EFFECT OF PLANTING TIME ON MORPHO-PHYSIOLOGICAL AND YIELD CONTRIBUTING CHARACTERS OF RICE (*Oryza sativa*)

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CERTIFICATE

This is to certify that the thesis entitled **'Effect of Planting Time on Morpho-Physiological and Yield Contributing Characters of Rice (*Oryza sativa*)'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of Master of Science in Agricultural Botany, embodies the result of a piece of bonafide research work carried out by **Naznin Ahmed**, Registration number: **14-06349** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:
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DEDICATED

TO

MY BELOVED PARENTS

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The Author

EFFECT OF PLANTING TIME ON MORPHO-PHYSIOLOGICAL AND YIELD CONTRIBUTING CHARACTERS OF RICE (*Oryza sativa*)

ABSTRACT

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka at the period of December, 2014 to April 2015 to find out the effect of planting time on morpho-physiological and yield contributing characters of rice. The experiment comprised of two factors. Factor A: planting time (2): T_1: 24th January planting; T_2: 23th February planting and Factor B: Rice variety (5): V_1: BRRI dhan29; V_2: BRRI hybrid 2; V_3: Hera 2; V_4: Tia and V_5: Taj 1. The experiment was laid out in a randomized complete block design (RCBD) with three replications. In case of planting time, at 20, 40, 60, 80 DAT and harvest, the taller plant (26.58, 56.63, 83.19, 92.29 and 111.16 cm, respectively) was recorded from T_1 and the shorter plant (24.64, 53.49, 78.90, 87.25 and 105.18 cm, respectively) was found from T_2. The maximum shoot reserve translocation (15.26%) was recorded from T_1 and the minimum (12.97%) from T_2. The maximum total grains panicle^{-1} (86.80) was recorded from T_1 and the minimum (79.80) from T_2. The maximum grain yield (4.00 t ha^{-1}) was observed from T_1 and the minimum (3.53 t ha^{-1}) from T_2. For rice variety, at 20, 40, 60, 80 DAT and harvest, the tallest plant (27.88, 58.08, 84.94, 94.41 and 112.03 cm, respectively) was observed from V_3, while the shortest plant (23.59, 50.38, 75.55, 82.92 and 100.93 cm, respectively) from V_1 The highest shoot reserve translocation (16.84%) was observed from V_3, while the lowest (10.94%) from V_1. The maximum total grains panicle^{-1} (89.83) was observed from V_3, while the minimum (67.83) from V_1. The highest grain yield (4.30 t ha^{-1}) was found from V_3, while the lowest (2.95 t ha^{-1}) from V_1. Due to interaction effect, at 20, 40, 60, 80 DAT and harvest, the tallest plant (29.94, 62.57, 89.58, 99.42 and 120.92 cm, respectively) was recorded from treatment combination of T_1V_3 and the shortest plant (23.31, 49.56, 75.57, 82.25 and 100.92 cm, respectively) was found from of T_2V_1. The highest shoot reserve translocation (17.83%) was recorded from T_1V_3 and the lowest shoot reserve translocation (10.43%) was found from of T_2V_1 treatment combination. The highest total grains panicle^{-1} (97.33) was recorded from T_1V_3 and the lowest (66.00) from of T_2V_1 treatment combination. The highest grain yield (4.64 t ha^{-1}) was recorded from T_1V_3 and the lowest grain yield (2.83 t ha^{-1}) was recorded

from of T_2V_1 treatment combination. Among different planting time and variety 24th January planting and Hera 2 was superior in terms of morpho-physiological, yield contributing characters and yield of rice.

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.), belongs to the family Gramineae, is the staple food for at least 62.8% of total planet inhabitants and it contributes on an average 20% of apparent calorie intake of the world and 30% of Asian populations (Hien *et al.*, 2006). It is the most important food in tropical and subtropical regions (Singh *et al*., 2012). More than three billion people in the world are taking rice as their main food (IRRI, 2009). About 84.67% of cropped area of Bangladesh is used for rice production, with annual production of 30.42 million tons from 10.4 million hectares of land (BBS, 2014). In Asia, more than 90% of all produced rice has been consumed (FAO, 2006).

The population of Bangladesh is increasing at an alarming rate and the cultivable land is decreasing due to urbanization and industrialization resulting in shortage of food. The nation is still adding about 2.3 million every year to its total of 150 million people (Momin and Husain, 2009). Thus, the present population will swell progressively to 223 million by the year 2030 which will demand additional 48 million tons of food grains (Julfiquar *et al*., 2008). Population growth required a continuous increase in rice production in Bangladesh. So, the highest priority has been given to produce more rice (Bhuiyan, 2004). Production of rice has to be increased by at least 60% to meet up food requirement of the increasing population by the year 2020 (Masum, 2009). According to FAO (2009) in Bangladesh, the average yield of rice is about 2.92 t ha^{-1} which is very low compared to other rice growing countries of the world, like China (6.30 t ha^{-1}), Japan (6.60 t ha^{-1}) and Korea (6.30 t ha^{-1}). Rice yields are either stagnating/declining in post green revolution era mainly due to late or early planting, imbalance use of fertilizer, irrigation and weeding schedule, type of cropping system practiced, lack of suitable rice genotypes for low moisture adaptability and disease resistance (Prakash, 2010).

The possibility of horizontal expansion of rice production area has come to a standstill for that in Bangladesh, farmers and scientists are diverting their attention towards vertical expansion. Therefore, attempts should be taken to increase the rice yield per unit area. For vertical expansion it is necessary to use of modern production technologies such as use of quality high yielding and hybrid varieties, optimum time of planting, appropriate number of seedling $hill^{-1}$, adopting proper plant protection measures, seedlings raising techniques, fertilizer management and so on. Variety is the key component to produce higher yield of rice depending upon their differences in genotypic characters, input requirements and off course the prevailing environmental conditions during the growing season. (BRRI, 2003). Planting time for successful rice production widely depends on varietal life duration, sensitivity to photoperiod, temperature, rainfall and other environmental factors. In Bangladesh hybrid rice has been introduced through BRRI, IRRI and different seed companies and it gains positive monumentaion in *boro* season (Haque and Biswas, 2011). These varieties however, needs further test under different planting times to interact with different environmental conditions of the growing seasons.

In Bangladesh, planting of *boro* rice starts from early January and continues upto last February. Such longer period of planting time is associated with inconsistent rainfall, late harvesting of preceding crops, early flood water and other socioeconomic factors (Zaman, 1986). It is assumed that late planting reduces vegetative phase which results reduced growth and yield of rice (Jhoun, 1989). In the contrary, early planted rice sometimes lodges due to over growth or other natural hazards prevailing in long growing season. It is therefore, essential to generate adequate information relating planting time of to exploit better growth and productivity. Planting time affects not only growth and productivity of rice but also affects generally on seed quality. Planting time affects seed quality through affecting seed growth and development as it prevail different environmental conditions in the processes of seed development and seed maturation (Castillo *et al*., 1994).

The growth process of rice plants under a given agro-climatic condition differs with variety (Alam *et al*., 2012). Now a days different hybrid rice variety are available in Bangladesh which have more yield potential than conventional high yielding varieties (Akbar, 2004). Zhende (1988) stated that hybrid rice has high tillering capacity. During vegetative growth, hybrid rice accumulates more dry matter in the early and middle growth stages which results in more spikelets panicle^{-1}. They have bigger panicles and more spikelets panicle^{-1}. These factors result in higher yields usually 15% or more than ordinary rice, also called inbred (Philrice, 2002). There are other hybrids at present which give an average yield of 5.7 tons/ha during the wet season (Vanzi, 2003). Generally the yield of hybrid rice is 10-15% higher than the improved inbred varieties. Very recently various new rice varieties were developed and available as BRRI dhan and maximum of them is exceptionally high yielding. Hossain and Deb (2003) reported that although farmers got about 16% yield advantage in the cultivation of hybrids compared to the popularly grown inbred varieties, the yield gains were not stable. On the other hand, compared with conventional cultivars, the hybrids had larger panicles, heavier seeds, resulting in an average grain yield increase of 7.27% (Bhuiyan *et al*., 2014). This variety however, needs further evaluation under different adaptive condition to interact with different environmental conditions.

Considering the above mentioned facts and based on the prior observation, an investigation was undertaken with the following objectives:

- To study morpho-physiological characteristics of the some selected rice varieties at two different transplanting dates in Boro season;
- To evaluate the yield and yield attributes of some selected rice varieties in Boro season.

CHAPTER II

REVIEW OF LITERATURE

Rice is the staple food and around ninety per cent of rice is grown and consumed in south and Southeast Asia, the highly populated area. Yield and yield contributing characteristics of rice are considerably depended on manipulation of basic ingredients of agriculture. The basic ingredients include varieties of rice, environment and agronomic practices (planting time, number of seedlings hill^{-1}, plant density, fertilizer, irrigation etc.). Research on this crop is going on various aspects in increase its potential yield including planting time and varieties which are responsible for the growth and yield of rice. Different researcher reported the effect of rice varieties on yield contributing component and grain yield but in Bangladesh condition it is not adequate and conclusive. However, some of the important and informative works and research findings related to the morpho-physiological attributes, yield contributing characters and yield due to planting time and different rice varieties, so far been done at home and abroad, reviewed in this chapter under the following heads-

2.1 Effect of planting time

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

2.1.1 Growth parameters

The time between July 15 and August 15 is the best for transplantation of high yielding cultivars of transplant *Aman* rice in Bangladesh. However, better results are obtained from early transplanting than late transplanting (Alim *et al.*, 1993; Hedayetullah *et al.*, 1994). It was revealed that mildly photoperiod-sensitive cultivars had a reduced likelihood of encountering low temperature compared with photoperiod-insensitive cultivars. The benefits of photoperiod sensitivity include greater sowing flexibility and reduced water use as growth duration is shortened when sowing is delayed (Farrell *et al*., 2006).

If photosensitive varieties are transplanted a little early, their vegetative growth extended which resulted more plant height and leafy growth. Due to increased plant height, such varieties lodge badly when transplanted early time. As a result, the grain yield from such a crop is reduced drastically. On the other hand, when transplanting is delayed beyond normal period, the grain development is very poor which results in more quantity of under developed grains and ultimately severe reduction in grain yield. Flowering of rainfed lowland rice occurs within optimum time if transplanted was occured from early May onwards up to the first week of August. However, sowing time can be delayed up to the first week of August for rainfed lowland cultivars if there is any crop failure due to flooding at the beginning of the cropping season **(**Sarkar and Reddy, 2006).

The vegetative stage of rice may be extended due to low temperature (Vergara and Chang, 1985). In November planting of BR3 when the temperature was cool, the vegetative phase was extended by 50 days and the relative tillering rate reached its peak at 40 to 50 days after transplanting. In contrast with planting in July when the temperature was high, the relative tillering rate reached the highest value within 15 to 25 days after transplanting. In most cases, tillering rate decreases because of low temperature. So, appropriate planting time and the use of photoperiod-sensitive cultivars can be advantageous in a region in avoiding low temperature damage during reproductive development. Gohain and Saikia (1996) reported that earlier planting of high yielding varieties of rice around mid-July was the best. Late planting might have exposed the crop to relatively more adverse condition in terms of water stagnation at the tillering phase and low temperature at the reproductive phase which might have pulled down the yield compared to earlier planting.

A combination of these growth variables explains variation in yield better than any individual growth variable. Thakur and Patel (1998) reported that dry matter production, leaf area index, leaf area duration (LAD), crop growth rate (CGR), net assimilation rate (NAR) and relative growth rate (RGR) are ultimately reflected in higher grain yield of rice. In rice, the optimum leaf area index (LAI) at flowering and optimum crop growth rate (CGR) during panicle initiation has been identified as the major determinants of yield. Crop growth rate is the most critical growth attributes for rice yield under intensive management during the latter half of the reproductive period (Horie, 2001). The CGR at this stage critically affects final spikelet number by regulating spikelet degeneration, potential single-grain weight by determining husk size, and grain filling by forming active sinks and determining endosperm cell number at initial grain filling. Early plating of hybrid rice, exhibited the maximum total and effective tillers per hill, leaf-area index, leaf-area duration, dry-matter accumulation, relative growth rate, fertile spikelets per panicle, 1000 grains weight and straw yields (Nayak, *et al.,* 2003). Hundal *et al.* (2005) observed the significant linear and exponential relationships between leaf area index and aboveground biomass and yield of rice. Planting time had direct influenced on above attributes.

2.1.2 Yield parameters

Patel *et al.* (1987) reported that grain yield of rice markedly declined with delayed planting time in rice. Panwar *et al.* (1989) noticed that spikelet number was the main component character affecting the rice yield. Haque *et al*. (1991) reported negative association of 1000 grain weight and yield per plant in traditional varieties but positive association of yield per plant with number panicle per plant in modern varieties. Yield components like panicle per plant, grains per panicle and 1000 grain weight increase yield in modern varieties (Saha Ray *et al*., 1993). Other reports revealed that number of panicles per hill, panicle length and 1000-grain weight were positively associated with grain yield of rice (Marwat *et al*., 1994). Number of panicles per hill and number of spikelets per panicle had negative direct effects on grain yield (Padmavathi *et* *al*., 1996). Surek *et al.* (1998) found that biological yield of rice had the highest direct effect on grain yield followed by harvest index and 1000 grain weight.

