days after transplanting (DAT). Maximum (18.69, 17.21 and 16.31) number of tillers hill^{-1} were produced by BRRI Hybrid dhan2, Tia and BRRI dhan48 respectively at 60 DAT, then with the advancement of age it declined up to maturity. The value decreased because some of the last emerged tillers died due to their failure in competing for light and nutrients as observed by Ishhizuka and Tanaka (1963). Variable effect of varieties on number of tillers hill^{-1} was also reported by Hussain *et al.* (1989), Idris and Matin (1990) noticed that number of tillers hill^{-1} differed among the varieties.

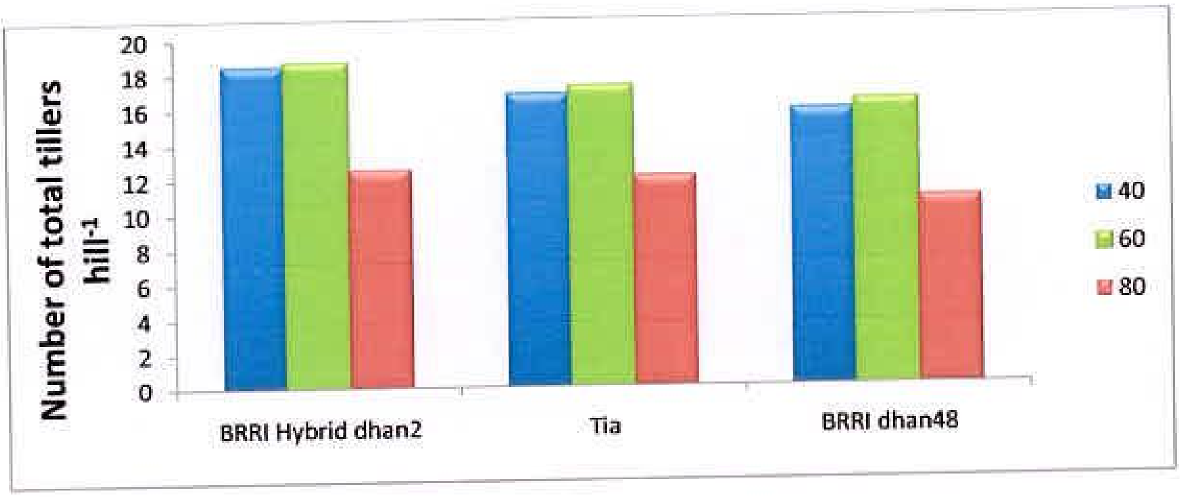

Figure 3. Effect of varieties on number of tillers hill^{-1} of rice at different days after transplanting during *Aus* season

4.1.2.2 Effect of transplanting dates on number of tillers hill^{-1}

Due to different transplanting dates, number of tillers hill^{-1} exerted significant variations (Figure 4). Number of tillers hill^{-1} showed a decreasing trend with the delayed transplanting starting from 16th March to 30th April (Figure 4) which indicate early transplanting showed the highest number of tillers hill^{-1}. The highest number of tillers hill^{-1} (19.91 at 60 DAT) was recorded from 16th March transplanting and the lowest number of tillers hill^{-1} (10.67 at 80 DAT) was recorded from 30th April transplanting. The results have the conformity with the results of Islam (1990b) who reported that planting date affects number of tillers hill^{-1}.

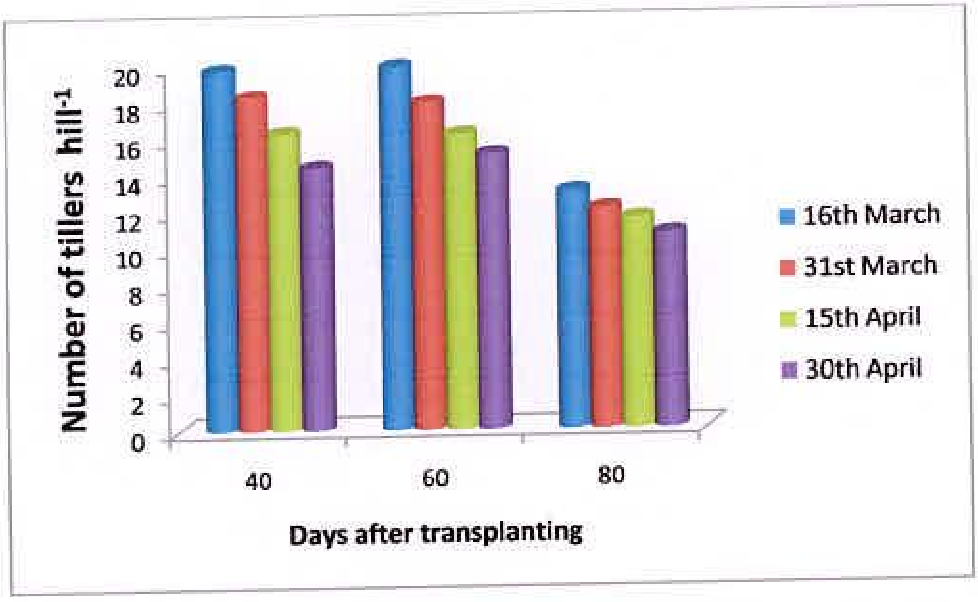

Figure 4. Effect of Transplanting dates on number of tillers hill^{-1} of rice at different days after transplanting during *Au* season

4.1.2.3 Interaction effect of varieties and transplanting dates on number of tillers hill^{-1}

Number of tillers hill^{-1} was significantly varied due to interaction effect of variety and transplanting dates (Table 2). At all growth stages the highest number of tillers hill^{-1} was recorded from treatment combination with BRRI Hybrid dhan2 when transplanted on 16th March followed by 31st March. In contrast the lowest number of tillers hill^{-1} was recorded from the treatment combination with BRRI dhan48 when transplanted on 30th April followed by15th April at most of the growth stages.

Table 2. Interaction effect of varieties and transplanting dates on number of tillers hill^{-1} of rice at different days after transplanting during *Aus* season

Interaction		Number of tillers hill^{-1}		
		40 days	60 days	80 days
BRRI Hybrid dhan2 X	16th March	21.70 a	21.54 a	13.82 a
	31st March	19.93 b	19.57 b	13.05 ab
	15th April	17.83 cd	17.10 cd	12.12 bc
	30th April	14.73 fg	16.57 cde	11.32 c
Tia X	16th March	20.10 b	19.37 b	13.45 a
	31st March	18.40 c	17.57 c	11.99 bc
	15th April	15.60 ef	15.97 de	11.59 c
	30th April	14.73 fg	14.57 fg	11.42 c
BRRI dhan48 X	16th March	17.53 cd	18.83 b	11.85 bc
	31st March	16.63 de	16.74 cd	11.15 c
	15th April	15.46 ef	15.54 ef	10.87 c
	30th April	13.80 g	14.14 g	9.270 d
$LSD_{0.05}$		1.466	1.133	1.262
CV (%)		3.21	1.93	3.45

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significance.

4.1.3 Leaf area hill^{-1} at different days after transplanting

4.1.3.1 Effect of varieties on leaf area hill^{-1}

The development of leaf area (LA) over time in rice varieties was presented in figure 5. Results revealed that LA increased till 60 days after transplanting (DAT). The increment of LA varied significantly due to variety at all growth stages. At 60 DAT, the LA production by BRRI Hybrid dhan2 was higher than other two varieties. In contrast, the variety BRRI dhan48 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 is consistent with the results of BINA (2006) who stated that variation in LA could be attributed to the changes in number of leaves. The results were also supported by the results of Yeasmin (2005).

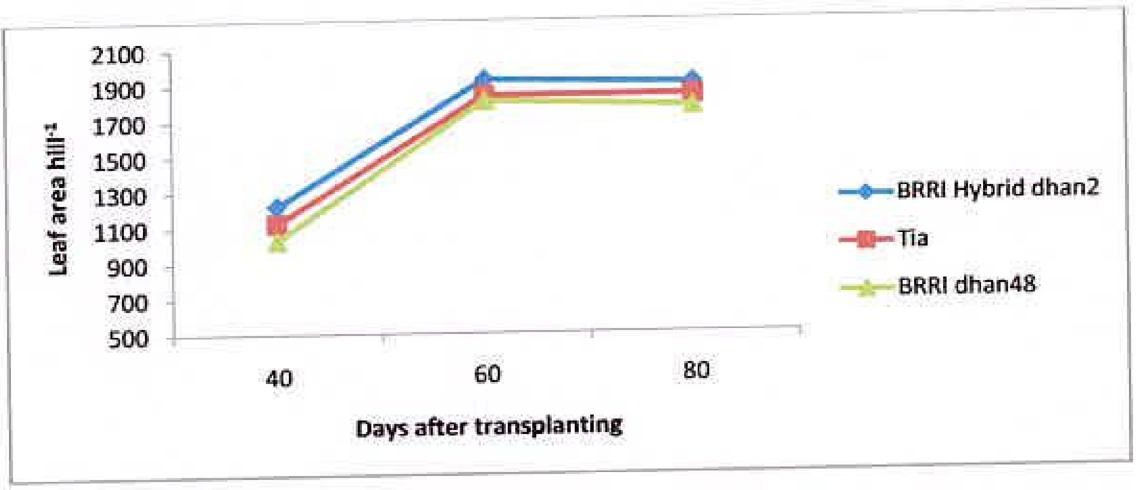

Figure 5. Effect of varieties on leaf area hill^{-1} (cm^2) of rice at different days after transplanting during *Aus* season

4.1.3.2 Effect of transplanting dates on leaf area hill^{-1}

Transplanting dates had significant influence on leaf area (LA) development hill^{-1} at all growth stages (Figure 6). It was observed that leaf area (LA) increased progressively with the advancement of time and growth stages till 60 DAT. The highest LA at all growth stages was recorded when transplanted on 16th March followed by 31st March transplanting. In contrast, the lowest LA was recorded from 30th April transplanting followed by 15th April transplanting at all growth stages. The leaf area was greater at 16th March transplanting because of increased production of tillers hill^{-1} (Figure 4). Similar result was also reported by BINA (2006) who reported that leaf area varied due to transplanting time.

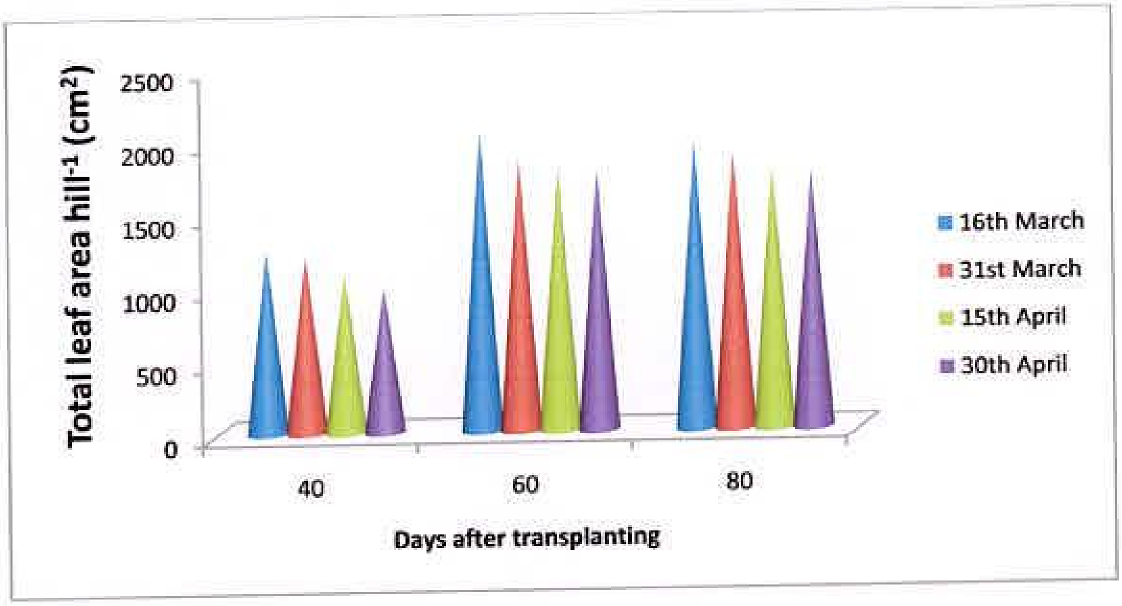

Figure 6. Effect of transplanting dates on leaf area hill^{-1} (cm^2) of rice at different days after transplanting during *Aus* season

4.1.3.3. Interaction effect of varieties and transplanting dates on leaf area hill^{-1}

Leaf area varied significantly due to interaction effect of variety and transplanting dates at all growth stages (Table 3). The highest leaf area hill^{-1} was recorded from treatment combination with BRRI Hybrid dhan2 (2188 cm^2 hill^{-1} at 60 DAT) when transplanted on 16th March. In contrast the lowest leaf area hill^{-1} was recorded from treatment combination with both BRRI dhan48 when transplanted on 30th April at most of the growth stages.

Table 3. Interaction effect of varieties and transplanting dates on total leaf area hill^{-1} (cm^2) of rice at different days after transplanting during *Aus* season

Interaction			Total leaf area hill^{-1} (cm^2)		
			40 days	60 days	80 days
BRRI Hybrid dhan2	X	16th March	1324 a	2188 a	2021 a
		31st March	1310 b	1909 c	1904 c
		15th April	1167 e	1858 d	1863 e
		30th April	1098 h	1763 i	1827 f
Tia	X	16th March	1234 c	2007 b	1940 b
		31st March	1210 d	1821 f	1883 d
		15th April	1112 g	1719 j	1743 i
		30th April	949 j	1806 g	1798 h
BRRI dhan48	X	16th March	1156 f	1913 c	1887 d
		31st March	1094 h	1834 e	1821 g
		15th April	974 i	1712 j	1654 k
		30th April	894.7 k	1780 h	1734 j
$LSD_{0.05}$			4.93	10.16	5.639
CV (%)			0.55	1.43	0.44

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significance.

4.1.4 Stem dry weight at different days after transplanting

4.1.4.1 Effect of varieties on the stem dry weight

Stem dry weight (g $hill^{-1}$) exerted significant variation due to varieties (Figure 7). It was recorded that stem dry weight (g $hill^{-1}$) increased progressively with the advancement of time and growth stages till 80 days after transplanting (DAT). The highest stem dry weight (g $hill^{-1}$) at all growth stages was observed in BRRI Hybrid dhan2 followed by Tia. In contrast the lowest stem dry weight (g $hill^{-1}$) was recorded from BRRI dhan48. Stem dry weight might be increased due to increased plant height and number of tillers.