The highest grain yield was obtained from 15 July transplanting of rice. The highest grain yield was obtained due to cumulative effect of longer panicle, highest number of grains per panicle and 1000 grain weights (Salam *et al*., 2004). Different yield and yield parameters like number of tillers per hill, grains per panicle, 1000 grain weight and sterility were significantly affected by transplanting time. Basmati-385 and Super Basmati produced maximum paddy yield (5,655 and 5,612 kg/ha) when transplanted on July 1 and July 11, respectively. Minimum sterility was recorded in rice varieties 98901 (5.25%) and Super Basmati (5.08%) and maximum (13.08%) in PK 5261-1-2-1. Minimum sterility was observed in rice transplanted on July 21 followed by July 1, July 11 and July 31 (Akram *et al*., 2004).

Linscombe *et al.* (2004) reported that planting date had a major effect on grain yield. Grain yield at one location in southwest Louisiana was highest (8600 kg ha^{-1}) when rice was planted in late March, and grain yield (6500 kg ha^{-1}) decreased linearly as planting was delayed until early June.

Yield and spikelet sterility of rice in temperate Kashmir was influenced by transplanting dates and nutrient management. Spikelet sterility was higher in rice transplanted on 30 June as compared with that on 15 June due to reduced growth phases and low temperature during reproductive phase. Further, increasing levels of N under delayed transplanted conditions increased spikelet sterility and reduced grain yield of rice (Singh *et al*., 2005).

Yield and quality of aromatic rice were superior when exposed to a lower temperature (day mean temperature 23^0C). Yield, filled grain rate, and number of filled grains per panicle reduced significantly under the highest temperature (day mean temperature 30^0C). The highest temperature also increased the chalkiness score, and reduced milled rice, milling quality of head rice, eating and aroma scores, and gel consistency in rice (Xu *et al.*, 2006). The higher the temperature and the longer the high temperature stress, the lower the pollen vigour and germination percentage, therefore, the less the seed setting rate and lower the yield (Zheng *et al.*, 2007).

Two genotypes were grown at 30/24^{0}C day/night temperature in a greenhouse, in both genotypes one hour exposure to 33.7^{0}C at anthesis caused sterility. In IR64, spikelet fertility was reduced about 7% by per degree increase of temperature (Jagadish *et al.*, 2007). Spikelet sterility of rice results from low temperatures during panicle development. However, this temperature alone cannot fully explain the fluctuations in sterility observed in the field, since the susceptibility of rice plants to low temperature often changes according to its physiological status during sensitive stages.

Low water temperature (below 20^{0}C) during vegetative growth stage of rice plant significantly increased the sterility. On the other hand, low air temperature during vegetative growth also significantly increased the sterility, but this effect was diminished by warm water temperature even at low air temperature. There was a close and negative correlation between sterility and water temperature during vegetative growth (Shimono *et al.*, 2007). These results suggest that temperatures before panicle initiation change the susceptibility of a rice plant to low temperatures during panicle development which results in spikelets sterility.

Islam *et al.* (2008) reported that direct wet-seeded rice produced 10% higher grain yield than transplanted rice and 31 December seeded rice produced the highest grain yield. Rice planted on 1 December significantly reduced the grains per panicle and January planted rice significantly reduced the panicle per unit area and ultimately effect grains yield.

2.2 Effect of variety

Rice yield can be increased in many ways of them developing new high yielding variety and by adopting hybrid varieties to achieve potential yield of rice is important. Variety itself is the genetical factor which contributes a lot for producing yield and yield components and different varieties perform differently in a particular environment.

2.2.1 Plant height

Shamsuddin *et al*. (1988) conducted a field trial with nine different rice varieties and observed that plant height differed significantly among the varieties tested. Sawant *et al*. (1986) conducted an experiment with the new rice lines R-73-1-1, R-711 and the traditional cv. Ratna and reported that the traditional cv. Ratna was the shortest. Miah *et al*. (1990) conducted an experiment were rice cv. Nizersail and mutant lines Mut. NSI and Mut. NSS were planted and found that plant height were greater in Mut. NSI than Nizersail.

BRRI (1991) observed the plant height differed significantly among BR3, BR11, BR14, Pajam and Zagali varieties in the *Boro* season. Hosain and Alam (1991) found that the plant height in modern rice varieties BR3, BR11, BR14 and Pajam were 90.4, 94.5, 81.3 and 100.7 cm, respectively.

Munoz *et al.* (1996) noted that IR8025A hybrid rice cultivar produced 16% longer plant than the commercial variety Oryzica Yacu-9. BINA (1993) evaluated the performance of four rice varieties (IRAATOM 24, BR14, BINA13 and BINA19). It was recorded that varieties differed significantly in respect of plant height of rice.

An experiment was conducted at BINA (1998) to find out varietal performance of advance line (BINA 8-110-2-6) along with three check varieties - Iratom 24, BR26 and BRRI Dhan27. The result indicated that BINA 8-110-2-6 appeared similar to BRRI Dhan27 in terms of plant height and panicle length.

Xu and Li (1998) observed that the maintainer lines were generally shorter than restorer line. Chen-Liang *et al*. (2000) showed that the cross between Peiai 64s and the new plant type lines had longest plant height.

Ghosh (2001) worked with four rice hybrids and four high yielding rice cultivars and concluded that hybrids have higher plant height as compared with high yielding varieties. Pruneddu and Spanu (2001) conducted an experiment and found that plant height ranged from less than 65 cm to 80–85 cm in Mirto, Tejo, Gladio, Lamone and Timo.

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

Mandavi *et al.* (2004) reported from their experiment that plant height was negatively correlated with grain yield. Thus, in improved genotypes, plant height was not a limiting factor for grain yield because of reduced lodging and conducted better translocation of assimilates.

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

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

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

An experiment was carried out by Alam *et al*. (2012) at Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi during the kharif season to study the effect of variety, spacing and number of seedlings hill^{-1} on the yield potentials of transplant aman rice. The experiment consisted of three high yielding varieties viz. BRRI dhan32, BRRI dhan33 and BR11, four levels of spacing and four levels of number of seedlings hill^{-1}. Variety had significant effects on plant height.

Haque and Biswash (2014) carried out an experiment with five varieties of hybrid rice which were collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29. In the experiment the highest plant height was 101.5 cm for BRRI dhan28 and the lowest plant height was for Richer (82.5 cm).

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

2.2.2 Tillering pattern

Hossain and Alam (1991) found that the growth characters like total tillers hill^{-1} differed significantly among BR3, BR11, Pajam and Jaguli. BINA (1993) conducted an experiment with four varieties/advance lines (IRATOM24, BR14, BINA13 and BINA19) and reported significant variation in number of non-bearing tillers hill^{-1}.

Islam (1995) in an experiment with four rice cultivars *viz*. BR10, BR11, BR22 and BR23 found that the highest number of non bearing tillers hill^{-1} was produced by cultivar BR11 and the lowest number by BR10. Chowdhury *et al*. (1993) reported that the cultivar BR23 showed superior performance over Pajam in respect of number of productive tillers hill^{-1}.

Ahmed *et al*. (1998) obtained 11 better maintainer lines with good maintainability for corresponding CMS lines in an evaluation program of 64 maintainers with respective CMS lines from different countries and recorded differences for number of effective tillers. Devaraju *et al*. (1998) in a study with two rice hybrids, Karnataka Rice Hybrid 1 (KRHI) and Karnataka Rice Hybrid-2 (KRH2), using HYV IR20 as the check, found that IR20, the tiller number was higher than that of KRH2.

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

Laza *et al.* (2001) concluded that the early vigor of hybrid rice (*Oryza sativa* L.) developed in temperate region has been mainly attributed to its higher tillering rate. However, the tillering rate of hybrids was significantly lower than or equal to that of conventional varieties.

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and observed that Mukti gave the highest tillers hill^{-1} compared to the others. Song *et al.* (2004) found that hybrids produced a significantly higher number of tillers than their parental species and Minghui-63 had the least number of tillers.

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

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

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

Haque and Biswash (2014) experimented with five varieties of hybrid rice which were collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29. In case of no. of effective tillers, Hira showed the best performance (17.7) and Sonarbangla-1 showed the least performance (13.3).

2.2.3 Dry matter

Reddy *et al.* (1994) observed that dry matter production and grain yield were positively and significantly associated with each other and also with Net Assimilation Rate (NAR).

Son *et al.* (1998) reported that dry matter production of four inbred lines of rice (low-tillering large panicle type), YR15965ACP33, YR17104ACP5, YR16510-

B-B-B-9, and YR16512-B-B-B-10, and cv. Namcheonbyeo and Daesanbyeo, were evaluated at plant densities of 10 to 300 plants m^{-2} and reported that dry matter production of low-tillering large panicle type rice was lower than that of Namcheonbyeo, regardless of plant density.

Evans and Fisher (1999) reported that achieving higher yield depends on increasing total crop biomass, because there is little scope to further increase the proportion of that biomass allocated to grain.

Sharma and Haloi (2001) conducted an experiment in Assam during the kharif season with 12 varieties of scented rice cultivars and observed that cv. Kunkuni Joha consistently maintained a higher rate of dry matter production at all growth stages and the highest dry matter accumulation at the panicle initiation stage.

Mandavi *et al.* (2004) carried out an experiment to study on the morphological and physiological indicators of rice genotypes, a field experiment was conducted at the Rice Research Institute of Iran. In that study, Onda had the greater total dry matter (TDM) among other genotypes (this genotype also had the highest grain yield). Higher TDM was obtained from improved genotype than traditional genotypes (1445 and 1626 GDD, respectively). At flowering the dry matter weight was higher for Jasesh and was lower for Ramazan Ali Tarom (923.93 g m^{-2} and 429 g m^{-2}, respectively). So the photosynthetic potential of improved genotypes was higher as reflected by their TDM which had positive correlation with grain yield.

Amin *et al*. (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety did.

Amin *et al.* (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (*viz.* Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (*viz.* KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety.

Xie *et al.* (2007) found that Shanyou-63 variety gave the higher yield (12 t ha^{-1}) compared to Xieyou46 variety (10 t ha^{-1}). Masum *et al*. (2008) found that total dry matter production differed due to varieties. Total dry matter of BRRI dhan44 Nizershail significantly varied at different sampling dates.

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

Field experiments were conducted by Haque *et al*. (2015) including two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Both hybrids accumulated higher amount of biomass before heading and exhibited greater remobilization of assimilates to the grain in early plantings compared to the inbred variety. Flag leaf photosynthesis parameters were higher in the hybrid varieties than those of the inbred variety. Results suggest that greater remobilization of shoot reserves to the grain rendered higher yield of hybrid rice varieties.

2.2.4 Yield contributing characters

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

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

BR3, IR20, and Pajam2 and found that number of grain panicle^{-1} were 107.6, 123.0 and 170.9 respectively, for the varieties.

Singh and Gangwer (1989) conducted an experiment with rice cultivars C-14-8, CR-10009, IET-5656 and IET-6314 and reported that grain number panicle^{-1}, 1000-grain weight were higher for C-14-8 than those of any other three varieties. Rafey *et al*. (1989) carried out an experiment with three different rice cultivars and reported that weight of 1000 grain differed among the cultivars studied.

BRRI (1991) also reported that the filled grains panicle^{-1} of different modern varieties were 95-100 in BR3, 125 in BR4 , 120-130 in BR22 and 110-120 in BR23 when they were cultivated in the *Aman* season. Idris and Matin (1990) also observed that panicle length differed among the six rice varieties and it was longer in IR20 than in indigenous high yielding varieties.

BINA (1993) evaluated the performance of four varieties IRATOM 24, BR14, BINA13 and BINA19. They found that varieties differed significantly on panicle length and sterile spikelets 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 hybrid lines of rice.

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

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

Guilani *et al*. (2003) carried out an experiment on crop yield and yield components of rice cultivars (Anboori, Champa and LD183) in Khusestan, Iran. They observed that grain number panicle^{-1} was not significantly different among cultivars. The highest grain number panicle^{-1} was obtained with Anboori. Grain fertility percentages were different among cultivars. Among cultivars, LD183 had the highest grain weight.

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

Chaturvedi *et al.* (2004) evaluated newly released commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar Dhan 1) and two high yielding varieties as checks (Pant Dhan 4 and Pant Dhan 12) for their agronomic and morpho-physiological traits in a field experiment. Hybrids although could not excel the best HYV owing to high percentage of spikelet sterility but they showed potential for higher yield as these produced large sink (higher number of spikelets m^{-2}).

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

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

Islam *et al.* (2009) conducted pot experiments during T. aman season in net house at Bangladesh Rice Research Institute (BRRI). Hybrid variety Sonarbangla-1 and inbred modern variety BRRI dhan31 were used in both the seasons. BRRI dhan3l had higher panicles plant^{-1} than Sonarbangla-1, but Sonarbangla-1 had higher number of grains panicle^{-1}, 1000-grain weight.

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

Islam *et al.* (2010) studied yield potential of 16 rice genotypes including 12 hybrids, 3 inbreds and 1 New Plant Type (NPT) at the International Rice Research Institute (IRRI) farm under optimum crop management to achieve maximum attainable yield during the wet season (WS) of 2004 and dry season (DS) of 2005. Yield and yield components were determined at maturity. Hybrid produced higher spikelets panicle^{-1} and 1000-grain weight than inbred rice. Spikelet filling percent was higher in inbred than hybrid rice. The NPT rice genotype had the lowest spikelet filling percent, but the highest 1000-grain weight across the season.

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

Forty five aromatic rice genotypes were evaluated by Kaniz Fatema *et al*. (2011) to assess the genetic variability and diversity on the basis of nine characters.

Significant variations were observed among the genotypes for all the characters. Thousand grain weight have been found to contribute maximum towards genetic diversity in 45 genotypes of aromatic rice.

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

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

Haque and Biswash (2014) experimented with five varieties of hybrid rice which were collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29. In panicle length status, Richer showed the best performance (27.7 cm) while BRRI dhan28 showed the least performance (26 cm). Number of filled grains panicle^{-1} was the highest for BRRI dhan29 (163.3), whereas, Jagoron only 118. Number of total grains was highest in BRRI dhan29 (201.7) and for Jagoron it was only 133.7. On the other hand, for 1000-grain weight, Aloron was the best than other hybrids.

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

Field experiments were conducted by Haque *et al*. (2015) including two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Filled grain (%) declined significantly at delayed planting in the hybrids compared to elite inbred due to increased temperature impaired inefficient transport of assimilates.

Dou *et al*. (2016) carried out an experiment with the objective to determine the effects of water regime/soil condition (continuous flooding, saturated, and aerobic), cultivar (‘Cocodrie’ and ‘Rondo’), and soil texture (clay and sandy loam) on rice grain yield, yield components and water productivity using a greenhouse trial. The spikelet number of Cocodrie was 29% greater than that of Rondo, indicating that rice cultivar had greater effect on spikelet number. Results indicated that cultivar selection is an important factors in deciding what water management option to practice.

2.2.5 Yield parameters

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

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

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

Suprihatno and Sutaryo (1992) conducted an experiment with seven IRRI hybrids and 13 Indonesian hybrids using IR64 and way-seputih. They observed that TR64 was highest yielding, significantly out yielding IR64616H, IR64618, IR64610H and IR62829A/IR54 which in turn out yielded way-seputih.

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

Leenakumari *et al.* (1993) evaluated eleven hybrid cultivars against four standard check varieties-Jaya, Rasi, IR20 and Margala. They concluded that hybrid cultivar OR 1002 gave the highest yield of 7.9 t ha^{-1} followed by the hybrid cultivar OR 1001 (6.2 t ha^{-1}). Among the control varieties, Jaya gave the highest yield (8.4 t ha^{-1}). In another field experiments at Gazipur rice cv. BR11 (weakly photosensitive), BR22, BR23 and Nizersail (strongly photosensitive) were sown at various intervals from July to September and transplanted from August to October. Among the cv. BR22 gave the highest grain yield from most of the sowing dates for both of the years (Ali *et al*., 1993).

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

BRRI (1995) conducted an experiment to find out varietal performances of BR4, BR10, BR11, BR22, BR23 and BR25 varieties including two local check

Challish and Nizersail, produced yields of 4.38, 3.18, 3.12, 3.12 and 2.70 5 t ha^{-1}, respectively.

Radhakrisna *et al.* (1996) conducted a trials at Mamdya, Karnataka and found that hybrid cultivar KRH-2 gave an average yield of 9.3 t ha−1 with an yield advantage of 1.5 t ha−1 over the best check variety Jaya.

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

Chowdhury (1997) undertook a research on BINA-19, BR14, BR3 and Iratom-24 varieties with different methods of transplanting. He found that the yields for BINA-19, BR14, BR3 and Iratom-24 were 6.49 t ha^{-1}, 6.22 t ha^{-1}, 6.22 t ha^{-1}, 5.75 t ha^{-1} and 5.60 t ha^{-1}, respectively.

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

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

Kamal *et al.* (1998) conducted an experiment to assess the yield of 9 modern varieties (MV) and 6 local improved varieties (LIV) and observed that modern variety BR11 gave the highest grain yield followed by BR10, BR23, Binasail and BR4.

Julfiquar *et al*. (1998) reported that BRRI evaluated 23 hybrids along with three standard checks during *Boro* season. It was reported that five hybrids

(IR58025A/IR54056, IR54883, PMS8A/IR46R) out yielded the check varieties (BR14 and BR16) with significant yield difference. Two hybrids out yielded the check variety of same duration yielded by more than 1 t ha^{-1}.

Patel (2000) studied the varietal performance of Kranti and IR36. He observed that Kranti produced significantly higher grain and straw yield than IR36 did. The mean yield increased with Kranti over IR36 was 7.1 and 10.0% for grain and straw, respectively.

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

Several *indica/japonica* (I/J) lines were screened and evaluated by Roy (2006) for higher grain yield in the boro season. The highest grain yield of 9.2 t ha^{-1} was obtained from selected I/J line IR58565-2B-12-2-2, which was equal to that of indica hybrid CNHR3 and significantly higher than that of modern variety IR36.

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

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

Samonte *et al*. (2011) reported that the two elite lines recommended for release are high yielding in Texas. RU0703190 is also very early maturing conventional long grain rice. The high yield potential of these new releases will impact grain production of rice farmers and their income.

An experiment was carried out by Alam *et al*. (2012) at Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi during the kharif season to study the effect of variety, spacing and number of seedlings hill^{-1} on the yield potentials of transplant aman rice. The experiment consisted of three high yielding varieties viz. BRRI dhan32, BRRI dhan33 and BR11, four levels of spacing and four levels of number of seedlings hill^{-1} viz. 2 seedlings hill^{-1}, 3 seedlings hill^{-1}, 4 seedlings hill^{-1} and 5 seedlings hill^{-1}. Variety had significant effects on almost all the yield component characters and yield. Variety BR11 produced the highest grain yield (5.92 t ha^{-1}).

Haque and Biswash (2014) experimented with five varieties of hybrid rice which were collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29. In case of biological yield (g), BRRI dhan29 showed highest yield (49.6 g) and Hira only 18 g.

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

An experiment was conducted by Hosain *et al*. (2014) at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during *Aus* season (March to July 2010) to observe the effect of transplanting dates on the yield and yield attributes of exotic hybrid rice varieties. The experiment comprised of three rice varieties (two hybrids-Heera2, Aloron and one inbred- BRRI dhan48). BRRI dhan48 produced the highest grain yield (3.51 t ha^{-1}).

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

Field experiments were conducted by Haque *et al*. (2015) including two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Both hybrid varieties out yielded the inbred. However, the hybrids and inbred varieties exhibited statistically identical yield in late planting. Results suggest that greater remobilization of shoot reserves to the grain rendered higher yield of hybrid rice varieties.

From the above literature, it is evident that transplanting time and varieties have a significant influence on yield and yield components of rice. The literature suggests that optimum transplanting time and suitable variety increases the grain yield of rice. Increase the grain yield is mainly attributed by the increases of number of tiller $hill^{-1}$, grains $panicle^{-1,}$ panicle length, thousand grain weights and other yield attributes due to suitable condition of development of these parameters for the effect of transplanting time and variety itself.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the effect of planting time on morpho-physiological and yield contributing characters of rice. The details of the materials and methods i.e. experimental period, location, soil and climatic condition of the experimental area, materials used, treatment and design of the experiment, growing of crops, data collection procedure and procedure of data analysis that followed in this experiment has been presented under the following headings:

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted at the period of December, 2014 to April 2015.

3.1.2 Experimental location

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

3.1.3 Soil characteristics

The soil belonged to “The Modhupur Tract”, AEZ-28 (FAO, 1988). Top soil was Silty Clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 6.2 and had organic carbon 0.43%. The experimental area was flat having available irrigation and drainage system and above flood level. The details have been presented in Appendix II.

3.1.4 Climatic condition

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

3.2 Experimental details

3.2.1 Planting material

Differnt rice varieties were used as the test crop in this experiment.

3.2.2 Treatment of the experiment

The experiment comprised of two factors.

Factor A: Planting time (2 levels):

i. T_1= 24th January planting
ii. T_2= 23th February planting

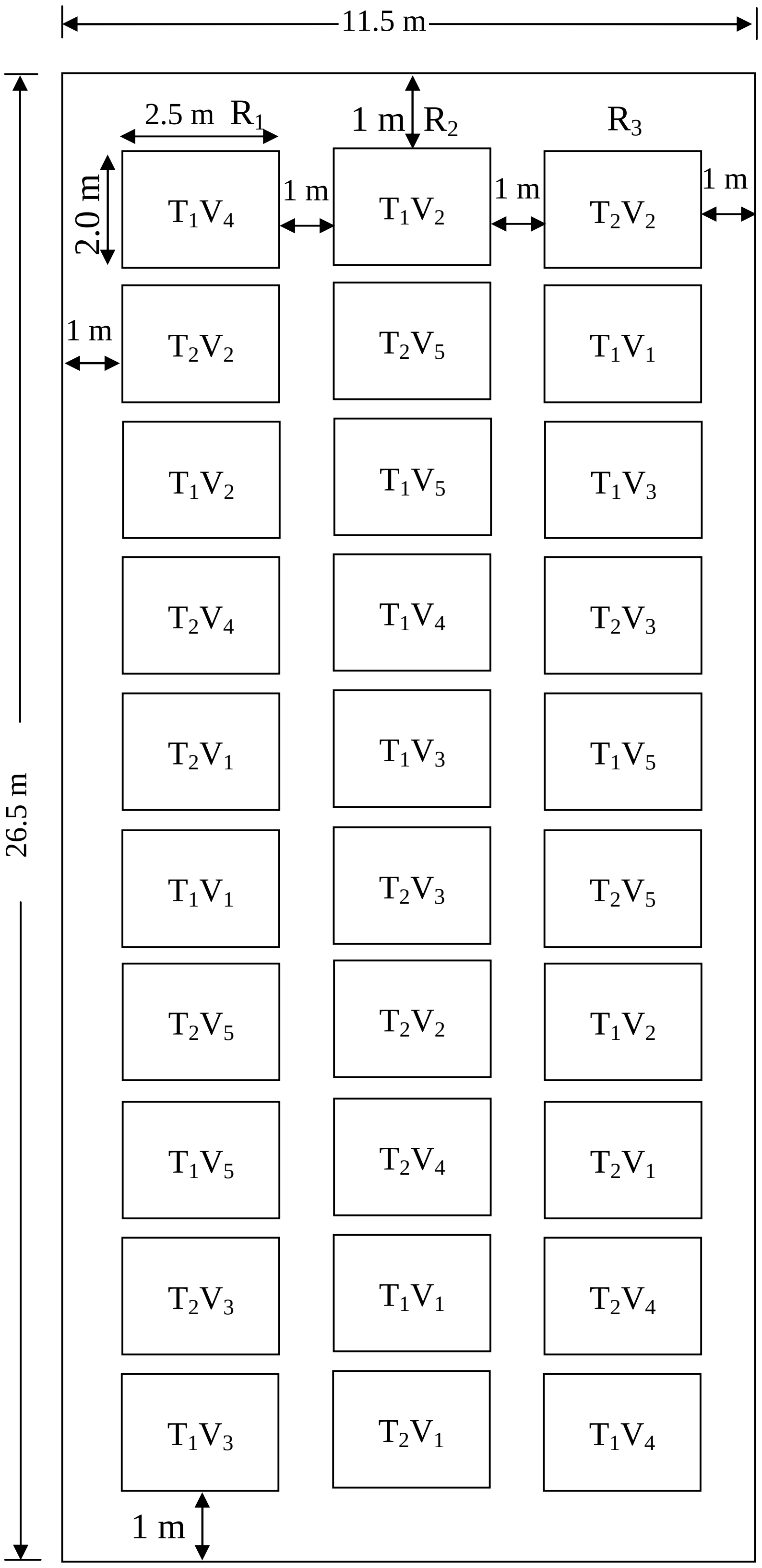
Factor B: Rice variety (5 varieties):

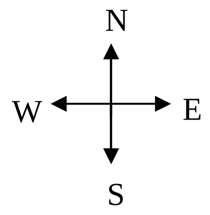
i. V_1= BRRI dhan29
ii. V_2= BRRI hybrid 2
iii. V_3= Hera 2
iv. V_4= Tia
v. V_5= Taj 1

As such there were 10 (2×5) treatments combinations viz., T_1V_1, T_1V_2, T_1V_3, T_1V_4, T_1V_5, T_2V_1, T_2V_2, T_2V_3, T_2V_4 and T_2V_5.