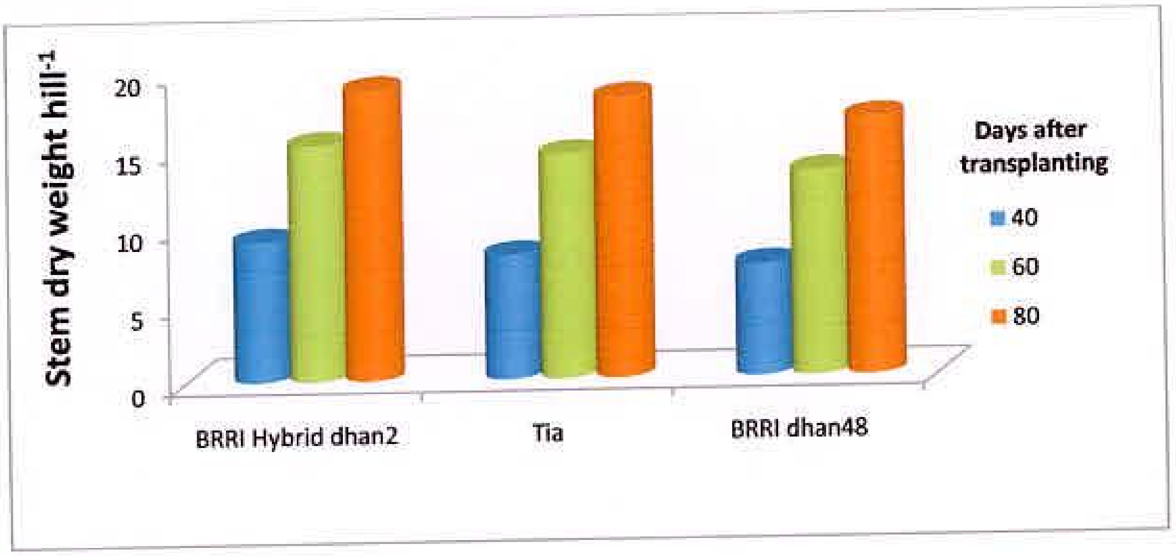

Figure 7. Effect of varieties on stem dry weight $hill^{-1}$ (g $hill^{-1}$) of rice at different days after transplanting during Aus season

4.1.4.2 Effect of transplanting dates on stem dry weight

Transplanting dates had significant influence on stem dry weight (g $hill^{-1}$) at all growth stages (Figure 8). Results revealed that stem dry weight (g $hill^{-1}$) showed a decreasing trend with the delayed transplanting starting from 16th March to 30th April. It was observed that stem dry weight (g $hill^{-1}$) increased progressively with the advancement of time and growth stages till 80 DAT. The highest stem dry weight (g $hill^{-1}$) at all growth stages was recorded when transplanted on 16[th] March followed by 31[st] March transplanting. In contrast the lowest stem dry weight (g $hill^{-1}$) was recorded from 30[th] April transplanting followed by 15[th] April transplanting at all growth stages. It might be due to lower plant height with delayed transplanting (Figure 2).

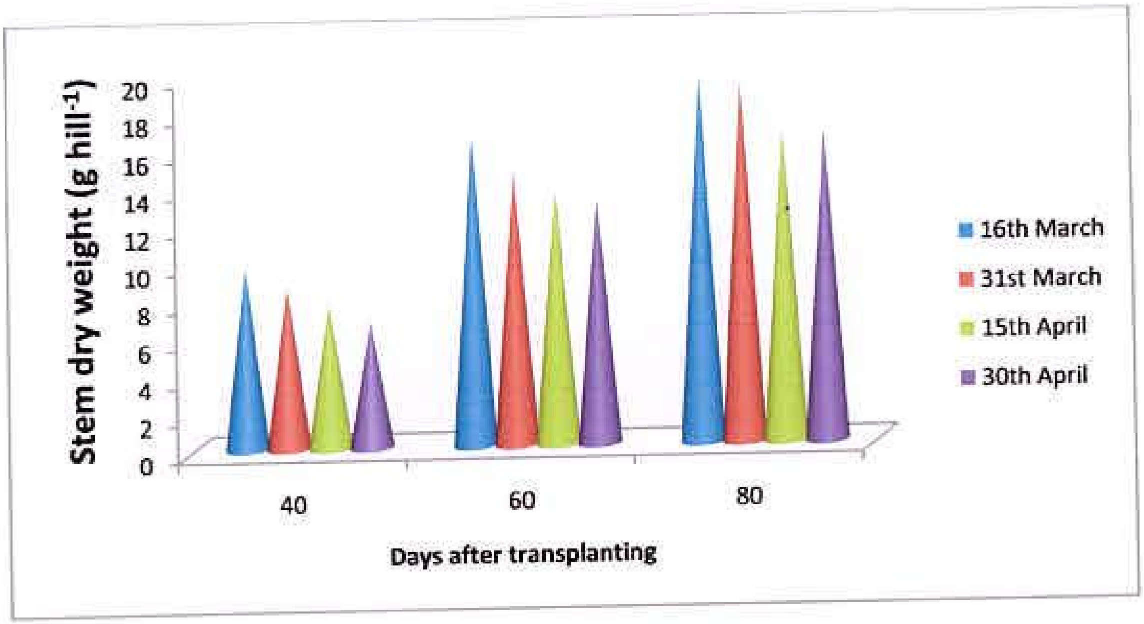

Figure 8. Effect of transplanting dates on stem dry weight (g $hill^{-1}$) of rice at different days after transplanting during *Aus season*

4.1.4.3 Interaction effect of varieties and transplanting dates on stem dry weight

Stem dry weight (g $hill^{-1}$) was significantly varied due to interaction effect of varieties and transplanting dates at all growth stages (Table 4). At all growth stages the highest stem dry weight (g $hill^{-1}$) was recorded from treatment combination with BRRI Hybrid dhan2 when transplanted on 16[th] March. In contrast the lowest stem dry weight (g $hill^{-1}$) was recorded from treatment combination with BRRI dhan48 when transplanted on 30[th] April at most of the growth stages.

Table 4. Interaction effect of varieties and transplanting dates on stem dry weight (g hill^{-1}) of rice at different days after transplanting during *Aus* season

Interaction			Stem dry weight (g hill^{-1})		
			40 days	60 days	80 days
BRRI Hybrid dhan2	X	16th March	10.85 a	17.56 a	20.87 a
		31st March	9.517 b	15.76 b	20.80 a
		15th April	8.537 c	14.16 cd	16.17 ef
		30th April	7.427 d	11.59 f	17.10 cde
Tia	X	16th March	9.247 b	16.06 b	18.97 b
		31st March	8.847 c	14.29 cd	18.77 b
		15th April	7.467 d	13.93 d	17.64 cd
		30th April	6.537 f	13.49 de	16.97 de
BRRI dhan48	X	16th March	8.630 c	15.45 bc	18.18 bc
		31st March	7.307 de	13.49 de	17.40 cd
		15th April	7.057 e	12.26 e	15.70 f
		30th April	6.077 g	11.56 f	15.24 f
$LSD_{0.05}$			0.3675	1.350	1.102
CV (%)			0.57	3.37	1.80

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significance.

4.1.5 Leaf dry weight at different days after transplanting

4.1.5.1 Effect of varieties on leaf dry weight

Leaf dry weight (g $hill^{-1}$) was significantly differed among the varieties (Figure 9). It was recorded that leaf dry weight (g $hill^{-1}$) increased progressively with the advancement of time and growth stages till 60 days after transplanting (DAT) due to increased number of tiller $hill^{-1}$ and leaf area. Then with the advancement of age it declined up to maturity. The value decreased because some of the last emerged tillers died and falling of premature leaf occurred. The highest leaf dry weight (g $hill^{-1}$) at all growth stages was observed in BRRI Hybrid dhan2 followed by Tia. In contrast the lowest leaf dry weight (g $hill^{-1}$) was recorded from BRRI dhan48.

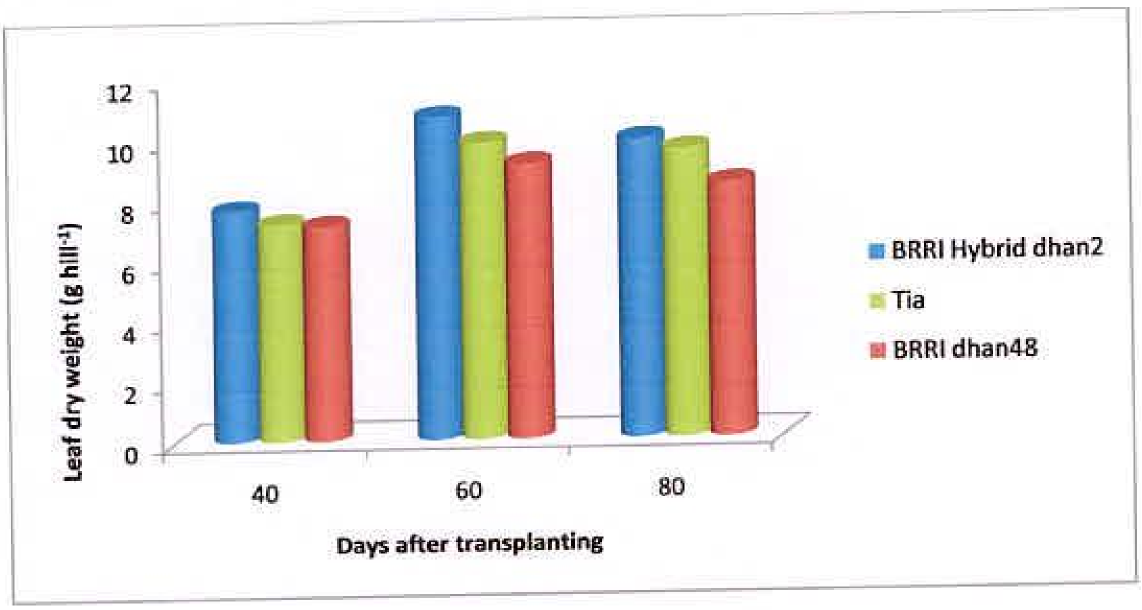

Figure 9. Effect of varieties on leaf dry weight $hill^{-1}$ (g $hill^{-1}$) of rice at different days after transplanting during *Aus* season

4.1.5.2 Effect of transplanting dates on leaf dry weight

Transplanting dates had significant influence on the leaf dry weight (g $hill^{-1}$) at all growth stages (Figure 10). Results revealed that leaf dry weight (g $hill^{-1}$) showed a decreasing trend with the delayed transplanting starting from 16th March to 30th April. It was observed that leaf dry weight (g $hill^{-1}$) increased progressively with the advancement of time and growth stages till 60 DAT. The highest leaf dry weight (g hill^{-1}) was recorded at all growth stages when transplanted on 16th March followed by 31st March transplanting. In contrast the lowest leaf dry weight (g hill^{-1}) was recorded from 30th April followed by 15th April transplanting at all growth stages.

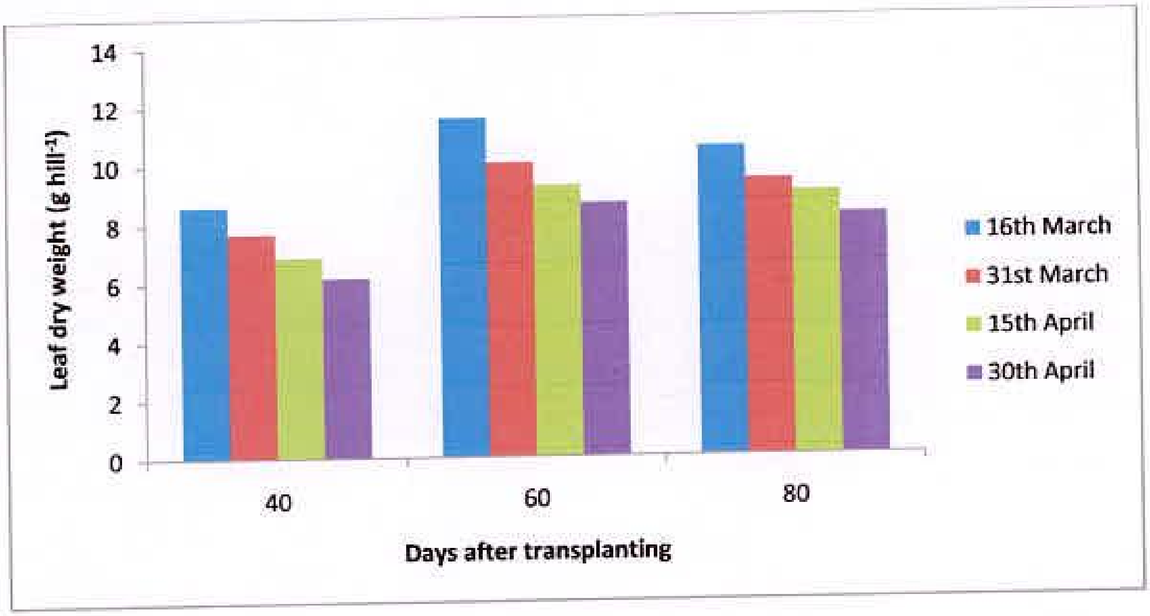

Figure 10. Effect of transplanting dates on leaf dry weight (g hill^{-1}) of rice at different days after transplanting during *Aus* season

4.1.5.3 Interaction effect of varieties and transplanting dates on leaf dry weight

Leaf dry weight (g hill^{-1}) was significantly varied due to interaction effect of variety and transplanting dates at all growth stages (Table 5). At all growth stages the highest leaf dry weight (g hill^{-1}) was recorded from treatment combination with BRRI Hybrid dhan2 when transplanted on 16th March. In contrast the lowest leaf dry weight (g hill^{-1}) was recorded from treatment combination with BRRI dhan48 when transplanted on 30th April.

Table 5. Interaction effect of varieties and transplanting dates on leaf dry weight (g hill^{-1}) of rice at different days after transplanting during *Aus* season

Interaction			Leaf dry weight (g hill^{-1})		
			40 days	60 days	80 days
BRRI Hybrid dhan2	X	16th March	8.793 a	12.53 a	11.26 a
		31st March	8.143 c	11.03 bc	10.17 bc
		15th April	7.093 e	9.793 de	9.537 de
		30th April	6.653 f	9.423 def	8.687 fg
Tia	X	16th March	8.373 bc	10.99 bc	10.69 ab
		31st March	7.723 d	10.21 cd	9.773 cd
		15th April	6.873 ef	9.443 def	9.047 ef
		30th April	5.873 g	8.693 fg	8.727 fg
BRRI dhan48	X	16th March	8.693 ab	11.20 b	9.670 cd
		31st March	7.203 e	8.913 ef	8.343 g
		15th April	6.683 f	8.573 fg	8.417 g
		30th April	5.963 g	7.833 g	7.337 h
$LSD_{0.05}$			0.3863	0.9297	0.5810
CV (%)			4.77	2.26	1.00

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significance.