3.2.3 Experimental design and layout

The experiment was laid out in a randomized complete block design (RCBD) with three replications, where the experimental area was divided into three blocks representing the replications to reduce soil heterogenetic effects. Each block was divided into 10 unit plots as treatments demarked with raised bunds. Thus the total numbers of plots were 30. The unit plot size was 2.5 m × 2.0 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.





Plot size: 2.5 m × 2.0 m

Plot spacing: 0.50 m

Between block: 1.00 m

Factor A: Planting time (2 levels):

i. T_1= 24th January planting

ii. T_2= 23th February planting

Factor B: Rice variety (5 varieties):

i. V_1= BRRI dhan29

ii. V_2= BRRI hybrid 2

iii. V_3= Hera 2

iv. V_4= Tia

v. V_5= Taj 1

Figure 1. Layout of the experimental plot

3.3 Growing of crops

3.3.1 Seed collection and sprouting

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

3.3.2 Raising of seedlings

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown on beds as uniformly as possible. Irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed. For 24th January planting seeds were sawn at 25th December, 2014 and for 24th February planting seeds were sawn at 25th January, 2015 in the seed beds.

3.3.3 Land preparation

The plot selected for conducting the experiment was opened in the 07th January 2015 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. Weeds and stubbles were removed. The experimental plot was partitioned into unit plots in accordance with the experimental design. Organic and inorganic manures as indicated below were mixed with the soil of each unit plot.

3.3.4 Fertilizers and manure application

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

3.3.5 Planting of seedling

Thirty eight days old seedlings were carefully uprooted from the seedling nursery and transplanted on 25th January, 2015 and 24th February, 2105 in well puddled plot. Two seedlings hill^{-1} was transplanted in each hill. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings of the same source whenever required followed by the treatment of number of seedlings hill^{-1}.

3.3.6 Intercultural operations

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

3.3.6.1 Irrigation and drainage

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

3.3.6.2 Weeding

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

3.3.6.3 Insect and pest control

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

3.4 Harvesting, threshing and cleaning

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

3.5 Data recording

3.5.1 Plant height

The height of plant was recorded in centimeter (cm) at 20, 40, 60, 80 DAT and at harvest. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the panicle or flag leaf.

3.5.2 Number of tillers hill^{-1}

Number of tillers hill^{1} was recorded at 20, 40, 60 and 80 DAT. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.5.3 SPAD Value

SPAD value was determined from plant samples by using an automatic SPAD meter immediately after removal of leaves from plants to avoid rolling and shrinkage. SPAD was recorded at 20, 40, 60 and 80 DAT.

3.5.4 Leaf area index

Leaf area index (LAI) measured manually at the time of 20, 40, 60 and 80 DAT. Data were recorded as the average of 05 plants selected at random the inner rows of each plots. The final data calculated multiplying by a correction factor 0.75 as per Yoshida (1981).

3.5.5 Days to booting

Days to booting were recorded by counting the number of days required to starting of 1st booting in each plot.

3.5.6 Days to panicle insertion

Days to panicle insertion were recorded by counting the number of days required to starting of 1st insertion of panicle in each plot.

3.5.7 Days to anthesis

Days to anthesis were recorded by counting the number of days required to starting of 1st booting in each plot.

3.5.8 Days to maturity

Days to maturity were recorded by counting the number of days required to harvest in each plot.

3.5.9 Shoot dry matter at pre-anthesis

Shoot dry matter at pre-anthesis period was recorded from 5 randomly collected shoot of each plot from inner rows leaving the boarder row. Collected shoot were oven dried at 70^0C for 72 hours then transferred into desiecator and allowed to cool down at room temperature, final weight was taken and converted into shoot dry matter content m^{-2}.

3.5.10 Shoot dry matter at maturity

Shoot dry matter at maturity period was recorded from 5 randomly collected shoot of each plot from inner rows leaving the boarder row. Collected shoot were oven dried at 70^0C for 72 hours then transferred into desiecator and allowed to cool down at room temperature, final weight was taken and converted into shoot dry matter content m^{-2}.

3.5.11 Changes in shoot dry matter

Changes in shoot dry matter was estimated by deducting shoot dry matter at pre-anthesis period to shoot dry matter at maturity period.

3.5.12 Shoot reserve translocation

Plants from 1 m^2 were sampled from each plot at pre-anthesis and maturity. The harvested plants were separated into leaf blades (leaf), culm and sheath (stem) and panicles. Dry matter of each component was determined after drying at 72^0C for 72 hours. The shoot reserve translocation was calculated by net loss in dry weight of vegetative organs between pre-anthesis and maturity (Bonnett and Incoll, 1992) using the following:

$$\text{Shoot reserve translocation (\%)} = \frac{A - M}{A} \times 100$$

Where,

A = Total shoot dry matter at pre-anthesis, g m^{-2}

M = Total shoot dry matter at maturity, g m^{-2}

3.5.13 Effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tiller during harvesting. Data on effective tillers hill^{-1} were counted from 5 selected hills and average value was recorded.

3.5.14 Ineffective tillers hill^{-1}

The total number of intiller hill^{-1} was counted as the number of non-panicle bearing tiller during harvesting. Data on ineffective tiller hill^{-1} were counted from 5 selected hills and average value was recorded.

3.5.15 Total tillers hill^{-1}

The total number of tiller hill^{-1} was counted by adding the number of effective tillers hill^{-1} and ineffective tillers hill^{-1}. Data on total tillers hill^{-1} were counted from 5 selected hills and average value was recorded.

3.5.16 Panicle length

The length of panicle was measured with a meter scale from 5 selected panicle and the average length was recorded as per panicle in cm.

3.5.17 Filled grains panicle^{-1}

The total numbers of filled grain were collected randomly from selected 5 panicle of a plot on the basis of grain in the spikelet and then average numbers of filled grains panicle^{-1} was recorded.

3.5.18 Unfilled grains panicle^{-1}

The total numbers of unfilled grain was collected randomly from selected 5 plants of a plot on the basis of not grain in the spikelet and then average numbers of unfilled grains panicle^{-1} was recorded.

3.5.19 Total grains panicle^{-1}

The total numbers of grain was collected randomly from selected 5 plants of a plot by adding filled and unfilled grain and then average numbers of grains panicle^{-1} was recorded.

3.5.20 Weight of 1000-grain

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

3.5.21 Grain yield

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

3.5.22 Straw yield

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

3.5.23 Biological yield

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

Biological yield = Grain yield + Straw yield.

3.5.24 Harvest index

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

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

3.6 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among different planting time and varieties of rice. The mean values of all the characters were calculated and analysis of variance was performed by using MSTAT-C software. The significance of the difference among the means values of different time and varieties of rice and their interaction was estimated by the Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of planting time on morpho-physiological and yield contributing characters of rice. Data on different growth characters, shoot reserve remobilization yield contributing characters and yield were recorded. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix IV-XII. The results have been presented with the help of table and graphs and possible interpretations given under the following headings:

4.1 Crop growth characters of rice

4.1.1 Plant height

Plant height at 20, 40, 60, 80 DAT (days after transplanting) and harvest showed statistically significant differences due to different planting time (Appendix IV). At 20, 40, 60, 80 DAT and harvest, the taller plant (26.58, 56.63, 83.19, 92.29 and 111.16 cm, respectively) was recorded from T_1 (24^{th} January planting) and the shorter plant (24.64, 53.49, 78.90, 87.25 and 105.18 cm, respectively) was found from T_2 (23^{th} February planting) under the present study (Figure 2). Varieties showed different plant height on the basis of their varietal characters. Variety is the key component to produce plant height of rice depending upon their differences in genotypic characters, input requirements and response, growth process and off course the prevailing environmental conditions during the growing season. Miah *et al*. (1990) reported that mutant NSI and Mutant

NSS were planted and found that plant height were greater in Mutant NSI than Nizersail. Munoz *et al.* (1996) noted that IR8025A hybrid rice cultivar produced 16% longer plant than the commercial variety Oryzica Yacu-9. Khalifa (2009) reported that H_1 hybrid rice variety surpassed other varieties in terms of plant height. Bhuiyan *et al*. (2014) reported that the different hybrid rice varieties had significant effects on plant height at maturity.

Statistically significant variation was recorded in terms of plant height at 20, 40, 60, 80 DAT and harvest due to different rice varieties (Appendix IV). At 20, 40, 60, 80 DAT and harvest, the tallest plant (27.88, 58.08, 84.94, 94.41 and 112.03 cm, respectively) was observed from V_3 (Heera 2) which was statistically similar (26.24, 56.69, 82.77, 92.13 and 110.69 cm, respectively) to V_4 (Tia) and followed (26.02, 55.32, 81.23, 90.62 and 109.59 cm, respectively) by V_5 (Taj 1), while the shortest plant (23.59, 50.38, 75.55, 82.92 and 100.93 cm, respectively) was recorded from V_1 (BRRI dhan29) which was followed (24.32, 54.82, 80.72, 88.76 and 107.62 cm, respectively) by V_2 (BRRI hybrid 2) at 20, 40, 60, 80 DAT and harvest, respectively (Figure 3). This result is in agreement with that of Hedayetullah *et al.* (1994) and they reported that plant height reduced with delayed transplanting of rice.

Interaction effect of different planting time and rice varieties showed statistically significant differences on plant height at 20, 40, 60, 80 DAT and harvest (Appendix IV). At 20, 40, 60, 80 DAT and harvest, the tallest plant (29.94, 62.57, 89.58, 99.42 and 120.92 cm, respectively) was recorded from treatment combination of T_1V_3 (24th January planting and Herra 2) and the shortest plant (23.31, 49.56, 75.57, 82.25 and 100.92 cm, respectively) was found from of T_2V_1 (23th February planting and BRRI dhan 29) treatment combination (Table 1).

4.1.2 Number of tillers hill^{-1}

Different planting time varied significantly for number of tillers hill^{-1} at 20, 40, 60 and 80 DAT due to (Appendix V). At 20, 40, 60 and 80 DAT, the maximum number of tillers hill^{-1} (2.55, 7.12, 13.69 and 15.69, respectively) was found from T_1, while the minimum number of tillers hill^{-1} (2.43, 6.53, 12.39 and 14.61, respectively) was recorded from T_2 (Figure 4). Masum *et al.* (2008) reported maximum (25.63) tiller at 45 DAT, then with advancement to age it declined up to maturity, whereas, in the case of BRRI dhan44, maximum (18.92) tiller production was observed around panicle initiation stage at 60 DAT .

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

Treatment	Plant height (cm) at				
	20 DAT	40 DAT	60 DAT	80 DAT	Harvest
T_1V_1	23.87 b	51.21 c	75.57 c	83.58 de	100.93 d
T_1V_2	23.87 b	54.22 bc	77.70 bc	86.99 de	106.14 bcd
T_1V_3	29.94 a	62.57 a	89.58 a	99.42 a	120.92 a
T_1V_4	25.62 ab	55.13 bc	84.48 ab	96.41 ab	113.47 abc
T_1V_5	29.62 a	60.05 ab	88.67 a	95.03 abc	114.35 ab
T_2V_1	23.31 b	49.56 c	75.53 c	82.25 e	100.92 d
T_2V_2	24.77 b	55.43 bc	83.75 ab	90.54 bcd	109.10 bcd
T_2V_3	25.83 ab	53.60 bc	80.31 bc	89.41 cd	103.14 cd
T_2V_4	26.86 ab	58.26 ab	81.07 bc	87.86 de	107.92 bcd
T_2V_5	22.41 b	50.59 c	73.78 c	86.21 de	104.83 bcd
$LSD_{(0.05)}$	4.06	5.92	6.87	6.33	9.67
Level of significance	*	**	**	*	*
CV(%)	9.24	6.27	4.94	4.11	5.21

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

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

T_1: 24th January planting

T_2: 23th February planting

V_1: BRRI dhan29

V_2: BRRI hybrid 2

V_3: Heera 2

V_4: Tia

V_5: Taj 1

Number of tillers hill^{-1} showed statistically significant variation at 20, 40, 60 and 80 DAT for different rice varieties (Appendix V). At 20, 40, 60 and 80 DAT, the maximum number of tillers hill^{-1} (2.63, 7.13, 14.63 and 16.43, respectively) was found from V_3 which was statistically similar (2.57, 7.00, 14.07 and 15.60, respectively) to V_4 and followed (2.50, 6.93, 13.10 and 15.23, respectively) by V_5, whereas the minimum number of tillers hill^{-1} (2.30, 6.20, 10.60 and 13.37, respectively) was observed from V_1 which was followed (2.43, 6.87, 12.80 and 15.13, respectively) by V_2 at 20, 40, 60 and 80 DAT, respectively (Figure 5). The number of tiller per hill decreased rationally irrespective of all planting times after peak as tiller survival was negatively correlated to the maximum tiller number (Sarkar and Reddy, 2006) and mutual shading of the crop (Farrell *et al*., 2006). Kainth and Mehra (1985) reported that in November planting of BR3 when the temperature was cool, the vegetative phase was extended by 50 days and the relative tillering rate reached its peak at 40 to 50 days after transplanting. In contrast with planting in July when the temperature was high, the relative tillering rate reached the highest value within 15 to 25 days after transplanting.