4.1.6 Panicle dry weight at different days after transplanting

4.1.6.1 Effect of varieties on panicle dry weight

Panicle dry weight significantly differed among the varieties at 60, 70 and 80 DAT (Figure 11). It was recorded that panicle dry weight (g $hill^{-1}$) increased progressively with the advancement of time and growth stages till harvest. The highest panicle dry weight (12.88 g $hill^{-1}$) at all growth stages was observed in BRRI dhan48. It might be due to higher spikelet filling percent. In contrast the lowest panicle dry weight (2.057 g $hill^{-1}$) was recorded from Tia followed by BRRI Hybrid dhan2 because of lower spikelet filling percent. Its might be due to higher spikelet sterility at high temperature (Appendix II).

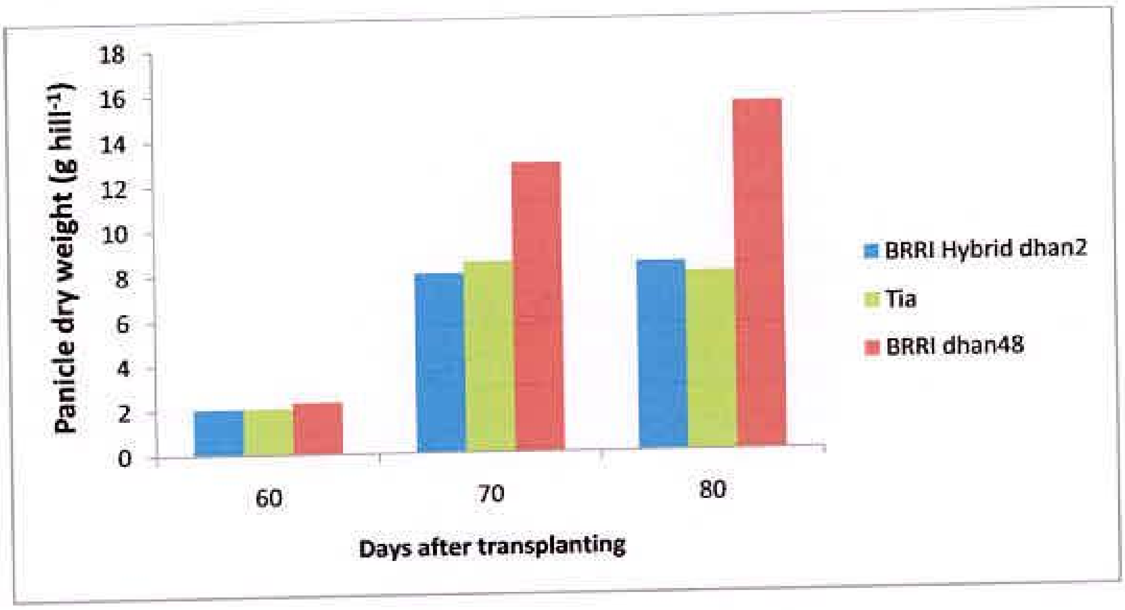

Figure 11. Effect of varieties on panicle dry weight (g $hill^{-1}$) of rice at different days after transplanting during *Aus* season

4.1.6.2 Effect of transplanting dates on panicle dry weight

Transplanting dates significantly differed on panicle dry weight (g $hill^{-1}$) (Figure 12). The results revealed that panicle dry weight (g $hill^{-1}$) showed a decreasing trend with the delayed transplanting starting from 16^{th} March to 30^{th} April (Table 17). It was observed that panicle dry weight (g $hill^{-1}$) increased progressively with the advancement of time and growth stages till 80 days after transplanting due to increased spikelet filling percent. The highest panicle dry weight (g $hill^{-1}$) at all growth stages was recorded when transplanted on 16th March followed by 31st March transplanting. In contrast the lowest panicle dry weight (g $hill^{-1}$) was recorded from 30th April followed by 15th April transplanting at all growth stages. It might be due to premature flowering with delay transplanting.

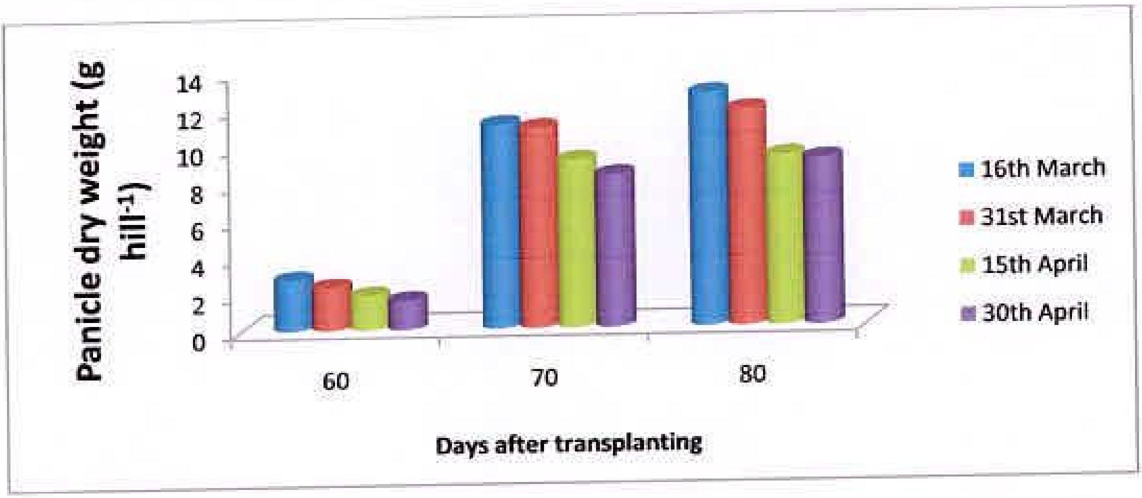

Figure 12. Effect of transplanting dates on panicle dry weight (g $hill^{-1}$) of rice at different days after transplanting during *Aus* season

4.1.6.3 Interaction effect of varieties and transplanting dates on panicle dry weight

Panicle dry weight (g $hill^{-1}$) was significantly varied due to interaction effect of variety and date of transplanting at all growth stages (Table 6). At 60 DAT highest panicle dry weight (3.057 g $hill^{-1}$) was recorded from the treatment combination with BRRI Hybrid dhan2 when transplanted on 16th March but at 70 and 80 DAT the highest panicle dry weight(15.82 and 20.31 g $hill^{-1}$) was recorded from treatment combination with BRRI dhan48 when transplanted on 16th March. In contrast the lowest panicle dry weight (g $hill^{-1}$) was recorded from the treatment combination with Tia when transplanted on 30th April at most of the growth stages.

Table 6. Interaction effect of varieties and transplanting dates on panicle dry weight (g $hill^{-1}$) of rice at different days after transplanting during *Aus* season

Interaction			Panicle dry weight (g $hill^{-1}$)		
			60 days	70 days	80 days
BRRI Hybrid dhan2	X	16th March	3.057 a	7.477 g	8.423 fg
		31st March	2.257 cd	8.667 f	9.843 d
		15th April	1.697 f	7.077 g	7.603 hi
		30th April	1.217 g	8.837 f	7.883 gh
Tia	X	16th March	2.607 bc	9.827 de	9.073 e
		31st March	2.007 def	9.697 e	8.783 ef
		15th April	1.857 def	7.177 g	7.273 ij
		30th April	1.817 ef	7.407 g	6.803 j
BRRI dhan48	X	16th March	2.647 abc	15.82 a	20.31 a
		31st March	2.807 ab	14.12 b	16.51 b
		15th April	2.117 de	10.56 cd	12.78 c
		30th April	1.770 ef	11.02 c	12.44 c
$LSD_{0.05}$			0.4109	0.8059	0.5868
CV (%)			2.01	1.70	0.83

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter differ significantly as per LSD at 5% level of significance.

4.1.7 Total dry matter production at different days after transplanting

4.1.7.1 Effect of varieties on total dry matter production

Total dry matter production (g $hill^{-1}$) was significantly differed among the varieties at all growth stages (Figure 13). Result revealed that the total dry matter (TDM) production $hill^{-1}$ gradually increased at all sampling dates from 40 to 80 DAT. From 40-60 DAT the highest TDM $hill^{-1}$ was recorded from case of BRRI Hybrid dhan2 followed by Tia due to increased leaf area and number of tillers $hill^{-1}$ but at 80 DAT highest TDM was recorded from BRRI dhan48 due higher spikelet filling percent. In contrast, the lowest TDM hill^{-1} was recorded from BRRI dhan-48 at 40 to 60 DAT but at 80 DAT lowest TDM was recorded from BRRI Hybrid dhan2 followed by Tia because of lower spikelet filling percent at high temperature and low sunshine hours. Genotypic variation in TDM production in rice was also observed by Amin *et al*. (2006) and Son *et al.* (1998).

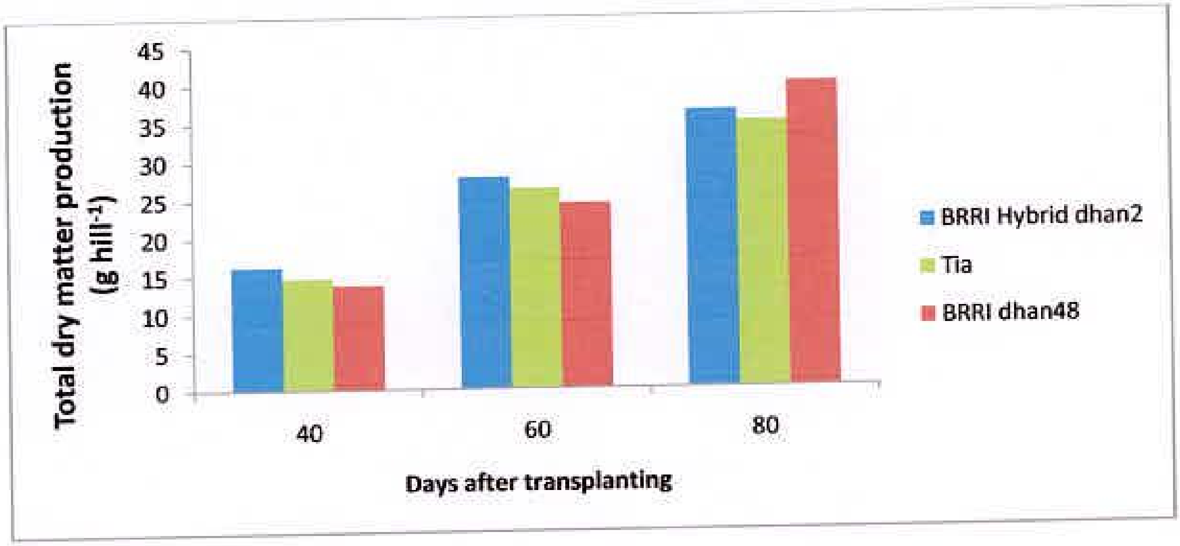

Figure 13. Effect of varieties on total dry matter production (g hill^{-1}) of rice at different days after transplanting during *Aus* season

4.1.7.2 Effect of transplanting dates on total dry matter production

Total dry matter production (g hill^{-1}) was significantly differed due to transplanting dates at all growth stages (Figure 14). Results revealed that total dry matter production (TDM) showed a decreasing trend with the delayed transplanting starting from 16th March to 30th April. It was observed that total dry matter production (g hill^{-1}) increased progressively with the age till harvest. The highest total dry matter production (g hill^{-1}) at all growth stages was recorded when transplanted on 16th March followed by 31st March transplanting because of increased leaf area which accumulated more assimilates than other dates of sowing. In contrast the lowest total dry matter production (g hill^{-1}) was recorded from 30th April transplanting followed by 15th April transplanting at all growth stages. The plants got less time for growth and development due to delayed transplanting. That is why, TDM was less in 30th April transplanting followed by 15th April transplanting.

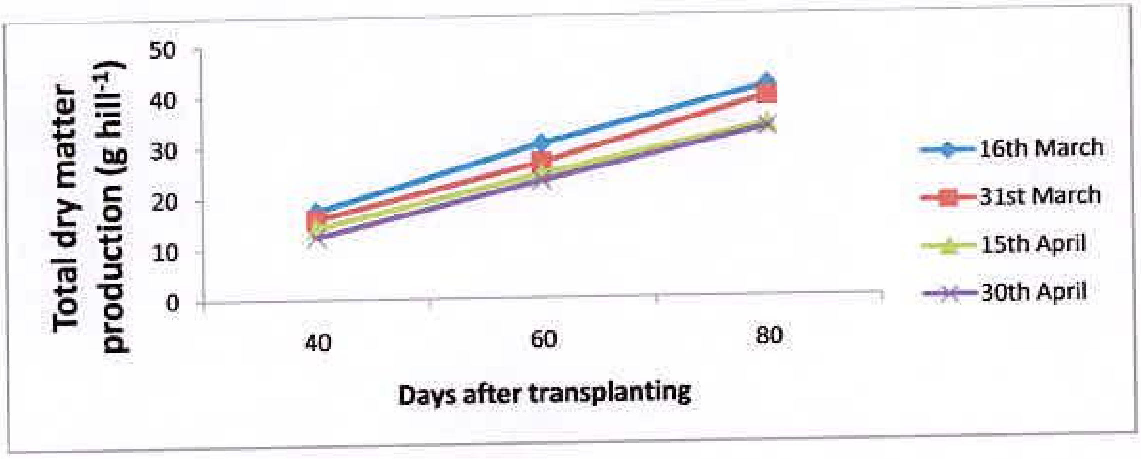

Figure 14. Effect of transplanting dates on total dry matter production (g hill^{-1}) of rice at different days after transplanting during *Aus* season

4.1.7.3 Interaction effect of varieties and transplanting dates on total dry matter production

Total dry matter production (g hill^{-1}) was significantly varied due to interaction effect of variety and transplanting dates at all growth stages (Table 7). At 30-60 DAT the highest total dry matter production (g hill^{-1}) was recorded from the treatment combination with BRRI Hybrid dhan2 when transplanted on 16th March and at 70 and 80 DAT the highest total dry matter production (g hill^{-1}) was recorded from the treatment combination with BRRI dhan48 when transplanted on 16th March. In contrast from 30-60 DAT the lowest total dry matter production (g hill^{-1}) was recorded from the treatment combination with BRRI dhan48 when transplanted on 30th April and at 70 and 80 DAT the lowest total dry matter production (g hill^{-1}) was recorded from the treatment combination with Tia followed by BRRI Hybrid dhan2.

Table 7. Interaction effect of varieties and transplanting dates on dry matter production (g hill^{-1}) of rice at different days after transplanting during *Aus* season

Interaction		Total dry matter production (g hill^{-1})		
		40 days	60 days	80 days
BRRI Hybrid dhan2 X	16th March	19.17 a	33.02 a	39.84 c
	31st March	17.23 b	28.85 c	40.14 c
	15th April	15.17 d	25.49 e	32.64 fg
	30th April	13.60 fg	23.99 f	32.98 fg
Tia X	16th March	17.17 b	29.95 b	36.64 e
	31st March	16.13 c	26.19 d	38.11 d
	15th April	13.87 ef	25.09 e	33.24 f
	30th April	11.97 h	24.15 f	31.74 g
BRRI dhan48 X	16th March	16.07 c	28.25 c	47.01 a
	31st March	14.10 e	25.05 e	41.61 b
	15th April	13.30 g	22.75 g	36.14 e
	30th April	11.48 i	21.33 h	35.39 e
$LSD_{0.05}$		0.4903	0.6397	1.312
CV (%)		0.41	0.40	1.19

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significance.

4.1.8 Days to panicle initiation, flowering and maturity

4.1.8.1 Effect of variety on days to panicle initiation, flowering and maturity

There was a significant variation in days to panicle initiation, flowering and maturity among the varieties (Table 8). BRRI dhan48 took the longest days to panicle initiation (40.56 DAT), flowering (66.48 DAT) and maturity (92.75DAT). BRRI Hybrid dhan2 took the shortest days to panicle initiation (33.97 DAT), flowering (59.18 DAT) and maturity (87.59 DAT).

Table 8. Effect of varieties on days to panicle initiation, flowering and maturity

Variety	Days after transplanting (DAT)		
	Panicle Initiation	Flowering	Maturity
BRRI Hybrid dhan2	33.97 c	59.18 c	87.59 c
Tia	36.46 b	60.06 b	89.75 b
BRRI dhan48	40.56 a	66.48 a	92.75 a
$LSD_{0.05}$	0.7657	0.7856	0.7657
CV (%)	1.82	1.17	0.76

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter differ significantly as per LSD at 5% level of significance.

4.1.8.2 Effect of transplanting dates on days to panicle initiation, flowering and maturity

Days to panicle initiation, flowering and maturity were significantly influenced by date of transplanting (Table 9). Results revealed that days to panicle initiation, flowering and maturity decreased with delayed transplanting. The longest days to panicle initiation (44.31 DAT), flowering (74.51 DAT) and maturity (97.21 DAT) were observed when planted on 16th March and the shortest days to panicle initiation (31.96 DAT), flowering (54.92 DAT) and maturity (85.97 DAT) were observed when planted on 30th April. The results also supported by Yeasmin (2005) who reported that days to maturity decreased with delayed transplanting.

Table 9. Effect of transplanting dates on days to panicle initiation, flowering and maturity

Transplanting time	Duration (days after transplanting)		
	Panicle Initiation	Flowering	Maturity
16th March	44.31 a	74.51 a	97.21 a
31st March	36.52 b	60.59 b	89.75 b
15th April	35.19 c	57.59 c	87.19 c
30th April	31.96 d	54.92 d	85.97 d
$LSD_{0.05}$	0.7037	0.7350	0.7037
CV (%)	1.82	1.17	0.76

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter differ significantly as per LSD at 5% level of significance.

4.1.8.3 Interaction effect of varieties and transplanting dates on days to panicle initiation, flowering and maturity

Interaction effect of variety and transplanting time on days to panicle initiation, flowering and maturity was significant at $P \leq 0.05$ (Table 10). The highest days to panicle initiation (46.65 DAT), flowering (79.48 DAT) and maturity (100.4 DAT) was observed in case of BRRI dhand48 when transplanted on 16th March. The lowest days to panicle initiation (27.96 DAT), flowering (53.82 DAT) and maturity (84.09 DAT) was observed in case of BRRI Hybrid dhan2 when transplanted on 30th April.

Table 10. Interaction effect of varieties and transplanting dates on days to panicle initiation, flowering and maturity

Interaction		Duration (days after transplanting)		
		Panicle Initiation	Flowering	Maturity
BRRI Hybrid dhan2 X	16th March	42.30 c	71.92 b	94.11 c
	31st March	33.30 f	55.82 ef	86.75 g
	15th April	32.30 fg	55.15 fg	85.42 hi
	30th April	27.96 h	53.82 h	84.09 j
Tia X	16th March	43.96 b	72.15 b	97.09 b
	31st March	34.96 e	57.15 e	90.75 de
	15th April	34.96 e	56.48 ef	86.42 gh
	30th April	31.96 g	54.48 gh	84.75 ij
BRRI dhan48 X	16th March	46.65 a	79.48 a	100.4 a
	31st March	41.30 c	68.82 c	91.75 d
	15th April	38.30 d	61.15 d	89.75 ef
	30th April	35.96 e	56.48 ef	89.09 f
$LSD_{0.05}$		1.232	1.279	1.248
CV (%)		1.82	1.17	0.76

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter differ significantly as per LSD at 5% level of significance.

4.1.9 Light interception (%)

4.1.9.1 Effect of varieties on light interception (%) at mid tillering and mid flowering stage

Light interception percent (%) at mid tillering and mid flowering stage was significantly differed among the varieties (Table 11). In both the stages the highest light interception was observed at top-middle, middle-bottom and total light interception was recorded in case of BRRI Hybrid dhan2 followed by Tia because of higher canopy due to increased number of tillers and leaf area (Figure 3 and 5). In contrast the lowest light interception at top-middle, middle-bottom and total light interception was recorded from in case of BRRI dhan48 because of lower canopy due to lower number of tillers and leaf area (Figure3 and 5).

Table 11. Effect of varieties on light interception percent at mid tillering and mid flowering stage

Variety	Light interception (%)					
	Mid tillering stage			Mid flowering stage		
	Top-Middle	Middle-Bottom	Total	Top-Middle	Middle-Bottom	Total
BRRI Hybrid dhan2	24.28 a	49.33 a	73.67 a	32.02	51.45	83.45
Tia	21.75 ab	49.00 a	71.58 a	30.35	53.58	84.37
BRRI dhan48	20.22 b	43.33 b	64.92 b	33.27	51.89	85.55
$LSD_{0.05}$	3.858	3.797	4.590	NS	NS	NS
CV (%)	19.30	9.64	7.73	14.93	9.52	4.95

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter differ significantly as per LSD at 5% level of significance. NS = Non-significant

4.1.9.2 Effect of transplanting dates on light interception (%) at mid tillering and mid flowering stage

Light interception (%) at mid tillering and mid flowering stage was not significantly differed among different transplanting dates except (top-middle and middle-bottom) at mid flowering stage. (Table12). Light interception at top-middle, middle-bottom during mid flowering stage was significant among different transplanting dates. At mid flowering stage (top-middle and middle-bottom), the highest light interception was recorded from case of 16th March transplanting followed by 31st March transplanting because of higher canopy due to increased number of tillers and leaf area. In contrast the lowest light interception at top-middle and middle-bottom at mid flowering stage was recorded from 30th April transplanting followed by 15th April transplanting because of lower canopy due to lower number of tillers and leaf area with delayed transplanting (Figure 4 and 6).

Table 12. Effect of transplanting dates on light interception percent at mid tillering and mid flowering stage

Transplanting time	Light interception (%)					
	Mid tillering stage			Mid flowering stage		
	Top-Middle	Middle-Bottom	Total	Top-Middle	Middle-Bottom	Total
16th March	24.510	47.21	71.49	36.93 a	52.86 a	89.22
31st March	23.18	46.11	70.38	34.60 ab	49.08 ab	83.89
15th April	23.40	46.45	71.07	31.27 b	47.76 ab	83.33
30th April	21.29	45.77	67.82	31.04 b	44.22 b	81.44
$LSD_{0.05}$	NS	NS	NS	4.795	4.958	NS
CV (%)	19.30	9.64	7.73	14.93	9.52	4.95

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter differ significantly as per LSD at 5% level of significance. NS = Non-significant.

4.1.9.3 Interaction effect of varieties and transplanting dates on light interception (%) at mid tillering and mid flowering stage

Interaction effect of variety and transplanting time on light interception (%) at mid tillering and mid flowering stage was significantly differed at $P \leq 0.05$ except middle to bottom and total light interception (%) at mid flowering stage (Table 13). In both the stages the highest light interception at top-middle, middle-bottom and total was recorded from the treatment combination with BRRI Hybrid dhan2 followed by Tia when transplanted on 16th March because of higher canopy due to greater vegetative phase. In contrast the lowest light interception at top-middle, middle-bottom and total light interception was recorded from the treatment combination with BRRI dhan48 when transplanted on 30th April followed by 15th April transplanting because of lower canopy due to shorter vegetative phase. Middle to bottom and total light interception (%) at mid flowering stage was statistically similar among the all combinations.

Table 13. Interaction effect of variety and transplanting dates on light interception (%) at mid tillering and mid flowering stage

Interaction		Light interception (%)					
		Mid tillering stage			Mid flowering stage		
		Top-Middle	Middle-Bottom	Total	Middle-Bottom	Middle-Bottom	Total
BRRI Hybrid dhan2 X	16th March	29.13 a	52.77 a	75.25 a	35.33	59.01 a	87.67
	31st March	28.78 a	51.37 ab	74.14 ab	36.36	53.68 ab	86.33
	15th April	28.11 a	51.33 ab	72.17 ab	35.67	51.34 ab	85.33
	30th April	27.45 ab	45.27 abc	70.39 ab	30.00	49.67 b	84.33
Tia X	16th March	28.45 a	51.00 ab	75.18 a	36.33	56.00 ab	88.09
	31st March	24.78 ab	49.00 abc	71.17 ab	32.67	53.00 ab	86.67
	15th April	23.61 ab	48.00 abc	68.83 ab	31.67	59.34 a	87.33
	30th April	21.45 ab	47.00 abc	65.84 bc	30.67	52.01 ab	82.33
BRRI dhan48 X	16th March	24.00 ab	45.00 abc	70.67 ab	36.00	56.68 ab	88.67
	31st March	22.31 ab	44.33 b	67.67 abc	31.67	53.68 ab	86.04
	15th April	20.91 ab	41.67 de	64.67 abc	29.33	52.01 ab	87.33
	30th April	18.33 b	40.15 c	57.33 c	29.00	51.05 ab	84.67
$LSD_{0.05}$		7.715	5.715	7.595	NS	5.587	NS
CV (%)		19.30	12.46	9.64	7.73	14.93	9.52

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significance. NS = Non-significant.

4.1.10 Chlorophyll content at flag leaf stage

4.1.10.1 Effect of variety on chlorophyll content at flag leaf stage

Chlorophyll content at flag leaf stage (mg g^{-1} fresh weight of leaf) varied significantly among the varieties (Table 14). Table shows that chlorophyll "a", content is higher than Chlorophyll "b". Chlorophyll "a" (3.813 mg g^{-1} leaf), Chlorophyll "b" (2.940 mg g^{-1} leaf), total chlorophyll (6.675 mg g^{-1} leaf) and ratio of chlorophyll content (1.475 mg g^{-1} leaf) was higher in BRRI Hybrid dhan2 followed by Tia. In contrast the lowest chlorophyll content was recorded from BRRI dhan48.

Table 14. Effect of variety on chlorophyll content at flag leaf stage (mg g^{-1} fresh weight of leaf)

Variety	Chlorophyll content at flag leaf stage (mg g^{-1} fresh weight of leaf)			
	Chlorophyll "a"	Chlorophyll "b"	Total chlorophyll	a/b ratio
BRRI Hybrid dhan2	3.813 a	2.940 a	6.675 a	1.475
Tia	3.651 a	2.742 a	6.392 b	1.334
BRRI dhan48	3.313 b	2.269 b	5.580 c	1.306
$LSD_{0.05}$	0.2372	0.3421	0.2372	NS
CV (%)	2.09	5.91	1.21	5.66

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter differ significantly as per LSD at 5% level of significance. NS = Non-significant.

4.1.10.2 Effect of transplanting dates on chlorophyll content at flag leaf stage

Chlorophyll "a" and total chlorophyll content at flag leaf stage (mg g^{-1} fresh weight of leaf) varied significantly at different transplanting dates (Table 15). Table showed that chlorophyll "a", content is higher than Chlorophyll "b". Chlorophyll (Chlorophyll "a", and Total chlorophyll) content was higher in 16th March followed by 31st March transplanting. In contrast the lowest Chlorophyll "a", and total chlorophyll content was recorded from 30th April transplanting followed by 15th April transplanting. Chlorophyll "b" and ratio of chlorophyll content had not significant variation among the transplanting dates.

Table 15. Effect of transplanting dates on chlorophyll content at flag leaf stage (mg g^{-1} fresh weight of leaf)

Transplantin time	Chlorophyll content at flag leaf stage (mg g^{-1} leaf)			
	Chlorophyll "a"	Chlorophyll "b"	Total chlorophyll	a/b ratio
16th March	3.733 a	2.777	6.510 a	1.351
31st March	3.603 ab	2.681	6.180 b	1.376
15th April	3.563 ab	2.590	6.113 b	1.344
30th April	3.470 b	2.553	6.060 b	1.416
$LSD_{0.05}$	0.2372	NS	0.2372	NS
CV (%)	2.09	5.91	1.21	5.66

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter differ significantly as per LSD at 5% level of significance. NS = Non-significant

4.1.10.3 Interaction effect of varieties and transplanting dates on chlorophyll content at flag leaf stage

Chlorophyll content at flag leaf stage (mg g^{-1} fresh weight of leaf) varied significantly at interaction between varieties and transplanting dates (Table 16). Chlorophyll "a" (3.873 mg g^{-1} leaf), Chlorophyll "b" (3.200 mg g^{-1} leaf), total chlorophyll (6.800 mg g^{-1} leaf) content was higher in case of treatment combination with BRRI Hybrid dhan2 when transplanted on 16th March. In contrast the lowest chlorophyll content was recorded from the treatment combination with BRRI dhan48 when transplanted on 30th April.