Statistically significant variation was recorded due to the interaction effect of different planting time and rice varieties on number of tillers hill^{-1} at 20, 40, 60 and 80 DAT (Appendix V). At 20, 40, 60 and 80 DAT, the maximum number of tillers hill^{-1} (2.67, 7.40, 16.07 and 17.20, respectively) was recorded from treatment combination of T_1V_3, while the minimum number of tillers hill^{-1} (2.27, 5.80, 10.27 and 13.33, respectively) was recorded from of T_2V_1 treatment combination (Table 2).

4.1.3 SPAD value

SPAD value at 20, 40, 60 and 80 DAT showed statistically significant differences due to different planting time (Appendix VI). At 20, 40, 60 and 80 DAT, the maximum SPAD value (33.33, 40.00, 45.22 and 34.47, respectively) was recorded from T_1 and the minimum SPAD value (31.46, 38.35, 43.99 and 31.20, respectively) was observed from T_2 (Figure 6).

Table 2. Interaction effect of planting time and variety on tillers hill^{-1} at different days after transplanting (DAT) of rice

Treatment	Tillers hill^{-1} (No.) at			
	20 DAT	40 DAT	60 DAT	80 DAT
T_1V_1	2.33 cd	6.60 cd	10.93 d	13.40 d
T_1V_2	2.53 abc	6.93 bc	13.40 c	15.20 bc
T_1V_3	2.67 a	7.40 a	16.07 a	17.20 a
T_1V_4	2.60 ab	7.20 ab	14.73 b	16.20 ab
T_1V_5	2.60 ab	7.47 a	13.33 c	16.47 ab
T_2V_1	2.27 d	5.80 e	10.27 d	13.33 d
T_2V_2	2.33 cd	6.80 bcd	12.20 c	15.07 bc
T_2V_3	2.60 ab	6.87 bc	13.20 c	15.67 b
T_2V_4	2.53 abc	6.80 bcd	13.40 c	15.00 bc
T_2V_5	2.40 bcd	6.40 d	12.87 c	14.00 cd
$LSD_{(0.05)}$	0.22	0.41	1.26	1.38
Level of significance	*	*	*	*
CV(%)	5.27	3.50	5.61	5.31

*: Significant at 0.05 level of probability

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

T_1: 24th January planting

T_2: 23th February planting

V_1: BRRI dhan29

V_2: BRRI hybrid 2

V_3: Heera 2

V_4: Tia

V_5: Taj 1

Statistically significant variation was recorded in terms of SPAD value at 20, 40, 60 and 80 DAT due to different rice varieties (Appendix VI). At 20, 40, 60 and 80 DAT, the maximum SPAD value (36.56, 43.44, 49.39 and 35.82, respectively) was observed from V_3 which was statistically similar (35.75, 42.33, 48.31 and 34.70, respectively) to V_4 and followed (33.11, 40.82, 46.81 and 33.56, respectively) by V_5. On the other hand, the minimum SPAD value (25.29, 31.27, 35.53 and 29.71, respectively) was found from V_1 which was followed 31.25, 38.02, 42.98 and 30.41, respectively) by V_2 at 20, 40, 60 and 80 DAT, respectively (Figure 7).

Interaction effect of different planting time and rice varieties showed statistically significant differences on SPAD value at 20, 40, 60 and 80 DAT (Appendix VI). At 20, 40, 60 and 80 DAT, the maximum SPAD value (38.54, 44.33, 50.01 and 37.60, respectively) was observed from treatment combination of T_1V_3, while the minimum SPAD value (24.83, 30.43, 34.60 and 28.31, respectively) was found from of T_2V_1 treatment combination (Table 3).

4.1.4 Leaf area index

Leaf area index at 20, 40, 60 and 80 DAT showed statistically significant differences due to different planting time (Appendix VII). At 20, 40, 60 and 80 DAT, the higher leaf area index (0.285, 1.38, 3.48 and 5.28, respectively) was found from T_1 and the lower leaf area index (0.259, 1.28, 3.20 and 5.04, respectively) was recorded from T_2 (Figure 8).

Statistically significant variation was recorded in terms of leaf area index at 20, 40, 60 and 80 DAT due to different rice varieties (Appendix VII). At 20, 40, 60 and 80 DAT, the highest leaf area index (0.305, 1.54, 3.74 and 5.74, respectively) was found from V_3 which was statistically similar (0.294, 1.43, 3.63 and 5.65, respectively) to V_4 and followed (0.277, 1.35, 3.45 and 5.23, respectively) by V_5, while the lowest leaf area index (0.212, 1.02, 2.62, 4.17, respectively) was observed from V_1 which was followed (0.275, 1.31, 3.27 and 5.02, respectively) by V_2 at 20, 40, 60 and 80 DAT, respectively (Figure 9).

Table 3. Interaction effect of planting time and variety on SPAD value at different days after transplanting (DAT) of rice

Treatment	SPAD value at			
	20 DAT	40 DAT	60 DAT	80 DAT
T_1V_1	25.75 f	32.11 c	36.46 d	31.12 cd
T_1V_2	32.00 de	37.95 b	42.63 c	31.35 cd
T_1V_3	38.54 a	44.33 a	50.01 a	37.60 a
T_1V_4	36.71 b	43.02 a	48.73 a	35.10 ab
T_1V_5	33.63 cd	42.59 a	48.28 a	37.21 ab
T_2V_1	24.83 f	30.43 c	34.60 d	28.31 d
T_2V_2	30.49 e	38.08 b	43.33 c	29.48 d
T_2V_3	34.59 c	42.56 a	48.78 a	34.03 bc
T_2V_4	34.78 c	41.64 a	47.89 a	34.30 bc
T_2V_5	32.60 d	39.04 b	45.33 b	29.91 d
$LSD_{(0.05)}$	1.64	2.49	1.98	3.04
Level of significance	*	*	*	*
CV(%)	4.95	3.70	5.59	6.39

*: Significant at 0.05 level of probability

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

T_1: 24th January planting

T_2: 23th February planting

V_1: BRRI dhan29

V_2: BRRI hybrid 2

V_3: Heera 2

V_4: Tia

V_5: Taj 1

Interaction effect of different planting time and rice varieties showed statistically significant differences on leaf area index at 20, 40, 60 and 80 DAT (Appendix VII). At 20, 40, 60 and 80 DAT, the highest leaf area index (0.320, 1.65, 3.89 and 5.96, respectively) was found from treatment combination of T_1V_3 and the lowest leaf area index (0.205, 1.01, 2.52 and 4.08, respectively) was found from of T_2V_1 treatment combination (Table 4).

4.1.5 Days to booting

Days to booting showed statistically significant differences due to different planting time (Appendix VIII). The maximum days to booting (68.13) was observed from T_1 and the minimum days to booting (65.33) was recorded from T_2 (Table 5).

Statistically significant variation was recorded in terms of days to booting due to different rice varieties (Appendix VII). The maximum days to booting (70.33) was found from V_3 which was statistically similar (70.17 and 68.50) to V_5 and V_4, while the minimum days to booting (61.33) was recorded from V_1 which was statistically similar (63.33) to V_2 (Table 5).

Interaction effect of different planting time and rice varieties showed statistically significant differences on days to booting (Appendix VIII). The maximum days to booting (72.67) was observed from treatment combination of T_1V_3 and the minimum days to booting (60.33) was recorded from of T_2V_1 treatment combination (Table 6).

4.1.6 Days to panicle insertion

Days to panicle insertion showed statistically significant differences due to different planting time (Appendix VIII). The maximum days to panicle insertion (78.33) was recorded from T_1 and the minimum days to panicle insertion (75.53) was found from T_2 (Table 5).

Table 4. Effect of planting time and variety on leaf area index at different days after transplanting (DAT) of rice

Treatment	Leaf area index (LAI) at			
	20 DAT	40 DAT	60 DAT	80 DAT
T_1V_1	0.218 e	1.04 c	2.72 d	4.25 d
T_1V_2	0.269 c	1.30 b	3.42 bc	4.87 c
T_1V_3	0.320 a	1.65 a	3.89 a	5.96 a
T_1V_4	0.307 a	1.61 a	3.81 a	5.66 a
T_1V_5	0.313 a	1.30 b	3.57 ab	5.67 a
T_2V_1	0.205 e	1.01 c	2.52 d	4.08 d
T_2V_2	0.281 bc	1.31 b	3.12 c	5.17 bc
T_2V_3	0.290 b	1.42 b	3.59 ab	5.52 ab
T_2V_4	0.280 bc	1.26 b	3.46 bc	5.64 a
T_2V_5	0.242 d	1.40 b	3.32 bc	4.79 c
$LSD_{(0.05)}$	0.02	0.15	0.31	0.41
Level of significance	*	**	*	**
CV(%)	7.36	6.73	5.41	4.58

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

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

T_1: 24^{th} January planting

T_2: 23^{th} February planting

V_1: BRRI dhan29

V_2: BRRI hybrid 2

V_3: Heera 2

V_4: Tia

V_5: Taj 1

Table 5. Effect of planting time and variety on days to booting, days to panicle initiation, days to anthesis and days to maturity of rice

Treatment	Days to booting	Days to panicle insertion	Days to anthesis	Days to maturity
Planting time				
T_1	68.13 a	78.33 a	98.33 a	131.87 a
T_2	65.33 b	75.53 b	95.93 b	128.47 b
$LSD_{(0.05)}$	1.72	1.40	1.18	1.95
Level of significance	**	**	**	**
Variety				
V_1	61.33 b	71.33 d	92.17 c	124.67 b
V_2	63.33 b	74.00 c	93.67 c	126.50 b
V_3	70.33 a	81.50 a	101.83 a	135.17 a
V_4	68.50 a	78.17 b	98.33 b	132.83 a
V_5	70.17 a	79.67 ab	99.67 b	131.67 a
$LSD_{(0.05)}$	2.99	2.43	2.04	3.38
Level of significance	**	**	**	**
CV(%)	3.69	5.60	1.73	4.14

**: Significant at 0.01 level of probability

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

T_1: 24th January planting

T_2: 23th February planting

V_1: BRRI dhan29

V_2: BRRI hybrid 2

V_3: Heera 2

V_4: Tia

V_5: Taj 1

Table 6. Interaction effect of planting time and variety on days to booting, days to panicle initiation, days to anthesis and days to maturity of rice

Treatment	Days to booting	Days to panicle insertion	Days to anthesis	Days to maturity
T_1V_1	62.33 de	72.00 de	93.33 de	126.00 de
T_1V_2	65.67 cd	76.33 c	95.33 cd	129.33 cd
T_1V_3	72.67 a	84.00 a	104.00 a	138.33 a
T_1V_4	71.33 ab	81.00 ab	100.67 b	135.33 ab
T_1V_5	68.67 abc	78.33 bc	98.33 bc	130.33 bcd
T_2V_1	60.33 e	70.67 e	91.00 e	123.33 e
T_2V_2	61.00 e	71.67 e	92.00 e	123.67 e
T_2V_3	68.00 bc	79.00 bc	99.67 b	132.00 bc
T_2V_4	65.67 cd	75.33 cd	96.00 bc	130.33 bcd
T_2V_5	71.67 ab	81.00 ab	101.00 b	133.00 bc
$LSD_{(0.05)}$	4.22	3.43	2.88	4.77
Level of significance	*	**	**	*
CV(%)	3.69	5.60	1.73	4.14

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

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

T_1: 24th January planting
T_2: 23th February planting

V_1: BRRI dhan29
V_2: BRRI hybrid 2
V_3: Heera 2
V_4: Tia
V_5: Taj 1

Statistically significant variation was recorded in terms of days to panicle insertion due to different rice varieties (Appendix VIII). The maximum days to panicle insertion (81.50) was observed from V_3 which was statistically similar (79.67) to V_5 and closely followed (78.17) by V_4, while the minimum days to panicle insertion (71.33) was recorded from V_1 which was closely followed (74.00) by V_2 (Table 5).

Interaction effect of different planting time and rice varieties showed statistically significant differences on days to panicle insertion (Appendix VIII). The maximum days to panicle insertion (84.00) was recorded from treatment combination of T_1V_3 and the minimum days to panicle insertion (70.67) was found from of T_2V_1 treatment combination (Table 6).

4.1.7 Days to anthesis

Days to anthesis showed statistically significant differences due to different planting time (Appendix VIII). The maximum days to anthesis (98.33) was recorded from T_1 and the minimum days to anthesis (95.93) was found from T_2 (Table 5).

Statistically significant variation was recorded in terms of days to anthesis due to different rice varieties (Appendix VIII). The maximum days to anthesis (101.83) was observed from V_3 which was closely followed (99.67 and 98.33) by V_5 and V_4 and they were statistically similar, while the minimum days to anthesis (92.17) was recorded from V_1 which was statistically similar (93.67) to V_2 (Table 5).