Table 16. Interaction effect of varieties and transplanting dates on chlorophyll content at flag leaf stage (mg g^{-1} fresh weight of leaf)

Interaction			Chlorophyll content at flag leaf stage (mg g^{-1} leaf)			
			Chlorophyll "a"	Chlorophyll "b"	Total chlorophyll	a/b
BRRI Hybrid dhan2	X	16th March	3.873 a	3.200 a	6.800 a	1.327
		31st March	3.873 a	2.927 ab	6.760 ab	1.223
		15th April	3.733 a	2.797 ab	6.530 ab	1.337
		30th April	3.773 a	2.837 ab	6.610 ab	1.337
Tia	X	16th March	3.843 a	2.917 ab	6.760 ab	1.317
		31st March	3.633 abc	2.717 abc	6.350 bcd	1.340
		15th April	3.463 abc	2.587 abcd	6.050 cd	1.343
		30th April	3.663 ab	2.747 abc	6.410 abc	1.337
BRRI dhan48	X	16th March	3.483 abc	2.487 bcd	5.970 de	1.410
		31st March	3.303 bc	2.127 cd	5.430 f	1.563
		15th April	3.213 c	2.387 bcd	5.600 ef	1.353
		30th April	3.253 bc	2.077 d	5.320 f	1.573
$LSD_{0.05}$			0.3996	0.5994	0.3996	NS
CV (%)			2.09	5.91	1.21	5.66

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significance.

NS: Non-significant

4.2 Yield contributing characters of rice in *Aus* season

4.2.1 Number of effective tillers hill^{-1}

4.2.1.1 Effect of varieties on number of effective tillers hill^{-1}

Total tillers determine the amount of dry matter production unit area^{-1} while effective tillers unit area^{-1} determined the final yield of rice. It was observed that variety had significant effect on numbers of effective tiller hill^{-1} (Table 17). The highest number of effective tillers hill^{-1} was recorded from BRRI dhan48 (8.671 hill^{-1}) In contrast the lowest number of effective tillers hill^{-1} was recorded from Tia (7.436 hill^{-1}) followed by BRRI Hybrid dhan2 (7.912 hill^{-1}). It might be due to higher number of sterile tiller at high temperature and low sunshine hour (Appendix-II). BRRI (1991) and Shamsuddin *et al.* (19988) also reported similar views that the number of effective tillers differed among different varieties.

4.2.1.2 Effect of transplanting dates on number of effective tillers hill^{-1}

Transplanting dates exerted significant effect on number of effective tillers hill^{-1} (Table 18). Results showed that number of effective tillers hill^{-1} decreased with delayed transplanting starting from 16th March to 30th April because delayed transplanting resulted shortest vegetative phase. The highest number of effective tillers hill^{-1} was recorded when transplanted on 16th March (9.107 hill^{-1}) transplanting followed by 31st March (7.392 hill^{-1}) transplanting. In contrast the lowest number of effective tillers hill^{-1} was recorded from 30th April (7.023 hill^{-1}) transplanting followed by 15th April (7.783 hill^{-1}) transplanting. The results agreed with Islam (1990b) who reported that planting date affects the no. of tillers hill^{-1}. The results also agree with Subbain *et al.* (1995) who reported that late planted crop gave less number of tillers and panicles.

4.2.1.3 Interaction effect of varieties and transplanting dates on number of effective tillers hill^{-1}

Interaction between varieties and transplanting dates had significant effect on the number of effective tillers hill^{-1} in rice (Table19). Results showed that higher number of effective tillers hill^{-1} was recorded from the treatment combination with BRRI dhan48 (9.693 hill^{-1}) when transplanted on 16th March. In contrast the lowest number of effective tillers hill^{-1} was recorded from the treatment combination with Tia (6.353 hill^{-1}) when transplanted on 30th April.

4.2.2 Panicle length

4.2.2.1 Effect of varieties on panicle length

Panicle length significantly differed among the varieties (Table 17). The highest panicle length was recorded from BRRI Hybrid dhan2 (24.79 cm) followed by Tia (24.62 cm). In contrast the lowest panicle length was recorded from BRRI dhan48 (24.06 cm). This confirms the report of Ahmed *et al.* (1997), Idris and Matin (1990) that panicle length was differed due to variety.

4.2.2.2 Effect of transplanting dates on panicle length

Date of transplanting exerted significant effect on panicle length (cm) of rice during *Aus* season (Table 18). Results showed that panicle length decreased with delayed transplanting in *Aus* season. The highest panicle length was recorded when transplanted on 16th March (25.01cm) followed by 31st March (25.00 cm) transplanting. In contrast the lowest panicle length was recorded from 30th April (23.78 cm) transplanting followed by 15th April (24.18 cm) transplanting. The results corroborate with the findings of Islam *et al.* (1990b) who reported the planting date affects the panicle length significantly.

4.2.2.3 Interaction effect of varieties and transplanting dates on panicle length

Interaction between varieties and transplanting dates had significant effect on panicle length of rice (Table 19). Results showed that higher panicle length was recorded from the treatment combination with BRRI Hybrid dhan2 (25.73 cm) when transplanted on 16th March. In contrast the lowest panicle length was recorded from BRRI dhan48 (22.83 cm) when transplanted on 30th April.

4.2.3 Number of filled spikelets panicle^{-1}

4.2.3.1 Effect of varieties on number of filled spikelets panicle^{-1}

Table 17 shows that varieties affected significantly in number of filled spikelets panicle^{-1}. The highest number of filled spikelets panicle^{-1} was recorded from BRRI dhan48 (87.13). In contrast the lowest number of filled spikelets panicle^{-1} was recorded from Tia (54.60) followed by BRRI Hybrid dhan2 (59.51). BRRI (1994) found that number of filled spikelets panicle^{-1} significantly differed among the varieties.

4.2.3.2 Effect of transplanting dates on number of filled spikelet panicle^{-1}

Transplanting dates had significant effect on number of filled spikelets panicle^{-1} (Table 18). Results showed that number of filled spikelets panicle^{-1} decreased with delayed transplanting. The highest number of filled spikelets panicle^{-1} was recorded when transplanted on 16th March (80.72) followed by 31st March (68.16) transplanting. In contrast the lowest number of filled spikelets panicle^{-1} was recorded from 30th April (58.93) transplanting followed by 15th April (60.51) transplanting. This result is in agreement with the findings of Om *et al.* (1993) who reported that delayed transplanting decreased number of filled spikelets panicle^{-1}.

4.2.3.3 Interaction effect of varieties and transplanting dates on number of filled spikelets panicle^{-1}

Interaction effect of varieties and transplanting dates had significant effect on number of filled spikelets panicle^{-1} (Table 19). Table showed that higher number of filled spikelets panicle^{-1} was recorded from the treatment combination with BRRI dhan48 (107.7) when transplanted on 16th March. In contrast the lowest number of filled spikelets panicle^{-1} was recorded from Tia (47.96) when transplanted on 30th April.

4.2.4 Number of unfilled spikelets panicle^{-1}

4.2.4.1 Effect of varieties on number of unfilled spikelets panicle^{-1}

Numbers of unfilled spikelets panicle^{-1} play a vital role in yield reduction. Result showed that variety had significant effect in respect of number of unfilled spikelets panicle^{-1} (Table 17). The highest number of unfilled spikelets panicle^{-1} was recorded from BRRI Hybrid dhan2 (64.22) followed by Tia (59.58). In contrast the lowest number of unfilled spikelets panicle^{-1} was recorded from BRRI dhan48 (26.16). BINA (1993) and Chowdury *et al.* (1993) also reported differences in number of unfilled spikelets panicle^{-1}.

Table 17. Effect of varieties on yield attributes and yield of rice in *Aus* season

Variety	Number of effective tillers hill^{-1}	Panicle length (cm)	Number of filled spikelets panicle^{-1}	Number of unfilled spikelets panicle^{-1}	Number of total spikelets panicle^{-1}
BRRI Hybrid dhan2	7.912 b	24.79 a	59.51 b	64.22 a	115.7 a
Tia	7.436 b	24.62 a	54.60 c	59.58 b	109.4 b
BRRI dhan48	8.671 a	24.06 b	87.13 a	26.16 c	103.1 c
$LSD_{0.05}$	0.5826	0.5270	0.8605	1.068	1.712
CV (%)	4.79	1.36	1.24	2.58	3.03

Table 17. Continued

Variety	Spikelet filling (%)	1000 grain weight (gm)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
BRRI Hybrid dhan2	46.36 b	23.91 b	2.752 b	4.545 b	7.668 b	39.47 b
Tia	43.27 b	25.98 a	2.637 b	5.077 a	7.845 ab	36.28 c
BRRI dhan48	75.34 a	22.24 c	3.589 a	4.287 b	8.097 a	46.46 a
$LSD_{0.05}$	4.548	0.7657	0.3469	0.3685	0.4157	0.6284
CV (%)	8.47	2.77	4.51	3.31	2.50	1.10

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significance. NS = Non-significant.

4.2.4.2 Effect of transplanting dates on number of unfilled spikelets panicle^{-1}

Transplanting dates had significant effect on number of unfilled spikelets panicle^{-1} (Table 18). Results showed that number of unfilled spikelets panicle^{-1} increased with delayed transplanting. The highest number of unfilled spikelets panicle^{-1} was recorded when transplanted on 30th April (51.94) followed by 15th April (49.85) transplanting. In contrast the lowest number of unfilled spikelets panicle^{-1} was recorded from 16th March (48.86) transplanting followed by 31st March (49.22) transplanting.

4.2.4.3 Interaction effect of varieties and transplanting dates on number of unfilled spikelets panicle^{-1}

Interaction effect of varieties and transplanting dates had significant effect on number of unfilled spikelets panicle^{-1} (Table 19). Table showed that higher number of unfilled spikelets panicle^{-1} was recorded from treatment combination with BRRI Hybrid dhan2 (74.99) when transplanted on 16th March. In contrast the lowest number of unfilled spikelets panicle^{-1} was recorded from BRRI dhan48 (24.75) when transplanted on 16th March.

4.2.5 Number of total spikelets panicle^{-1}

4.2.5.1 Effect of varieties on number of total spikelets panicle^{-1}

Number of total spikelets panicle^{-1} was significantly differed among the varieties (Table 17). BRRI Hybrid dhan2 produced the highest number (115.7) of total spikelets panicle^{-1} followed by Tia (109.4). BRRI dhan48 produced the lowest number (103.1) of total spikelets panicle^{-1}. The result was confirmed by Kamal *et al.* (1988) that the number of total spikelets panicle^{-1} differed among the varieties.

4.2.5.2 Effect of transplanting dates on number of total spikelets panicle^{-1}

Transplanting dates influenced the production of number of total spikelets panicle^{-1} significantly (Table 18). Table showed that number of total spikelets panicle^{-1} decreased with delayed transplanting. The highest number of total spikelets panicle^{-1} was recorded when transplanted on 16th March (125.3) followed by 31st March (114.9) transplanting. In contrast the lowest number of total spikelets panicle^{-1} was recorded from 30th April (95.32) transplanting followed by 15th April (102.1) transplanting. These results also supported by Islalm *et al.* (1999b) who observed that grain number decreased with delayed transplanting.

4.2.5.3 Interaction effect of varieties and transplanting dates on number of total spikelets panicle^{-1}

Interaction effect of transplanting dates and variety had significant effect on number of total spikelets panicle^{-1} (Table 19). Table showed that higher number of total spikelets panicle^{-1} was recorded from treatment combination with BRRI dhan48 (129.3) when transplanted on16th March. In contrast the lowest number of total spikelets panicle^{-1}was recorded from BRRI dhan48 (82.70) when transplanted on 30th April.

4.2.6 Spikelet filling (%)

4.2.6.1 Effect of varieties on spikelet filling (%)

Varietal effect on spikelet filling percent was found significant. Highest spikelet filling percent was recorded from BRRI dhan48 (75.34 %) due favorable environmental condition. In contrast the lowest spikelet filling percent was recorded from Tia (43.27 %) followed by BRRI Hybrid dhan2 (46.36 %). It might be due to more sensitiveness of hybrid rice to high temperature during spikelet filling stage cause sterility of spikelets. High temperature means 34^{0} c or above that cause sterility spikelets (BRRI, 1992). This result agrees with the result of Ahmed *et al.* (1997) who reported that spikelet filling percent differed among the varieties.

4.2.6.2 Effect of transplanting dates on spikelet filling (%)

Transplanting dates had significant effect on spikelet filling percent (Table 18). Results showed that spikelet filling percent decreased with delayed transplanting. The highest spikelet filling percent was recorded when transplanted on 16th March (60.25 %) followed by 31st March (57.31%) transplanting. In contrast the lowest spikelet filling percent was recorded from 30th April (52.39%) transplanting followed by 15th April (54.34%) transplanting. The result is supported by Subbain et al. (1995) who reported that panicle initiation and flowering in delayed planting adversely affects on fertilization.

4.2.6.3 Interaction effect of varieties and transplanting dates on spikelet filling (%)

Interaction effect of varieties and transplanting dates had significant effect on spikelet filling percent (Table 19). Table showed that higher spikelet filling percent was recorded from treatment combination with BRRI dhan48 (80.97 %) when transplanted on 16th March. In contrast the lowest spikelet filling percent was recorded from treatment combination with Tia (44.60%) when transplanted on 30th April.

4.2.7 1000-grain weight

4.2.7.1 Effect of varieties on 1000-grain weight

1000-grain weight was significantly influenced by varieties (Table 17). The highest 1000-grain weight was recorded from Tia (25.98 g) followed by BRRI Hybrid dhan2 (23.91 g). In contrast the lowest 1000-grain weight was recorded from BRRI dhan48 (22.24 g). This result is in agreement with the finding of Refey *et al.* (1989) and Shamsuddin *et al.* (1988) who stated that weight of 1000-grain differed due to the varietal differences.

4.2.7.2 Effect of transplanting dates on 1000-grain weight

Weight of 1000-grain showed non-significant variation due to different transplanting dates (Table 18).

4.2.7.3 Interaction effect of varieties and transplanting dates on 1000-grain weight

Interaction effect of varieties and transplanting dates had significant effect on 1000-grain weight (g) (Table 19). Table showed that highest 1000-grain weight was recorded from treatment combination with Tia (26.11 g) when transplanted on 16^{th} March. In contrast the lowest 1000-grain weight was recorded from treatment combination with BRRI dhan48 (21.14 g) when transplanted on 30^{th} April.

Table 18. Effect of transplanting dates on yield attributes and yield of rice in *Aus* season

Transplanting time	Number of effective tillers hill^{-1}	Panicle length (cm)	Number of filled spikelets panicle^{-1} (No.)	Unfilled spikelets panicle^{-1} (No.)	Total spikelets panicle^{-1} (No.)
16th March	9.107 a	25.01 a	80.72 a	48.86 c	125.3 a
31st March	8.112 b	25.00 a	68.16 b	49.30 bc	114.9 b
15th April	7.783 b	24.18 b	60.51 c	49.85 b	102.1 c
30th April	7.023 c	23.78 b	58.93 d	51.94 a	95.32 d
$LSD_{0.05}$	0.5346	0.4998	0.7795	0.9838	1.573
CV (%)	4.79	1.36	1.24	2.58	3.03

Table 18. Continued

Transplanting time	Spikelet filling (%)	1000 grain weight (gm)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
16th March	60.25 a	24.33	3.607 a	5.763 a	9.814 a	41.73 a
31st March	57.31 a	24.22	3.017 b	4.488 b	7.940 b	41.51 a
15th April	54.34 ab	24.21	2.827 bc	4.287 bc	7.153 c	40.80 b
30th April	52.39 b	23.40	2.520 c	4.007 c	6.573 d	38.90 c
$LSD_{0.05}$	5.021	NS	0.3182	0.3388	0.3825	0.5771
CV (%)	9.17	2.77	4.51	3.31	2.50	1.10

In a column, figures bearing same letter(s) do not differ significantly at where as figures with dissimilar letter differ significantly as per LSD at 5% level of significance. NS = Non-significant.