Interaction effect of different planting time and rice varieties showed statistically significant differences on days to anthesis (Appendix VIII). The maximum days to anthesis (104.00) was recorded from treatment combination of T_1V_3 and the minimum days to anthesis (91.00) was found from of T_2V_1 treatment combination (Table 6).

4.1.8 Days to maturity

Days to maturity showed statistically significant differences due to different planting time (Appendix VIII). The maximum days to maturity (131.87) was found from T_1 and the minimum days to maturity (128.47) was recorded from T_2 (Table 5).

Statistically significant variation was recorded in terms of days to maturity due to different rice varieties (Appendix VIII). The maximum days to maturity (135.17) was found from V_3 which was statistically similar (132.83 and 131.67) to V_4 and V_5, while the minimum days to maturity (124.67) was observed from V_1 which was statistically similar (126.50) to V_2 (Table 5).

Interaction effect of different planting time and rice varieties showed statistically significant differences on days to maturity (Appendix VIII). The maximum days to maturity (138.33) was observed from treatment combination of T_1V_3 and the minimum days to maturity (123.33) was found from of T_2V_1 treatment combination (Table 6).

4.2 Shoot reserve remobilization in rice

4.2.1 Shoot dry matter at pre-anthesis

Shoot dry matter at pre-anthesis period showed statistically significant differences due to different planting time (Appendix IX). The maximum shoot dry matter at pre-anthesis (27.73 g m^2) was recorded from T_1 and the minimum shoot dry matter at pre-anthesis (26.12g m^2) was recorded from T_2 (Table 7).

Statistically significant variation was recorded in terms of shoot dry matter at pre-anthesis due to different rice varieties (Appendix IX). The highest shoot dry matter at pre-anthesis (29.49 g m^2) was found from V_3 which was statistically similar (28.19 g m^2) to V_4 and closely followed (27.38g m^2) by V_5, whereas the lowest shoot dry matter at pre-anthesis (23.79 g m^2) was recorded from V_1 which was closely followed (25.78 g m^2) by V_2 (Table 7).

Table 7. Effect of planting time and variety on pre-anthesis dry matter accumulation in shoot and its translocation to the grain

Treatment	Shoot dry matter at pre-anthesis ($g\ m^{-2}$)	Shoot dry matter at maturity ($g\ m^{-2}$)	Changes in shoot dry matter ($g\ m^{-2}$)	Shoot reserve translocation (%)
Planting time				
T_1	27.73 a	23.43 a	4.30 a	15.26 a
T_2	26.12 b	22.70 b	3.42 b	12.97 b
$LSD_{(0.05)}$	0.84	0.61	0.35	1.06
Level of significance	**	*	**	**
Variety				
V_1	23.79 d	21.18 d	2.61 d	10.94 b
V_2	25.78 c	22.54 c	3.24 c	12.52 b
V_3	29.49 a	24.52 a	4.97 a	16.84 a
V_4	28.19 ab	23.91 ab	4.28 b	15.11 a
V_5	27.38 b	23.19 bc	4.19 b	15.16 a
$LSD_{(0.05)}$	1.45	1.06	0.61	1.84
Level of significance	**	**	**	**
CV(%)	4.43	3.78	13.09	10.74

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

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

T_1: 24th January planting

T_2: 23th February planting

V_1: BRRI dhan29

V_2: BRRI hybrid 2

V_3: Heera 2

V_4: Tia

V_5: Taj 1

Interaction effect of different planting time and rice varieties showed statistically significant differences on shoot dry matter at pre-anthesis (Appendix IX). The highest shoot dry matter at pre-anthesis (30.19 g m^2) was recorded from treatment combination of T_1V_3, while the lowest shoot dry matter at pre-anthesis (22.98 g m^2) was found from of T_2V_1 treatment combination (Table 8).

4.2.2 Shoot dry matter at maturity

Shoot dry matter at maturity showed statistically significant differences due to different planting time (Appendix IX). The maximum Change in shoot dry matter at maturity (23.43 g m^2) was observed from T_1, while the minimum Change in shoot dry matter at maturity (22.70 g m^2) was found from T_2 (Table 7).

Statistically significant variation was recorded in terms of Change in shoot dry matter at maturity due to different rice varieties (Appendix IX). The highest Change in shoot dry matter at maturity (24.52 g m^2) was observed from V_3 which was statistically similar (23.91 g m^2) to V_4 and closely followed (23.19 g m^2) by V_5, whereas the lowest Change in shoot dry matter at maturity (21.18 g m^2) was found from V_1 which was closely followed (22.54 g m^2) by V_2 (Table 7).

Interaction effect of different planting time and rice varieties showed statistically significant differences on shoot dry matter at maturity (Appendix IX). The highest shoot dry matter at maturity (24.81 g m^2) was recorded from treatment combination of T_1V_3 and the lowest shoot dry matter at maturity (20.58 g m^2) was recorded from of T_2V_1 treatment combination (Table 8).

4.2.3 Change in shoot dry matter

Change in shoot dry matter showed statistically significant differences due to different planting time (Appendix IX). The maximum change in shoot dry matter (4.30 g m^2) was found from T_1 and the minimum shoot dry matter at maturity (3.42 g m^2) was recorded from T_2 (Table 7).

Table 8. Interaction effect of planting time and variety on pre-anthesis dry matter accumulation in shoot and its translocation to the grain

Treatment	Shoot dry matter at pre-anthesis ($g\ m^{-2}$)	Shoot dry matter at maturity ($g\ m^{-2}$)	Changes in shoot dry matter ($g\ m^{-2}$)	Shoot reserve translocation (%)
T_1V_1	24.60 de	21.77 cd	2.83 bc	11.45 cd
T_1V_2	25.42 cd	22.02 cd	3.40 b	13.29 bcd
T_1V_3	30.19 a	24.81 a	5.38 a	17.83 a
T_1V_4	29.01 ab	24.06 ab	4.95 a	17.02 a
T_1V_5	29.42 ab	24.50 ab	4.92 a	16.70 a
T_2V_1	22.98 e	20.58 d	2.40 c	10.43 d
T_2V_2	26.14 cd	23.06 bc	3.08 bc	11.75 cd
T_2V_3	28.78 ab	24.22 ab	4.56 a	15.84 ab
T_2V_4	27.37 bc	23.75 ab	3.62 b	13.20 bcd
T_2V_5	25.34 cd	21.88 cd	3.46 b	13.62 bc
$LSD_{(0.05)}$	2.05	1.50	0.87	2.60
Level of significance	*	*	*	**
CV(%)	4.43	3.78	13.09	10.74

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

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

T_1: 24th January planting

T_2: 23th February planting

V_1: BRRI dhan29

V_2: BRRI hybrid 2

V_3: Heera 2

V_4: Tia

V_5: Taj 1

Statistically significant variation was recorded in terms of change in shoot dry matter due to different rice varieties (Appendix IX). The highest change in shoot dry matter (4.97 g m^2) was observed from V_3 which was closely followed (4.28 g m^2 and 4.19 g m^2) by V_4 and V_5 and they were statistically similar, while the lowest change in shoot dry matter (2.61 g m^2) was recorded from V_1 which was followed (3.24 g m^2) by V_2 (Table 7).

Interaction effect of different planting time and rice varieties showed statistically significant differences on change in shoot dry matter (Appendix IX). The highest change in shoot dry matter (4.95 g m^2) was recorded from treatment combination of T_1V_4 and the lowest change in shoot dry matter (2.40 g m^2) was observed from of T_2V_1 treatment combination (Table 8).

4.2.4 Shoot reserve translocation

Shoot reserve translocation showed statistically significant differences due to different planting time (Appendix IX). The maximum shoot reserve translocation (15.26%) was recorded from T_1 and the minimum shoot reserve translocation (12.97%) was found from T_2 (Table 7).

Statistically significant variation was recorded in terms of shoot reserve translocation due to different rice varieties (Appendix IX). The highest shoot reserve translocation (16.84%) was observed from V_3 which was statistically similar (15.16% and 15.11%) to V_5 and V_4, while the lowest shoot reserve translocation (10.94%) was recorded from V_1 which was statistically similar (12.52%) to V_2 (Table 7).

Interaction effect of different planting time and rice varieties showed statistically significant differences on shoot reserve translocation (Appendix IX). The highest shoot reserve translocation (17.83%) was recorded from treatment combination of T_1V_3 and the lowest shoot reserve translocation (10.43%) was found from of T_2V_1 treatment combination (Table 8).

4.3 Yield contributing characters of rice

4.3.1 Effective tillers hill^{-1}

Effective tillers hill^{-1} showed statistically significant differences due to different planting time (Appendix X). The maximum number of effective tillers hill^{-1} (13.47) was found from T_1 and the minimum number of effective tillers hill^{-1} (11.40) was observed from T_2 (Table 9). Khalifa (2009) reported that H_1 hybrid rice variety surpassed other varieties in consideration of effective tillers hill^{-1}.

Statistically significant variation was recorded in terms of effective tillers hill^{-1} due to different rice varieties (Appendix X). The maximum number effective tillers hill^{-1} (13.33) was recorded from V_3 which was statistically similar (13.00 and 12.83) to V_4 and V_5, while the minimum number of effective tillers hill^{-1} (10.50) was found from V_1 which was followed (12.50) by V_2 (Table 9).

Interaction effect of different planting time and rice varieties showed statistically significant differences on effective tillers hill^{-1} (Appendix X). The maximum number of effective tillers hill^{-1} (14.67) was recorded from treatment combination of T_1V_3 and the minimum number of effective tillers hill^{-1} (10.00) was observed from of T_2V_1 treatment combination (Table 10).

4.3.2 Ineffective tillers hill^{-1}

Ineffective tillers hill^{-1} showed statistically significant differences due to different planting time (Appendix X). The maximum number of ineffective tillers hill^{-1} (2.60) was recorded from T_2 and the minimum number of ineffective tillers hill^{-1} (2.27) was found from T_2 (Table 9).

Statistically significant variation was recorded in terms of ineffective tillers hill^{-1} due to different rice varieties (Appendix X). The maximum number of ineffective tillers hill^{-1} (3.00) was observed from V_3 which was closely followed (2.50 and 2.33) to V_4 and V_5 and they were statistically similar, while the minimum number of ineffective tillers hill^{-1} (2.00) was observed from V_1 which was statistically similar (2.33) to V_2 (Table 9).

Table 9. Effect of planting time and variety on yield contributing characters of rice

Treatment	Effective tillers hill^{-1} (No.)	Ineffective tillers hill^{-1} (No.)	Total tillers hill^{-1} (No.)
Planting time			
T_1	13.47 a	2.27 b	15.73 a
T_2	11.40 b	2.60 a	14.00 b
$LSD_{(0.05)}$	0.30	0.23	0.47
Level of significance	**	**	**
Variety			
V_1	10.50 c	2.00 c	12.50 c
V_2	12.50 b	2.33 bc	14.83 b
V_3	13.33 a	3.00 a	16.33 a
V_4	13.00 ab	2.50 b	15.50 b
V_5	12.83 ab	2.33 bc	15.17 b
$LSD_{(0.05)}$	0.52	0.40	0.81
Level of significance	**	**	**
CV(%)	3.43	13.47	4.47

**: Significant at 0.01 level of probability

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

T_1: 24th January planting

T_2: 23th February planting

V_1: BRRI dhan29

V_2: BRRI hybrid 2

V_3: Heera 2

V_4: Tia

V_5: Taj 1

Table 10. Interaction effect of planting time and variety on yield contributing characters of rice

Treatment	Effective tillers hill^{-1} (No.)	Ineffective tillers hill^{-1} (No.)	Total Itillers hill^{-1} (No.)
T_1V_1	11.00 d	2.00 c	13.00 ef
T_1V_2	13.33 b	2.33 bc	15.67 bc
T_1V_3	14.67 a	3.33 a	18.00 a
T_1V_4	14.00 ab	2.00 c	16.00 bc
T_1V_5	14.33 a	2.00 c	16.33 b
T_2V_1	10.00 e	1.67 c	11.67 f
T_2V_2	11.67 cd	2.33 bc	14.00 de
T_2V_3	12.00 c	2.67 ab	15.00 cd
T_2V_4	12.00 c	3.00 a	15.00 cd
T_2V_5	11.33 cd	2.67 ab	14.00 de
$LSD_{(0.05)}$	0.73	0.56	1.14
Level of significance	**	*	*
CV(%)	3.43	13.47	4.47

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

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

T_1: 24th January planting

T_2: 23th February planting

V_1: BRRI dhan29

V_2: BRRI hybrid 2

V_3: Heera 2

V_4: Tia

V_5: Taj 1

Interaction effect of different planting time and rice varieties showed statistically significant differences on ineffective tillers $hill^{-1}$ (Appendix X). The maximum number of ineffective tillers $hill^{-1}$ (3.33) was recorded from treatment combination of T_1V_3 and the minimum number of ineffective tillers $hill^{-1}$ (1.67) was found from of T_2V_1 treatment combination (Table 10).