4.3 Yield of *Aus* rice

4.3.1 Grain yield

4.3.1.1 Effect of varieties on grain yield

In present study variety had significant effect on the grain yield (t ha^{-1}) of rice (Table 17). The highest grain yield of rice was recorded from case of BRRI dhan48 (3.58 t ha^{-1}). In contrast the lowest grain yield of rice was recorded from Tia (2.637 t ha^{-1}) followed by BRRI Hybrid dhan2 (2.752 t ha^{-1}). Grain yield is a function of interplay of various yield components such as number of productive tillers $hill^{-1}$, number of filled grains $panicle^{-1}$ and 1000-grain weight (Hassan *et al.*, 2003). Grain yield differed due to varieties were reported by Suprithatno and Sutaryo (1992), Alam (1998), Singh and singh (2000), Rahman (2002), Mondal *et al.* (2005), Yeasmin (2005) and IRRI (1978) who recorded variable grain yield among tested varieties. The probable reason for variation in yield may be due high temperature high temperature and low sunshine hours which causes spikelet sterility. This confirms the report of Krishnan and Nayak (1998), stated that pollen grains were desiccated by high temperature.

4.3.1.2 Effect of transplanting dates on grain yield

Transplanting dates exerted significant effect on grain yield (t ha^{-1}) (Table 18). Results showed that grain yield decreased with delayed transplanting. The highest grain yield was recorded when transplanted on 16^{th} March (3.607 t ha^{-1}) followed by 31^{st} March (3.017 t ha^{-1}) transplanting. In contrast the lowest grain yield was recorded from 30^{th} April (2.520 t ha^{-1}) transplanting followed by 15^{th} April (2.827 t ha^{-1}) transplanting. It might be due to shorter vegetative phase and climatic conditions. The results agreed with the findings of Chandra and Manna, (1988), Ali *et al.* (1995), Ghosh and Ganguly, (1994), BRRI, 1998; Chowdhury and Guha, (2000); Assaduzzaman (2006); BINA (2006) who stated that delayed transplanting reduces grain yield of rice due to shorter vegetative phase. Singh *et al.* (1997) and

Joseph and Havanagi (1987) also reported that seedlings planted early or late influence the yield due to change in the climatic conditions.

4.3.1.3 Interaction effect of varieties and transplanting dates on grain yield

Interaction effect of varieties and transplanting dates had significant effect on grain yield (t ha^{-1}) (Table 19). Highest grain yield t ha^{-1} was recorded from treatment combination of BRRI dhan48 (4.817 t ha^{-1}) when transplanted on 16th March. In contrast the lowest grain yield was recorded from Tia (2.437 t ha^{-1}) when transplanted on 30th April.

4.3.2 Straw yield

4.3.2.1 Effect of varieties on straw yield

In the present study variety had significant effect on the straw yield (t ha^{-1}) of rice (Table 17). The highest straw yield of rice was recorded from Tia (5.077 t ha^{-1}) followed by BRRI Hybrid dhan2 (4.545 t ha^{-1}). In contrast the lowest straw yield of rice was recorded from BRRI dhan4 (4.287 t ha^{-1}). It may be due to highest plant height in Tia (Figure 1). The result is in agreement with the findings of Panda and Leeuwrik (1971) who reported that straw yield could be assigned to plant height.

4.3.2.2 Effect of transplanting dates on straw yield

Transplanting dates exerted significant effect on straw yield (t ha^{-1}) (Table 18). Results showed that straw yield decreased with delayed transplanting. It might be due to less vegetative growth at delayed transplanting. The highest straw yield was recorded when transplanted on 16th March (5.763 t ha^{-1}) followed by 31st March (4.488 t ha^{-1}) transplanting. In contrast the lowest straw yield was recorded from 30th April (4.007 t ha^{-1}) transplanting followed by 15th April (4.287 t ha^{-1}) transplanting. BRRI (2005) reported that straw yield decreased with delayed transplanting that supports the present experimental results.

4.3.2.3 Interaction effect of varieties and transplanting dates on straw yield

Interaction effect of varieties and transplanting dates had significant effect on straw yield (t ha^{-1}) (Table 19). Table shows that highest straw yield (t ha^{-1}) was recorded from treatment combination with Tia (6.457 t ha^{-1}) when transplanted on16th March. In contrast the lowest straw yield was recorded from treatment combination with BRRI dhan48 (3.427 t ha^{-1}) when transplanted on 30th April.

Table 19. Interaction effect of varieties and transplanting dates on yield attributes and yield of rice in *Aus* season

Interaction		Number of effective tillers hill^{-1}	Panicle length (cm)	Number of filled spikelets panicle^{-1} (No.)	Unfilled spikelets panicle^{-1} (No.)	Total spikelets panicle^{-1} (No.)
BRRI Hybrid dhan2 X	16th March	8.953 ab	25.73 a	67.72 e	74.99 a	126.7 a
	31st March	8.530 bc	24.63 bc	63.26 f	63.08 c	120.9 b
	15th April	7.723 cd	24.13 c	52.19 h	64.41 c	111.4 c
	30th April	6.443 ef	24.00 cd	54.89 g	54.41 e	104.0 d
Tia X	16th March	8.673 bc	24.70 bc	66.76 e	56.08 de	119.9 b
	31st March	7.373 de	24.73 bc	55.42 g	56.75 d	118.6 b
	15th April	7.343 de	25.23 ab	48.29 i	56.75 d	99.77 e
	30th April	6.353 f	24.53 bc	47.96 i	68.75 b	99.27 e
BRRI dhan48 X	16th March	9.693 a	25.66 a	107.7 a	24.75 g	129.3 a
	31st March	8.433 bc	24.57 bc	85.82 b	26.75 f	105.3 d
	15th April	8.283 bcd	23.20 de	81.06 c	26.75 f	95.00 f
	30th April	8.273 bcd	22.83 e	73.96 d	26.41 fg	82.70 g
$LSD_{0.05}$		0.9371	0.8709	1.384	1.719	2.761
CV (%)		4.79	1.36	1.24	2.58	3.03

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significance.

Table 19. Continued

Interaction		Spikelet filling (%)	1000 grain weight (gm)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
BRRI Hybrid dhan2 X	16th March	80.97 a	23.97 b	2.987 bc	5.477 b	8.913 b	41.35 c
	31st March	78.23 a	24.21 b	2.957 bc	4.750 c	8.450 bc	40.15 d
	15th April	69.43 b	23.94 b	2.577 c	4.087 de	6.840 ef	40.02 d
	30th April	73.47 ab	23.51 bc	2.487 c	3.867 ef	6.470 fg	36.34 ef
Tia X	16th March	50.20 cd	26.11 a	3.017 bc	6.457 a	9.130 b	35.65 f
	31st March	49.67 cd	26.47 a	2.587 c	4.627 cd	7.840 cd	37.00 e
	15th April	44.77 d	25.77 a	2.507 c	4.497 cd	7.240 de	37.05 e
	30th April	48.00 cd	25.57 a	2.437 c	4.727 c	7.170 de	35.42 f
BRRI dhan48 X	16th March	55.23 c	22.57 c	4.817 a	5.357 b	11.40 a	48.20 a
	31st March	45.67 d	22.31 cd	3.507 b	4.087 de	7.530 de	47.38 a
	15th April	44.77 d	22.94 bc	3.397 b	4.277 cde	7.380 de	45.32 b
	30th April	44.60 d	21.14 d	2.637 c	3.427 f	6.280 g	44.92 b
$LSD_{0.05}$		9.79	1.232	0.5544	0.5927	0.6716	1.013
CV (%)		5.27	2.77	4.51	3.31	2.50	1.10

In a column figures having similar letter (s) do not differ significantly where as figures with dissimilar letter (s) differ significantly as per LSD at 5% level of significance.

4.3.3 Biological yield

4.3.3.1 Effect of varieties on biological yield

In the present study variety had significant effect on the biological yield (t ha^{-1}) of rice (Table 17). The highest biological yield of rice was recorded from BRRI dhan48 (8.097 t ha^{-1}) followed by Tia (7.845 t ha^{-1}). In contrast the lowest biological yield of rice was recorded from BRRI Hybrid dhan2 (7.668 t ha^{-1}). The result is in agreement with the findings of Panda and Leeuwrik (1971) who reported that biological yield could be varied from cultivar to cultivar.

4.3.3.2 Effect of transplanting dates on biological yield

Effect of transplanting dates resulted significant variation on biological yield (t ha^{-1}) (Table 18). Results showed that biological yield decreased with delayed transplanting. The highest biological yield was recorded when transplanted on 16th March (9.814 t ha^{-1}) followed by 31st March (7.94 t ha^{-1}) transplanting which might be due to higher grain and straw yield. In contrast the lowest biological yield was recorded from 30th April (6.573 t ha^{-1}) followed by 15th April (7.153 t ha^{-1}) transplanting. Zaman (1980) expressed similar views that late transplanting reduced biological yield.

4.3.3.3 Interaction effect of varieties and transplanting dates on biological yield

Interaction effect of varieties and transplanting dates had significant effect on biological yield (t ha^{-1}) (Table 19). Table shows that highest biological yield (t ha^{-1}) was recorded from treatment combination with BRRI dhan48 (11.40 t ha^{-1}) when transplanted on 16th March. In contrast the lowest biological yield was recorded from treatment combination with BRRI dhan48 (6.28 t ha^{-1}) when transplanted on 30th April.

4.3.4 Harvest index percent (%)

4.3.4.1 Effect of varieties on harvest index percent (%)

From table 17 it was found that varieties had significant effect on harvest index. From the results it is evident that the highest harvest index was recorded from BRRI dhan48 (46.46 %). In contrast the lowest harvest index was recorded from Tia (36.28 %) followed by BRRI Hybrid dhan2 (39.47 %). Low harvest index in Tia was caused by poor grain yield. Genotypic variations in harvest index was also observed by many workers Bhuiyan *et al.* (1992), BRRI (1998), Chowdhury and Guha (2000), BINA (2006).

4.3.4.2 Effect of transplanting dates on harvest index percent (%)

Results showed that harvest index decreased with delayed transplanting (Table 18). The highest harvest index was recorded when transplanted on 16th March (41.73 %) followed by 31st March (41.51 %) transplanting. In contrast the lowest harvest index was recorded from 30th April (38.90 %) followed by 15th April (40.80 %) transplanting. Zaman (1980) expressed similar views that late transplanting reduced biological yield.

4.3.4.3 Interaction effect of varieties and transplanting dates on harvest index percent (%)

Interaction effect of varieties and transplanting dates had significant effect on harvest index (%) (Table 19). Table shows that the highest harvest index (%) was recorded from treatment combination with BRRI dhan48 (48.20 %) when transplanted on16th March. In contrast the lowest harvest index was recorded from treatment combination with Tia (35.42 %) when transplanted on 30th April.

CHAPTER 5

SUMMARY AND CONCLUSION

The two factorial field experiment was conducted at the Agricultural Botany experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka during *Aus* season from March to July 2010, with a view to find out the influences of transplanting dates on the growth and yield of some hybrid rice along with one inbred variety. The experiment was consisted of two levels of treatments viz. A: Three varieties where two of them were hybrids and one was inbred: BRRI Hybrid dhan2, Tia (Hybrid) and BRRI dhan48 (Inbred). B: Four transplanting dates: 16^{th} March, 31^{st} March, 15^{th} April and 30^{th} April. The experiment was laid out in randomized complete block design. There were 12 treatment combinations. The total number of unit plots were 36. The unit plot size was 4m x 3m. The land was fertilized with 120, 80, 80, 20 and 5 kg ha^{-1} N, P_2O_5, K_2O, S and Zn applied in the form of urea, triple super phosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate respectively . The full amounts of triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied at final land preparation as a basal dose. Urea was applied in three equal installments. The first one-third of urea was top dressed after seedling recovery, second one- at 15 days after first top dressing and rest at the time of panicle initiation. The 25 days old seedlings were transplanted with 25 cm spacing between lines and 15 cm spacing between hills. All intercultural operations were practiced as and when required.

Data were taken on plant height, leaf area, stem dry weight, leaf dry weight, panicle dry weight, total dry weight and number of total tillers $hill^{-1}$ at 40, 60 and 80 DAT. Chlorophyll content was determined at flag leaf stage. Days to panicle initiation, flowering and maturity was recorded as and when required. Light interception percent was recorded at mid-tillering and mid-flowering stage. Number of effective tillers $hill^{-1}$, number of filled spikelets $panicle^{-1}$, number of unfilled spikelets panicle^{-1}, total spikelets panicle^{-1}, spikelet filling percent, 1000-grain weight (g), grain yield, straw yield, biological yield and harvest index (%) were recorded after harvest. Finally grain, straw and biological yields plot^{-1} were converted to t ha^{-1} and the data were analyzed with the help of computer package MSTATC. The mean differences among the treatments were adjusted by Duncan's Multiple Range Test (DMRT) test at 5% level of significance.

Experimental results showed that variety had significant differences for all the studied growth characters except light interception (%) at mid flowering stage and ratio of chlorophyll "a" and "b". BRRI dhan48 gave maximum total dry mass production (40.03 g hill^{-1}) at 80 DAT, higher effective tillers hill^{-1} (8.671), the highest number of filled spikelets panicle^{-1} and the highest spikelet filling percent. As a result BRRI dhan48 contributed to higher grain yield (3.589 t ha^{-1}). Harvest index (%) was also higher in BRRI dhan48. On the other hand hybrid rice BRRI Hybrid dhan2 gave higher number of total tillers hill^{-1}, total leaf area (cm^2), Light interception (%), total chlorophyll content, panicle length and total number of spikelets panicle^{-1}, and Tia gave higher plant height, 1000-grain weight, higher straw yield, lower harvest index. Transplanting dates exerted significant influence on all the growth, yield and yield contributing characters. Values of these characters were highest for early transplanting (16th March and 31st March) and lowest for 30th April transplanting. On the other hand light interception (%) at mid tillering stage, ratio of chlorophyll ("a" and "b"), 1000-grain (g) weight and Harvest index (%) was not significantly differed among transplanting dates. Interaction between varieties and transplanting dates significantly affected all the growth characters.