4.3.3 Total tillers $hill^{-1}$

Total tillers $hill^{-1}$ showed statistically significant differences due to different planting time (Appendix X). The maximum number of total tillers $hill^{-1}$ (15.73) was recorded from T_1 and the minimum number of total tillers $hill^{-1}$ (14.00) was found from T_2 (Table 9). Khalifa (2009) reported that H_1 hybrid rice variety surpassed other varieties in consideration of total tillers $hill^{-1}$.

Statistically significant variation was recorded in terms of total tillers $hill^{-1}$ due to different rice varieties (Appendix X). The maximum number of total tillers $hill^{-1}$ (16.33) was found from V_3 which was closely followed (15.50 and 15.17) by V_4 and V_5 and they were statistically similar, while the minimum number of total tillers $hill^{-1}$ (12.50) was observed from V_1 which was closely followed (14.83) by V_2 (Table 9).

Interaction effect of different planting time and rice varieties showed statistically significant differences on total tillers $hill^{-1}$ (Appendix X). The maximum number of total tillers $hill^{-1}$ (18.00) was recorded from treatment combination of T_1V_3 and the minimum number of total tillers $hill^{-1}$ (11.67) was obtained from of T_2V_1 treatment combination (Table 10).

4.3.4 Panicle length

Panicle length showed statistically significant differences due to different planting time (Appendix X). The longer panicle (23.43 cm) was recorded from T_1 and the shorter panicle (22.52) was found from T_2 (Figure 10). Wang *et al.* (2006) reported that compared with conventional cultivars, the hybrids had larger panicles.

Statistically significant variation was recorded in terms of panicle length due to different rice varieties (Appendix X). The longest panicle (24.64 cm) was observed from V_3 which was statistically similar (23.53 cm) to V_4 and closely followed (23.02 cm) by V_5, while the shortest panicle (20.47 cm) was recorded from V_1 which was closely followed (23.21 cm) by V_2 (Figure 11).

Interaction effect of different planting time and rice varieties showed statistically significant differences on panicle length (Appendix X). The longest panicle (25.23 cm) was recorded from treatment combination of T_1V_3 and the shortest panicle (20.26 cm) was found from of T_2V_1 treatment combination (Figure 12).

4.3.5 Filled grains panicle^{-1}

Filled grains panicle^{-1} showed statistically significant differences due to different planting time (Appendix XI). The maximum filled grains panicle^{-1} (80.73) was recorded from T_1 and the minimum filled grains panicle^{-1} (74.20) was found from T_2 (Table 11). Obulamma *et al.* (2004) recorded highest number of filled grain panicle^{-1} in hybrid APHR 2 than hybrid DRRH 1.

Statistically significant variation was recorded in terms of filled grains panicle^{-1} due to different rice varieties (Appendix XI). The highest filled grains panicle^{-1} (83.17) was observed from V_3 which was statistically similar (81.67, 80.50 and 79.00) to V_4, V_5 and V_2, while the lowest filled grains panicle^{-1} (63.00) was recorded from V_1 (Table 11).

Interaction effect of different planting time and rice varieties showed statistically significant differences on filled grains panicle^{-1} (Appendix XI). The highest filled grains panicle^{-1} (90.33) was recorded from treatment combination of T_1V_3 and the lowest filled grains panicle^{-1} (61.33) was found from of T_2V_1 treatment combination (Table 12).

Table 11. Effect of planting time and variety on yield contributing characters of rice

Treatment	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	Total grains panicle^{-1} (No.)	Weight of 1000-grains (g)
Planting time				
T_1	80.73 a	6.07 a	86.80 a	23.71 a
T_2	74.20 b	5.60 b	79.80 b	22.74 b
$LSD_{(0.05)}$	2.52	0.23	2.60	0.61
Level of significance	**	**	**	**
Variety				
V_1	63.00 b	4.83 d	67.83 b	20.62 d
V_2	79.00 a	6.00 b	85.00 a	23.73 b
V_3	83.17 a	6.67 a	89.83 a	25.14 a
V_4	81.67 a	6.17 b	87.83 a	24.06 b
V_5	80.50 a	5.50 c	86.00 a	22.56 c
$LSD_{(0.05)}$	4.36	0.40	4.50	1.05
Level of significance	**	**	**	**
CV(%)	4.64	5.62	4.46	5.73

**: Significant at 0.01 level of probability

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

T_1: 24th January planting

T_2: 23th February planting

V_1: BRRI dhan29

V_2: BRRI hybrid 2

V_3: Heera 2

V_4: Tia

V_5: Taj 1

Table 12. Interaction effect of planting time and variety on yield contributing characters of rice

Treatment	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	Total grains panicle^{-1} (No.)	Weight of 1000-grains (g)
T_1V_1	64.67 d	5.00 c	69.67 d	20.88 c
T_1V_2	82.00 bc	6.00 b	88.00 bc	23.38 b
T_1V_3	90.33 a	7.00 a	97.33 a	25.76 a
T_1V_4	85.00 ab	6.33 b	91.33 ab	24.48 ab
T_1V_5	81.67 bc	6.00 b	87.67 bc	24.03 b
T_2V_1	61.33 d	4.67 c	66.00 d	20.37 c
T_2V_2	76.00 c	6.00 b	82.00 c	24.08 b
T_2V_3	76.00 c	6.33 b	82.33 c	24.53 ab
T_2V_4	78.33 bc	6.00 b	84.33 c	23.64 b
T_2V_5	79.33 bc	5.00 c	84.33 c	21.08 c
$LSD_{(0.05)}$	6.17	0.56	6.37	1.49
Level of significance	*	*	*	*
CV(%)	4.64	5.62	4.46	5.73

*: Significant at 0.05 level of probability

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

T_1: 24th January planting
T_2: 23th February planting

V_1: BRRI dhan29
V_2: BRRI hybrid 2
V_3: Heera 2
V_4: Tia
V_5: Taj 1

4.3.6 Unfilled grains panicle^{-1}

Unfilled grains panicle^{-1} showed statistically significant differences due to different planting time (Appendix XI). The maximum unfilled grains panicle^{-1} (6.07) was recorded from T_1 and the minimum unfilled grains panicle^{-1} (5.60) was found from T_2 (Table 11). Hosain *et al.* (2014) reported that hybrid varieties Heera2 and Aloron gave the higher spikelet sterility.

Statistically significant variation was recorded in terms of unfilled grains panicle^{-1} due to different rice varieties (Appendix XI). The highest unfilled grains panicle^{-1} (6.67) was observed from V_3 which was closely followed (6.17 and 6.00) by V_4 and V_2 and they were statistically similar, while the lowest unfilled grains panicle^{-1} (4.83) was recorded from V_1 which was closely followed (5.50) by V_5 (Table 11).

Interaction effect of different planting time and rice varieties showed statistically significant differences on unfilled grains panicle^{-1} (Appendix XI). The highest unfilled grains panicle^{-1} (7.00) was recorded from treatment combination of T_1V_3 and the lowest unfilled grains panicle^{-1} (4.67) was found from of T_2V_1 treatment combination (Table 12).

4.3.7 Total grains panicle^{-1}

Total grains panicle^{-1} showed statistically significant differences due to different planting time (Appendix XI). The maximum total grains panicle^{-1} (86.80) was recorded from T_1 and the minimum total grains panicle^{-1} (79.80) was found from T_2 (Table 11). Guilani *et al.* (2003) observed that grain number panicle^{-1} was not significantly different among cultivars.

Statistically significant variation was recorded in terms of total grains panicle^{-1} due to different rice varieties (Appendix XI). The highest total grains panicle^{-1} (89.83) was observed from V_3 which was statistically similar (87.83, 86.00 and 85.00) to V_4, V_5 and V_2, while the lowest total grains panicle^{-1} (67.83) was recorded from V_1 (Table 11). Islam *et al.* (2008) reported that direct wet-seeded rice produced 10% higher grain yield than transplanted rice and 31 December seeded rice produced the highest grain yield. Rice planted on 1 December significantly reduced the grains per panicle and January planted rice significantly reduced the panicle per unit area.

Interaction effect of different planting time and rice varieties showed statistically significant differences on total grains panicle^{-1} (Appendix XI). The highest total grains panicle^{-1} (97.33) was recorded from treatment combination of T_1V_3 and the lowest total grains panicle^{-1} (66.00) was found from of T_2V_1 treatment combination (Table 12).

4.3.8 Weight of 1000 seeds

Weight of 1000 seeds showed statistically significant differences due to different planting time (Appendix XI). The maximum weight of 1000 seeds (23.71 g) was recorded from T_1 and the minimum weight of 1000 seeds (22.74 g) was found from T_2 (Table 11). Wang *et al*. (2006) reported that compared with conventional cultivars, the hybrids had heavier seeds.

Statistically significant variation was recorded in terms of weight of 1000 seeds due to different rice varieties (Appendix XI). The highest weight of 1000 seeds (25.14 g) was observed from V_3 which closely followed (24.06 g and 23.73 g) by V_4 and V_2 and they were statistically similar, while the lowest weight of 1000 seeds (20.62 g) was recorded from V_1 which was followed (22.56 g) by V_5 (Table 11). Alim *et al.*, 1993 reported that better results are obtained from early transplanting than late transplanting.

Interaction effect of different planting time and rice varieties showed statistically significant differences on weight of 1000 seeds (Appendix XI). The highest weight of 1000 seeds (25.76 g) was recorded from treatment combination of T_1V_3 and the lowest weight of 1000 seeds (20.37 g) was found from of T_2V_1 treatment combination (Table 12).

4.4 Yield of rice and harvest index

4.4.1 Grain yield

Grain yield showed statistically significant differences due to different planting time (Appendix XII). The maximum grain yield (4.00 t ha^{-1}) was observed from T_1 and the minimum grain yield (3.53 t ha^{-1}) was recorded from T_2 (Table 13). Wang *et al*. (2006) reported that compared with conventional cultivars, the hybrids had larger panicles, heavier seeds, resulting in an average yield increase of 7.27%. Kanfany *et al*. (2014) reported that grain yield of rice hybrids (bred by the International Rice Research Institute) was not significantly higher than that of the check cultivar. Swain *et al*. (2006) reported that the control cultivar IR64, with high translocation efficiency and 1000-grain weight and lowest spikelet sterility recorded a grain yield of 5.6 t ha^{-1} that was statistically similar to the hybrid line PA6201. Xie *et al.* (2007) reported different yield for different variety.

Statistically significant variation was recorded in terms of grain yield due to different rice varieties (Appendix XII). The highest grain yield (4.30 t ha^{-1}) was found from V_3 which was statistically similar (4.21 t ha^{-1}) to V_4 and closely followed (3.84 t ha^{-1}) by V_5, while the lowest grain yield (2.95 t ha^{-1}) was observed from V_1 which was closely followed (3.51 t ha^{-1}) by V_2 (Table 13). These results agrees with the results of Nafziger (1994), in that an optimum planting date exists and the planting before or after that optimum results in yield reduction of crops. Singh *et al.,* 1995; Patel *et al.,* 1987 reported that grain yield of rice markedly declined with delayed planting.

Interaction effect of different planting time and rice varieties showed statistically significant differences on grain yield (Appendix XII). The highest grain yield (4.64 t ha^{-1}) was recorded from treatment combination of T_1V_3 and the lowest grain yield (2.83 t ha^{-1}) was recorded from of T_2V_1 treatment combination (Table 14).

Table 13. Effect of planting time and variety on grain, straw and biological yield and harvest index of rice

Treatment	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological Yield ($t\ ha^{-1}$)	Harvest index (%)
<u>Planting time</u>				
T_1	4.00 a	4.86 a	8.86 a	44.99 a
T_2	3.53 b	3.67 b	8.20 b	42.94 b
$LSD_{(0.05)}$	0.15	0.18	0.24	1.48
Level of significance	**	*	**	**
<u>Variety</u>				
V_1	2.95 d	4.06 d	7.01 d	42.09 c
V_2	3.51 c	4.69 c	8.20 c	42.84 bc
V_3	4.30 a	5.06 ab	9.35 a	45.89 a
V_4	4.21 a	5.21 a	9.43 a	44.71 ab
V_5	3.84 b	4.81 bc	8.65 b	44.29 abc
$LSD_{(0.05)}$	0.25	0.29	0.39	2.34
Level of significance	**	**	**	*
CV(%)	5.55	4.97	3.72	4.39

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

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

T_1: 24th January planting
T_2: 23th February planting

V_1: BRRI dhan29
V_2: BRRI hybrid 2
V_3: Heera 2
V_4: Tia
V_5: Taj 1

Table 14. Interaction effect of planting time and variety on grain, straw and biological yield and harvest index of rice

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest index (%)
T_1V_1	3.07 ef	4.07 f	7.14 ef	43.05 bc
T_1V_2	3.53 d	4.50 de	8.03 cd	43.89 bc
T_1V_3	4.64 a	4.95 bc	9.59 ab	48.38 a
T_1V_4	4.37 ab	5.42 a	9.79 a	44.64 bc
T_1V_5	4.38 ab	5.35 ab	9.73 a	45.00 b
T_2V_1	2.83 f	4.05 f	6.88 f	41.14 c
T_2V_2	3.50 d	4.87 cd	8.37 c	41.79 bc
T_2V_3	3.95 c	5.16 abc	9.11 b	43.39 bc
T_2V_4	4.05 bc	5.01 abc	9.06 b	44.78 bc
T_2V_5	3.29 de	4.27 ef	7.56 de	43.57 bc
$LSD_{(0.05)}$	0.36	0.41	0.55	3.314
Level of significance	**	**	**	*
CV(%)	5.55	4.97	3.72	4.39

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

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

T_1: 24th January planting
T_2: 23rd February planting

V_1: BRRI dhan29
V_2: BRRI hybrid 2
V_3: Heera 2
V_4: Tia
V_5: Taj 1

4.4.2 Straw yield

Straw yield showed statistically significant differences due to different planting time (Appendix XII). The maximum straw yield (4.86 t ha^{-1}) was found from T_1, whereas the minimum straw yield (3.67 t ha^{-1}) was recorded from T_2 (Table 13). Patel (2000) observed significantly higher grain and straw yield from Kranti than IR36.

Statistically significant variation was recorded in terms of straw yield due to different rice varieties (Appendix XII). The highest straw yield (5.21 t ha^{-1}) was observed from V_4 which was statistically similar (5.06 t ha^{-1}) to V_3 and followed (4.81 t ha^{-1}) by V_5, while the lowest straw yield (4.06 t ha^{-1}) was recorded from V_1 which was followed (4.69 t ha^{-1}) by V_2 (Table 13).

Interaction effect of different planting time and rice varieties showed statistically significant differences on straw yield (Appendix XII). The highest straw yield (5.42 t ha^{-1}) was recorded from treatment combination of T_1V_4 and the lowest straw yield (4.05 t ha^{-1}) was found from of T_2V_1 treatment combination (Table 14).

4.4.3 Biological yield

Biological yield showed statistically significant differences due to different planting time (Appendix XII). The maximum biological yield (8.86 t ha^{-1}) was recorded from T_1 and the minimum biological yield (8.20 t ha^{-1}) was found from T_2 (Table 13).

Statistically significant variation was recorded in terms of biological yield due to different rice varieties (Appendix XII). The highest biological yield (9.43 t ha^{-1}) was observed from V_4 which was statistically similar (9.35 t ha^{-1}) to V_3 and closely followed (8.65 t ha^{-1}) by V_5, while the lowest biological yield (7.01 t ha^{-1}) was recorded from V_1 which was closely followed (8.20 t ha^{-1}) by V_2 (Table 13). Kainth and Mehra, 1985 reported that when transplanting is delayed beyond normal period, the grain development is very poor which results in more quantity of under developed grains and ultimately severe reduction in yield.

Interaction effect of different planting time and rice varieties showed statistically significant differences on biological yield (Appendix XII). The highest biological yield (9.79 t ha^{-1}) was recorded from treatment combination of T_1V_4 and the lowest biological yield (6.88 t ha^{-1}) was found from of T_2V_1 treatment combination (Table 14).

4.4.4 Harvest index

Harvest index showed statistically significant differences due to different planting time (Appendix XII). The maximum harvest index (44.99%) was recorded from $T_{1,}$ whereas the minimum harvest index (42.94%) was observed from T_2 (Table 13).

Statistically significant variation was recorded in terms of harvest index due to different rice varieties (Appendix XII). The highest harvest index (45.89%) was observed from V_3 which was statistically similar (44.71% and 44.29%) to V_4 and V_5, while the lowest harvest index (42.09%) was found from V_1 which was statistically similar (42.84%) to V_2 (Table 13).

Interaction effect of different planting time and rice varieties showed statistically significant differences on harvest index (Appendix XII). The highest harvest index (48.38%) was observed from treatment combination of T_1V_3 and the lowest harvest index (41.14%) was recorded from of T_2V_1 treatment combination (Table 14).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka at the period of December, 2014 to April 2015 to find out the effect of planting time on morpho-physiological and yield contributing characters of rice. The experiment comprised of two factors. Factor A: Planting time (2): T_1: 24th January planting; T_2: 23th February planting and Factor B: Rice variety (5): V_1: BRRI dhan29; V_2: BRRI hybrid 2; V_3: Hera 2; V_4: Tia and V_5: Taj 1. The experiment was laid out in a randomized complete block design (RCBD) with three replications. Data on different morpho-physiological and yield contributing characters were recorded and statistically significant variation was recorded for all the parameters.

In case of planting time, at 20, 40, 60, 80 DAT and harvest, the taller plant (26.58, 56.63, 83.19, 92.29 and 111.16 cm, respectively) was recorded from T_1 and the shorter plant (24.64, 53.49, 78.90, 87.25 and 105.18 cm, respectively) was found from T_2. At 20, 40, 60 and 80 DAT, the maximum number of tillers hill^{-1} (2.55, 7.12, 13.69 and 15.69, respectively) was found from T_1, while the minimum number (2.43, 6.53, 12.39 and 14.61, respectively) from T_2. At 20, 40, 60 and 80 DAT, the maximum SPAD value (33.33, 40.00, 45.22 and 34.47, respectively) was recorded from T_1 and the minimum SPAD value (31.46, 38.35, 43.99 and 31.20, respectively) from T_2. At 20, 40, 60 and 80 DAT, the higher leaf area index (0.285, 1.38, 3.48 and 5.28, respectively) was found from T_1 and the lower leaf area index (0.259, 1.28, 3.20 and 5.04, respectively) from T_2. The maximum shoot reserve translocation (15.26%) was recorded from T_1 and the minimum (12.97%) from T_2. The maximum number of total tillers hill^{-1} (15.73) was recorded from T_1 and the minimum number (14.00) from T_2. The longer panicle (23.43 cm) was recorded from T_1 and the shorter panicle (22.52) from T_2. The maximum total grains panicle^{-1} (86.80) was recorded from T_1 and the minimum total grains panicle^{-1} (79.80) was found from T_2. The maximum weight of 1000 seeds (23.71 g) was recorded from T_1 and the minimum weight of 1000 seeds

(22.74 g) was found from T_2. The maximum grain yield (4.00 t ha^{-1}) was observed from T_1 and the minimum grain yield (3.53 t ha^{-1}) was recorded from T_2. The maximum straw yield (4.86 t ha^{-1}) was found from T_1, whereas the minimum straw yield (3.67 t ha^{-1}) was recorded from T_2. The maximum biological yield (8.86 t ha^{-1}) was recorded from T_1 and the minimum (8.20 t ha^{-1}) from T_2. The maximum harvest index (44.99%) was recorded from $T_{1,}$ whereas the minimum harvest index (42.94%) was observed from T_2.

For rice variety, at 20, 40, 60, 80 DAT and harvest, the tallest plant (27.88, 58.08, 84.94, 94.41 and 112.03 cm, respectively) was observed from V_3, while the shortest plant (23.59, 50.38, 75.55, 82.92 and 100.93 cm, respectively) was recorded from V_1. At 20, 40, 60 and 80 DAT, the maximum number of tillers $hill^{-1}$ (2.63, 7.13, 14.63 and 16.43, respectively) was found from V_3, whereas the minimum number of tillers $hill^{-1}$ (2.30, 6.20, 10.60 and 13.37, respectively) was observed from V_1. At 20, 40, 60 and 80 DAT, the maximum SPAD value (36.56, 43.44, 49.39 and 35.82, respectively) was observed from V_3 and, the minimum SPAD value (25.29, 31.27, 35.53 and 29.71, respectively) was found from V_1. At 20, 40, 60 and 80 DAT, the highest leaf area index (0.305, 1.54, 3.74 and 5.74, respectively) was found from V_3, while the lowest leaf area index (0.212, 1.02, 2.62 and 4.17, respectively) was observed from V_1. The maximum number of total tillers $hill^{-1}$ (16.33) was found from V_3, while the minimum number of total tillers $hill^{-1}$ (12.50) was observed from V_1. The highest shoot reserve translocation (16.84%) was observed from V_3, while the lowest shoot reserve translocation (10.94%) was recorded from V_1. The longest panicle (24.64 cm) was observed from V_3, while the shortest panicle (20.47 cm) was recorded from V_1. The highest total grains $panicle^{-1}$ (89.83) was observed from V_3 which was statistically similar (87.83, 86.00 and 85.00) to V_4, V_5 and V_2, while the lowest total grains $panicle^{-1}$ (67.83) was recorded from V_1. The highest weight of 1000 seeds (25.14 g) was observed from V_3, while the lowest weight of 1000 seeds (20.62 g) was recorded from V_1. The highest grain yield (4.30 t ha^{-1}) was found from V_3, while the lowest grain yield (2.95 t ha^{-1}) was observed from V_1. The highest straw yield (5.21 t ha^{-1}) was observed from V_4, while the lowest straw yield (4.06 t ha^{-1}) from V_1. The highest biological yield (9.43 t ha^{-1}) was observed from V_4, while the lowest biological yield (7.01 t ha^{-1}) was recorded from V_1. The highest harvest index (45.89%) was observed from V_3, while the lowest harvest index (42.09%) was found from V_1.

Due to interaction effect of planting time and variety, at 20, 40, 60, 80 DAT and harvest, the tallest plant (29.94, 62.57, 89.58, 99.42 and 120.92 cm, respectively) was recorded from treatment combination of T_1V_3 and the shortest plant (23.31, 49.56, 75.57, 82.25 and 100.92 cm, respectively) was found from of T_2V_1. At 20, 40, 60 and 80 DAT, the maximum number of tillers $hill^{-1}$ (2.67, 7.40, 16.07 and 17.20, respectively) was recorded from treatment combination of T_1V_3, while the minimum number of tillers $hill^{-1}$ (2.27, 5.80, 10.27 and 13.33, respectively) was recorded from of T_2V_1. At 20, 40, 60 and 80 DAT, the maximum SPAD value (38.54, 44.33, 50.01 and 37.60, respectively) was observed from treatment combination of T_1V_3, while the minimum SPAD value (24.83, 30.43, 34.60 and 28.31, respectively) was found from of T_2V_1 treatment combination. At 20, 40, 60 and 80 DAT, the highest leaf area index (0.320, 1.65, 3.89 and 5.96, respectively) was found from treatment combination of T_1V_3 and the lowest leaf area index (0.205, 1.01, 2.52 and 4.08, respectively) was found from of T_2V_1 treatment combination. The highest shoot reserve translocation (17.83%) was recorded from treatment combination of T_1V_3 and the lowest shoot reserve translocation (10.43%) was found from of T_2V_1 treatment combination. The maximum number of total tillers $hill^{-1}$ (18.00) was recorded from treatment combination of T_1V_3 and the minimum number of total tillers $hill^{-1}$ (11.67) was obtained from of T_2V_1 treatment combination. The longest panicle (25.23 cm) was recorded from T_1V_3 and the shortest panicle (20.26 cm) was found from of T_2V_1 treatment combination. The highest total grains $panicle^{-1}$ (97.33) was recorded from T_1V_3 and the lowest total grains $panicle^{-1}$ (66.00) was found from of T_2V_1 treatment combination. The highest weight of 1000 seeds (25.76 g) was recorded from T_1V_3 and the lowest weight of 1000 seeds (20.37 g) was found from of T_2V_1 treatment combination. The highest grain yield (4.64 t ha^{-1}) was recorded from T_1V_3 and the lowest grain yield (2.83 t ha^{-1}) was recorded from of T_2V_1 treatment combination. The highest straw yield (5.42 t ha^{-1}) was recorded from treatment combination of T_1V_4 and the lowest straw yield (4.05 t ha^{-1}) was found from of T_2V_1 treatment combination. The highest biological yield (9.79 t ha^{-1}) was recorded from T_1V_4 and the lowest biological yield (6.88 t ha^{-1}) was found from of T_2V_1 treatment combination. The highest harvest index (48.38%) was observed from T_1V_3 and the lowest harvest index (41.14%) was recorded from of T_2V_1 treatment combination.

Conclusion:

- The highest tillers/hills (18.00), highest shoot reserve translocation (17.83%), longest panicle (25.23 cm), highest total grains $panicle^{-1}$ (97.33) and highest weight of 1000 seeds (25.76 g) were achieved from Heera 2 at 24th January transplanting date;

- Heera-2 produced highest grain yield (4.64 t ha^{-1}) at 24th January transplanting date which was statistically similar to Taj 1 (4.38 t ha^{-1}) and Tia (4.37 t ha^{-1}) at same transplanting date.

Recommendation:

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

- Other variety (s) with different management practices might be included for future study;

- Such type of study is needed in different agro-ecological zones (AEZ) of Bangladesh for testing the regional compliance and other quality attributes.

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