In case of effective tillers hill^{-1}, BRRI dhan48 produced the highest number of effective tillers hill^{-1} while Tia produced the lowest number of effective tillers hill^{-1}. Among different transplanting dates, 16th March transplanting produced the highest effective tillers hill^{-1} and 30th April transplanting produced the lowest effective tillers hill^{-1}. Interaction between varieties and transplanting dates BRRI dhan48 X 16th March produced the highest effective tillers hill^{-1} and Tia X 30th April produced lowest effective tillers hill^{-1}.

BRRI Hybrid dhan2 produced the highest panicle length while BRRI dhan48 produced the lowest panicle length. Among different transplanting dates, 16th March transplanting produced the highest panicle length and 30th April transplanting produced the lowest panicle length. Interaction effects between varieties and transplanting dates, BRRI Hybrid dhan2 X 16th March produced the highest panicle length and BRRI dhan48 X 30th April produced lowest panicle length.

The highest number of filled spikelets panicle^{-1} was produced by BRRI dhan48 while Tia produced the lowest number of filled spikelets panicle^{-1}. 16th March transplanting produced the highest filled spikelets panicle^{-1} (72.86) and 30th April transplanting produced the lowest filled spikelets panicle^{-1} (51.26). Interaction between varieties and transplanting dates, BRRI dhan48 X 16th March produced the highest filled spikelets panicle^{-1} (105.1) and Tia X 30th April produced the lowest filled spikelets panicle^{-1} (45.37).

On the other hand, the highest number of unfilled spikelets panicle^{-1} (59.50) produced by Tia while BRRI dhan48 produced the lowest number of unfilled spikelets panicle^{-1}. Among different transplanting dates, 30th April transplanting produced the highest unfilled spikelets panicle^{-1} and 16th March transplanting produced the lowest unfilled spikelets panicle^{-1}. Among the treatment combinations, Tia X 30th April produced the highest number of unfilled spikelets panicle^{-1} and BRRI dhan48 X 16th March produced the lowest unfilled spikelets panicle^{-1}.

BRRI Hybrid dhan2 produced the highest total spikelets panicle^{-1} while BRRI dhan48 produced the lowest total spikelets panicle^{-1}. Among the different transplanting dates, 16th March transplanting produced the highest total spikelets panicle^{-1} and 30th April transplanting produced the lowest total spikelets panicle^{-1}. Interaction between varieties and transplanting dates, BRRI dhan48X 16th March produced the highest total spikelets panicle^{-1} and BRRI dhan48 X 30th April produced the lowest total spikelets panicle^{-1}.

The highest spikelet filling percent was found in BRRI dhan48 while Tia gave the lowest spikelet filling percent. In respect of results at different transplanting dates, 16th March transplanting produced the highest spikelet filling percent and 30th April transplanting produced the lowest spikelet filling percent. Among different treatment combinations, BRRI dhan48 X 16th March produced the highest spikelet filling percent and Tia X 30th April produced the lowest spikelet filling percent.

Tia produced the highest 1000-grain weight while BRRI dhan48 produced the lowest 1000-grain weight. Transplanting dates did not significantly affect the 1000-grain weight. In case of interactions between varieties and transplanting dates, Tia X 16th March transplanting produced the highest 1000-grain weight and BRRI dhan48 X 30th April transplanting produced the lowest 1000-grain weight.

In case of grain yield (t ha^{-1}), BRRI dhan48 produced the highest grain yield while Tia produced the lowest grain yield. 16th March transplanting produced the highest grain yield and 30th April transplanting produced the lowest grain yield. Interaction between varieties and transplanting dates, BRRI dhan48 X 16th March transplanting produced the highest grain yield, and Tia X 30th April transplanting produced the lowest grain yield.

Tia produced the highest straw yield while BRRI dhan48 produced the lowest straw yield. Among different transplanting dates, 16th March transplanting produced the highest straw yield and 30th April transplanting produced the lowest straw yield. Among all the treatment combinations, Tia X 16th March transplanting produced the highest straw yield and BRRI dhan48 X 30th April transplanting produced the lowest straw yield.

In case of biological yield (t ha $^{-1}$), Tia produced the highest biological yield while BRRI dhan48 produced the lowest biological yield. Among the different transplanting dates, 16th March transplanting produced the highest biological yield and 30th April transplanting produced the lowest biological yield. In case of interaction between varieties and transplanting dates, BRRI dhan48 X 16th March transplanting produced the highest biological yield and BRRI dhan48 X 30th April transplanting produced the lowest biological yield.

Harvest index was also significantly affected by varieties but not significantly differed by transplanting dates. BRRI dhan48 produced the highest harvest index. In contrast Tia produced the lowest harvest index. Interaction between varieties and transplanting dates also significantly affected harvest index. Treatment combination of BRRI dhan48 X 16th March transplanting showed the highest harvest index and Tia X 30th April transplanting showed the lowest harvest index.

Conclusions:

Based on the results of the present study, the conclusion may be drawn as:

- BRRI dhan48 produced the highest grain yield among the tested varieties followed by BRRI Hybrid dhan2.
- The highest grain yield was found from the crop transplanted on 16th March. On the contrary delayed transplanting (30th April) resulted the lowest grain yield.
- Due to interaction, BRRI dhan48 X 16th March transplanting produced the highest grain yield. Transplanting all the varieties on 16th March showed

significantly higher yield and yield decreased with delayed transplanting in all the treatment combinations.

Recommendation:

However, to reach a specific conclusion and to provide reasonable recommendation, more research works on inbred and hybrid rice regarding the influence of transplanting dates in *Aus* season are needed.

CHAPTER 6

REFERENCES

Ahmed, M. R., Rashid, M. A., Alam, M. S., Billah, K. A. and Jameel, F. (1997). Performance of eight transplant *Aman* rice varieties under Irrigated Conditions. *Bangladesh Rice J.* **8** (1&2): 42-44.

Ahmed, N., Eunus, M., Rahman, M., Begum, M. Taleb, M.A. (1998). Effect of nitrogen on growth and yield of three photosensitive rice cultivars. *Bangladesh J. Agril. Sci.* **25**(2): 273-283.

AICRIP (All India Co-coordinate Rice Improvement Project) (1992). Progress report. 3: 120-124.

AIS (Agricultural Information Service) (2011). Krishi Dairy. Khamarbari, Farmgate, Dhaka-1215.

Alam, M. J., Hossain, S. M. A. and Rahman, M. H. (1996). Agronomic performance of some selected varieties of *Boro* rice. *Porg. Agric*. 7(2) 157-159.

Ali, M. Y., Raman, M. M. and Hoque, M. F. (1995). Effect of time of transplanting and age of seedling on the performance of *Boro* rice. *Bangladesh J. Sci. Ind. Res*. 30: 45-53.

Alim, A., Zaman, S. M. H., Sen, J. L., Ullah, M. T. and chowdhry, M. A. (1962) Review of Half a Century of Rice Research in East Pakistan. Agril. Dept., Govt. East Pakistan. pp. 33-63.

Amin, M. R., Hamid, A., Choudhury, R. U., Raquibullah, S. M. and Asaduzzaman M. (2006). Nitrogen Fertilizer effect on tillering, dry matter production and yield of traditional Varieties of Rice. *Intl. J. Sustain. Crop. Prod*. **1**(1): 17-20.

Anonymous. (2005). Cultivation methods of BINA released varieties/ technologies (Bengali version). Bangladesh Institute of Nuclear Agriculture. P. O. Box-4. Mymensingh. p. 42.

Assaduzzaman, M. (2006). Effect of spacing and date of transplanting on the performance of Boro rice cv. BRRI dhan29. M.S. Thesis, Dept. Agron., Bangladesh Agricultural University, Mymensingh.

Babu, A. M. (1987). Effect of planting date and variety on growth and yield of rice. *Oryza*. **25** (3): 319-322.

BAU (Bangladesh Agricultural University). (1998). Technical Report on Hybrid Rice Alok 6201. Dept. Soil Sci., Bangldesh Agril. Univ. Mymensingh. pp. 1-3.

BBS (Bangladesh Bureau of Statistics), (2006). Monthly statistical bulletin of Bangladesh. Bangladesh Bureau of Statistics, Stat. Div., Minis. Plann., Govt., Peoples' Rep., Bangladesh. p. 57.

BBS (Bangladesh Bureau of Statistics), 2008. Statistical year book of Bangladesh. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Govt. of the People's Republic of Bangladesh. PP. 16-18.

Bhuiya, M. S. U., Islam, N., Sarker, A. U. and Sarker, N. C. (1992). Effect of planting time on growth and yield of *Aus* rice. *Bangladesh J. Agric. Sci*. 19: 229-235.

Bhuiyan, N. I., Paul, D. N. R and Jabber, M. A. (2004). Feeding the Extra millions by 2025: Challenges for Rice Research and Extension in Bangladesh. *In. Proc.* Workshop on modern rice cultivation in Bangladesh. 29-31 January 2002. Bangladesh Rice Res. Inst. Gazipur. pp. 1-3.

BINA (Bangladesh Institute of Nuclear Agriculture). (1992). Annual Report for (1990-91). Bangladesh Inst. Nucl. Agric. P. O. Box. No. 4 Mymensingh. Bangladesh. pp. 143-147.

BINA (Bangladesh Institute of Nuclear Agriculture). (1993). Annual Report for (1992-93). Bangladesh Inst. Nucl. Agric. P. O. Box. No. 4 Mymensingh. Bangladesh. pp. 143.

BINA (Bangladesh Institute of Nuclear Agriculture) (1998). Technical Report on Hybrid Rice Alok 6201. Div. Agron., BINA, BAU campus, Mymensingh. p. 1-7.

BINA (Bangladesh Institute of Nuclear Agriculture) (1998b). Technical Report on Hybrid Rice Alok 6201. Div. Agron., BINA, BAU campus, Mymensingh. p. 5-12.

BINA (Bangladesh Institute of Nuclear Agriculture) (2001). Annual Report for 1998-99. BINA, BAU campus, Mymensingh. p. 313-334.

BINA (Bangladesh Institute of Nuclear Agriculture) (2006). Annual Report for 2005-06. BINA, BAU campus, Mymensingh. p. 307.

BRKB (Bangladesh Rice Knowledge Bank). (2007). Rice in Bangladesh. Bangladesh Rice Knowledge Bank. www.knowledgebank.brri.org. Accessed on July 01, 2007.

BRRI (Bangladesh Rice Research Institule). (1990). Anual Report for 1987. BRRI, Joydebpur, Gazipur. pp.10-33.

BRRI (Bangladesh Rice Research Institule). (1991). Anual Report for 1988. BRRI, Joydebpur, Gazipur. Pub no. 92. pp.94-100.

BRRI (Bangladesh Rice Research Institule). (2000). Anual Report for 1997. BRRI, Joydebpur, Gazipur. pp.88-256.

BRRI (Bangladesh Rice Research Institule). (2001). Cold injury problem in Boro rice. In. Proc. of the workshop on modern rice cultivation in Bangladesh. 14-16 February 1999. Bangladesh Rice Res. Inst. Gazipur. Pub. No. 132. Pp. 37-40, 53-54.

BRRI (Bangladesh Rice Research Institute). (1992). Anual Report for 1990-91. BRRI, Bangladesh Rice Res. Inst. Joydebpur, Gazipur.

BRRI (Bangladesh Rice Research Institute). (1994). Annual Report for 1993-94. BRRI, Gazipur-1701.p. 156.

BRRI (Bangladesh Rice Research Institute). (1995). Annual Report for 1994-95. BRRI, Gazipur-1701.p. 65.

BRRI (Bangladesh Rice Research Institute). (1997). BRRI Annual Report for 1997. Bangladesh Rice Res. Inst., Joydevpur, Gazipur, Bangladesh. pp. 38-40.

BRRI (Bangladesh Rice Research Institute). (1998). Annual Report for 1997-98. BRRI, Gazipur-1701.p. 178.

BRRI (Bangladesh Rice Research Institute). (2005). Anual Report for 2004-05. BRRI, Bangladesh Rice Res. Inst. Joydebpur, Gazipur. pp. 236-238.

BRRI (Bangladesh Rice Research Institute). (2007). Anual Report for 2008-09. BRRI, Bangladesh Rice Res. Inst. Joydebpur, Gazipur.

BRRI (Bangladesh Rice Research Institute). (2009). Anual Report for 2006. BRRI, Bangladesh Rice Res. Inst. Joydebpur, Gazipur. pp. 75.

Chandra, S. and Manna, J. (1988). Effect of date of planting and spacing on grain yield and grain quality of scented rice *(Oryza sativa)* varieties in wet season in costal Orissa. *Indian J. Agric. Sci.*67: pp. 93-97.

Chowdhury, B.H., Borah, R. C., Deka, S. C. and Ahmed, S. A. (2000). Varietal difference in nitrogen , phosphorus, potassium, iron contents and grain yield in rice varieties under wetland field condition. *Crop Res. Hisar*. **20** (1):20-24.

Chowdhury, M. J. U., Sarkar, M. A. R. and kashem, M. A. (1993). Efffect of variety and number of seedlings hill^{-1} on the yield and its components on late transplant *Aman* rice. *Bangladesh J. Agril. Sci*. **20** (2): 311-316.

Chowdhury, P. K. D. and Guha, B. (2000). Performance of rice varieties under different time of planting in boro season. Annals of Biology Luidhiana 16: 41-44.

Coombs, J., D.O. Hall, S.P. Long and J.M.O. Scurlok. 1985. Techniques in Bio-productivity and Photosynthesis (2nd ed.). Paragamon Intl. Oxford. pp. 223-234.

Costa, D. J. and Hoque, M. N. (1986). Superimposed variety trial on T. aman [Transplanted rice in Bangladesh]. Proc. Central Review Workshop, On-Farm Research Div. Jul. 5-10. BARI., Joydebpur, Bangladesh. pp. 25-26.

Cui, J., Kusutani, A., Toyota, M. and Asanuma, K. (2000). Studies on the varietal differences of harvest index in rice. *Japanese J. Crop Sci.* **69** (3): 357-358.

Devaraju, K. M., Gowda, H. and Raju, B. M. (1998). Nitrogen response of Karnataka Rice Hybrid 2. *Intl. Rice Res. Notes*. **23** (2): 43.

Dhiman, S. D., Nandal, D. P. and Hari, O. M. (1997). Performance of scented, dwarf rice *(Oryza sativa)* varieties under different time of transplanting. *Indian J. Agron*. **42** (2): 253-255.

Gangwar, K. S., and Sharma, S. K. (1997). Influence of planting dates on productivity of traditional scented rice varieties. *Intl. Rice Res. Notes*. **22** (1): 42.

Gardner, F. P., Pearce, R. B. and Mistechell, R. L. (1985). Physiology of Crop Plants. Lowa State Univ. Press, Powa. p. 66.

Gohain, T. and Saikai, L. 1996. Effect of late transplanting on growth and yield of rainfed low land rice (*Oryza sativa*). *Indian J. Agron.* **41** (3): 488.

Gomez, A. K. and Gomez, A. A. (1984). Statistical Procedure for Agricultural Research. 2nd edition. John Wily and Sons. New York. p. 680.

Gosh, D. C., and Ganguly. S. (1994). Cultural factors affecting growth, lodging and productivity of wet land rice. *Indian Agric*. **38** (2): 99-103.

Haque, Z., (1997). Photoperiodism and thermo sensitivity of transplanted Aman rice in Banglades. *In. Proc*. Intl. Sem. Photoperiod- sensitive Transplant Rice. October. 1997. pp. 18-25.

Hasanuzzaman, M., Nahar, K. and Karim, R. 2007. Effectiveness of different weed control methods on the performance of transplanted rice. *Pakistan J. Weed Sci. Res.* **13** (1-2): 17-25.

Hossain, M. and Pingali, P. L. (1998). Rice Research. Technological progress, and impact on productivity and poverty; and an overview, *In: Proc, Intl. Conf. Impact Rice Res*. 3-5 June, 1996. Bankok, Thailand. pp.1-2.

Hossain, S. T. and Alim, M. N. (1991). Effect of water stress on the performance of the yield of fine rice. *Bangladesh J. Environ. Sci*. **6**: 251-257.

Hussain, T., Jilani, G. and Gaffar, M. A. (1989). Influence of rate and time of N application on growth and yield of rice in Pakistan. *Intl. Rice Res. Newsl.* **14** (6): 18.

Hundal, S. S., Prabhjyit, K. and Kaur, P. 1999. Evaluation of agronomic practices for rice using computer simulation model CERES Rice. *Oryza*. **36** (1): 63-65.

Idris, M. and Matin, M. A. (1990). Response of four exotic strains of aman rice to urea. *Bangladesh J. Agril. Sci.* **17** (2): 271-257.

IRRI (International Rice Research Institute). (1978). Annual report for 1977. IRRI, Los Banos, Philipines, p. 320.

IRRI (International Rice Research Institute). (1993). IRRI Almanac. Intl. Rice Res. Inst. Los Banos, Philippnes. pp. 301-303.

IRRI (International Rice Research Institute). (2004). Rice Today. *Intl. Rice Res. Inst.* **3** (3): 12-27.

Islam, M. R., Rahman, M. S., Rahman, M. H. Awal, M. A. and Hossain, M. G. (1999a). Effect of date of planting on riec yield and yield attributes of two advance mutants of rice in Aman season. *Bangladesh J. Nuclear. Agric.* **15**: 34-40.

Islam, N., Kamal, A. K. M. and Islam, M. R. (1999b). Effect of cultivar and time of nitrogen application on grain yield and grain protein content of rice. *Bangladesh Rice J.* **1** (1): 10-16.

Islam, S. (1995). Effect of variety and fertilization on yield and nutrient uptake in transplant aman rice. M. S. thesis. Dep. Agron. Bangladesh Agril. Univ. Mymensingh. pp. 26, 29.

Liu, Xinhua, (1995). II-you 92: a new hybrid rice later season. Chinese Rice Res. Newsl. 3 (2): 12 [Rice Abst. 1996. 19 (2): 75].

Joseph, K. and Havanagi, G. V. (1987). Effect of dates of planting and irrigation on yield and yield attributes of rice varieties. *Indian J. Agron.* **32** (4): 411-413.

Julfiquar, A. W., Virmani, S. S., Haque, M. M., Mazid, M. A. and Kamal, M. M. (2009). Hybrid rice in Bangladesh: opportunities and challenges. Rice research for food security and poverty allevation. Proc. Int. Rice Research Conference.

Julfiqure, A. W., Hossain, M. A., Ansari, T. H. and Islam, M. A., (1997). The augmented design as an aid to preliminary selection of new rice hybrids. *Bangladesh J. Life Sci.* 9 (1): 23-29.

Kamal, A. M. A., Zaman, M. A. and Islam, M. A. (1988). Effect of cultivars and NPK combination on the yield contributing characters of rice. *Bangladesh J. Agril. Sci.* **15** (1): 105-110.

Kenmore, P. (2003). Sustainable rice production, food security, and enhanced livelihoods. Rice Science: Innovations and Impact for livelihood. Intl. Rice Res. Inst. Los Bonos, Philipines, pp. 27-34.

Khisha, K. (2002). An evaluating of Madagascar System of Rice Production in Aman Season with Three High Potential Rice Varieties. M. S. Thesis, Dept. Agron., Bangladesh Agril. Univ., Mymensingh. pp. 36-63.

Kim-Jong Geun, Euisoo, C., Junsang, H., Sung, S., Meingjoong, K., Seitlyang, Y. and Youngchul, L. 2007. Effect of growth stage and variety on the yield and quality of whole crop rice. *Journal of the Korean Society of Grassland Science,* **27** (1): 1-8.

Krishnan, P. and Nayak, S. K. (1998). Development rate and growth duration of rice (*Oryza sativa*) in response to delayed transplanting. *Indian J. Agric. Sci.* **68** (9): 593-595.

Kulkarni, N., Reddy, P. P., Rao, M. S., Gangaran, A. and Reddy, N. S. 1989. Evaluation of early duration rice cultivars for normal and late sowing on certain Telangana Distrists. J. Res. APAU. **17** (2): 181-184.

Leenakumari, S., Mahadevappa, M., Vidyachandra, B. and Krishnamurthy, R. A. (193). Performance of experimental rice hybrids in Bangalore, Karnataka, India. *Intl. Rice Res. Notes.* **18** (1): 16.

Mejos, N. V. and Pava, H. M. (1980). Influence of age of seedlings at transplanting on the performance of two low land rice varieties. *J. Agric. Food Nutr*. **2** (2): 96-104.

Miah, M. H. N., Karim, M. A., Rahman, M. S. and Islam, M. S. (1990). Performance of Nizersail mutants under different spacing. *Bangladesh J. Train. and Dev.* **3** (2): 31-34.

Mondal, M. M. A., Islam, A. F. M. S and siddique, M. A. (2005). Performance of 17 modern transplant aman cultivar in the northern region of Bangladesh. *Bangladesh J. Crop Sci.* **16**: 23-29.

Muthukrishnan, P., Ponnuswamy, K., Santhi, P, and Subramanian, M. (2000). Effect of transplanting time on the performance of rice hybrids in Cauvery Delfazone. *Madras Agril. J.* **87** (7-9): 506-507.

Naher, Q., Kashem, M. A., Salam, M. U., Salim, M. and Hossain, S. M. A. 2000. Effect of year round transplanting on the growth duration and yield of two modern varieties of rice. *Bangladesh J. Crop Sci.* **11** (1&2): 71-81.

Om , H., Dhiman, S.D., Nandal, D.P. and Verma, S.L. (1998). Effect of method nursery raising and nitrogen on growth and yield of hybrid rice *(Oryza sativa). Indian J. Agron.* **43** (1): 68-70.

Om, H., Katyal, S. K., Dhiman, S.D. and Sheoran, O.P. (1999). Physiological parameters and grain yield as influenced by time of transplanting and rice (*Oryza sativa*) hybrids. *Indian J. Agron.* **44** (4): 696-700.

Om, H., Singh, O. P. and Joon, R., (1993). Effect of time of transplanting and spacing on Basmati rice. *Haryana J. Agron.* **9** (1): 87. [Cited from Rice Abs. 1994, 17 (4): 273]

Panda, S. C. and Leeuwrik, D. M. (1971). Effect of spacing on the growth and yield of high yielding varieties. Oryzae. **8** (2): 39-45.

Pardashty, H., Sarvesant, Z. T., Nasir, M. and Fallah, V. Fallah, V. (2000). Effect of transplanting date on yield and yield Components of some rice cultivars. Seed and Plant. **16** (2): 146-158.

Patel, J. R., (2000). Effect of water regime, variety and blue-green algal on rice (*Oryza sativa*) hybrids. *Indian J. Agron.* **45** (1):103-106.

Prabagara, S. R. and Ponnuswamy, A. S. (1998). Seasonal influence of flowering behavior and plant growth characters on parental lines of hybrid rice. Intl. Rice Res. Notes. 23:2, 27-28.

Radhakrishna, R. M., Vidya Chandra, B., Lingaraju, S. and Gangadhariah, S. 1996. Karanataka rice hybrids. In: Abst., Proc. 3rd Intl. Symp. On Hybrid Rice. November 14-16. Director, Rice Res., Hyderabad. p. 38.

Rafey, A., Khan, P. A. and Srisvastava, V. C. (1989). Effect of Nitrogen on growth, yield and nutrient uptake of upland rice. *Indian J. Agron.* **34** (2): 133-134.

Rahman, H. M. H. (2002). Physiological and biochemical characterization of some aromatic and fine grain local landrace rice. M. S. Thesis, Dept. Crop. Bot., Bangladesh Agric. Univ., Mymensingh.

Rao, K. S., Moorthy, B. T. S., Dash, A. B. and Lodh, S. B. (1996). Effect of time of transplanting on grain yield and quality traits of Bangladesh-type scented rice varieties in coastal Orissa. *Indian J. Agril. Sci.* **66** (6): 333-337.

Roy, B. C. (1999). Nitrogen fertilizer Management and its Effects on Growth and Yield of Rice varieties in Bangladesh. Phd Dissertation. Verlag Grauer, Stuttgart, Germany. p. 50.

Rudraradhya, M. M., Panchakshariah, S. and Patil, B. R. (1998). Performance of hybrid rice in South Karnataka. Intl. Rice. Res. Notes. 23: 2 & 33.

Russel, D. F. (1986). MSTAT-C package programe. Crop and Soil Science Department, Michigan State University, USA.

Sattar M. A. and Bhuiyan, S. I. 1994. Performance of direct- seeded and transplanted rice under different water management practices. *Bangladesh Rice J.* **3** (1&2): 1-5.

Sawant, A. C., Throat, S. T. Khadse, R. R. and Bhosalef, R. J. (1986). Response of early rice varieties to nitrogen levels and spacing in costal Maharashtra. *J. Maharashtra Agril. Univ.* **11** (2): 182-184.

Shamsuddin, A. M., Islam, M. A. and Hossain, A. (1988). Comparative study on the yield and agronomic characters of nine cultivars of aus rice. *Bangladesh J. Agril. Sci.* **15** (1): 121-124.

Singh, S. and Gangwer, (1989). Comparative studies on production potentials in traditional tall and improved rice cultivars. *J. Andaman Sci. Assoc.* **5** (1): 81-87.

Singh, K. M., Pal, S. K., Verma, U. N., Thakur, R. and Singh, M. K. (1997). Effect of time and methods of planting on performance of rice(*Oryza sativa*) cultivars under medium land of Bihar Plateau. *Indian J. Agron.* **42** (3): 443-445.

Singh, S. P., Rao, K. V. and Pillai, K. G. 1998. Effect of planting geometry and N levels on grain yield of hybrid culture. Int. Rice Res. Notes. **23** (2): 38.

Singh, V. P. and Singh, V. K. 2000. Effect of sowing date and nitrogen levels on productivity of spring sown rice in low hill of Urunachal Prodesh. *Indian J. Agron.* 45: 560-563.

Son, Y., Park, S. T., Kim, S. Y., Lee, H. W. and Kim, S. C. (1998). Effects of plant density on the yield and yield components of low tillering large panicle type rice. *RDA J. Crop Sci. I.* 40: 2.

Subbain, P., Gopalasundaram, P. and Palaniappan, S. P. (1995). Energetic and water use efficiency of intensive cropping system. *Indian J. Agron.* **40** (3): 398-401.

Suprithantno, B. and Sutaryo, B. (1992). Yield performance of some new rice hybrids varieties in Indonesia. *Intl. Rice Res. Newsl.* **17** (3): 12.

Swain, D. K., Herath, S., Bheskar, B. C., Krishnan, P., Rao, K. S., Nayak, S. K. and Dash, R. N. 2007. Developing ORYZA 1N for medium and long-duration rice variety selection under non water stress conditions. *Agronomy Journal.* **99** (2): 428-440.

Wang, S., Cao, W., Jiang, D., Dai, T. and Zbu, Y. (2001). Physiological characteristics and high yield techniques with SRI rice. In: Assessments of the System of Rice Intensification. Proc. Intl. Conf., Sanya, China. April 1-4, 2002. pp.117-121.

Witham, H., D. F. Blaydes and R. M. Devlin, (1986). Exercises in plant physiology (2nd edition). PWS publishers, Boston, USA. pp. 128-131.

Yeasmin, S. 2005. Performance of Boro rice varieties as affected by date of transplanting under system of rice intensification. M. S. Thesis, Dept. Agron., Bangladesh Agricultural University, Mymensingh.

Yoshida, S. (1981). Fundamentals of Rice Crop Science, IRRI, Philippines: 1- 41.

Zaman, S. M. H. (1980). Simple techniques of rice production. In: Proc. of the workshop on modern rice cultivation in Banglades. Feb. 1980. Bangladesh Rice Res. Inst. Gazipur. pp. 31-39.

APPENDICES

Appendix I. Map showing the experimental sites under study

Appendix II. Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimental site during the period from February 2010 to August 2010

Month	*Air temperature (°c)		*Relative humidity (%)	*Rain fall (mm) (total)	*Sunshine (hr)
	Maximum	Minimum			
February, 2010	28.1	15.5	68	28.9	5.5
March, 2010	32.5	20.4	64	65.8	5.2
April, 2010	33.6	23.6	69	165.3	4.9
May, 2010	32.9	24.5	81	339.4	4.7
June, 2010	32.1	26.1	81	340.4	4.7
July, 2010	31.4	26.2	84	373.1	3.3
August, 2010	31.6	26.3	80	316.5	4.9

* Monthly average,

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

Appendix III. Characteristics of Farm soil as analyzed by Soil Resource and Development Institute (SRDI), Khamar Bari, Farmgate, Dhaka.

A. morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Experimental 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
Partical size analysis	
% Sand	25.68
% Silt	53.85
% clay	20.47
Textural class	silty-loam
P^H	7.1
Organic carbon (%)	0.31
Organic matter (%)	0.54
Total N (%)	0.027
Available P (ppm)	23.06
Exchangeable K (me/100 g soil)	0.60
Available S (ppm)	45

Source: SRDI

Appendix IV: Layout of experimental field