EFFECT OF TRANSPLANTING DATE ON YIELD AND SEED QUALITY OF T. AMAN RICE VARIETIES

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JUNE, 2021

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REGISTRATION NO. 14-06102

A Thesis
submitted to the Institute of Seed Technology,
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
SEED TECHNOLOGY

SEMESTER: JANUARY-JUNE, 2019

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*This is to certify that thesis entitled **"EFFECT OF TRANSPLANTING DATE ON YIELD AND SEED QUALITY OF T. AMAN RICE VARIETIES"** submitted to the **INSTITUTE OF SEED TECHNOLOGY,** Sher-e- Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN SEED TECHNOLOGY,** embodies the result of a piece of bona fide research work carried out by MD. MEHEDE HASAN, Registration no. 14-06102 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2021
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DEDICATED
TO
MY BELOVED
PARENTS

ACKNOWLEDGEMENT

At first, the author takes the opportunity to express his deepest sense of gratefulness to the Almighty Allah who enabling the author to complete his research work for the degree of Master of Science (MS) in Seed Technology.

The author does not have adequate words to express his heartfelt sense of gratification, ever indebtedness and sincere appreciation to his benevolent teacher and research supervisor, Prof. Dr. A. K. M. Ruhul Amin, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka- 1207, for his constant help, scholastic guidance, planning experiment, valuable suggestions, timely and solitary instructive criticism for successful completion of the research work as well as preparation of this thesis.

It is a great pleasure for the author to express his sincere appreciation, profound sense, respect and immense indebtedness to his respected co-supervisor, Associate Prof. Dr. Sheikh Muhammad Masum, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka-1207, for providing him with all possible help during the period of research work and preparation of the thesis.

The author would like to express his deepest respect and boundless gratitude to the Director and all the teachers of the Institute of Seed Technology, Sher-e-Bangla Agricultural University, Dhaka-1207 for their sympathetic co-operation and inspiration throughout this study and research work.

Cordial thanks are also due to all laboratory staff and field workers of SAU farm for their co- operation to complete this research work.

The author feels proud to express his sincere appreciation and gratitude to the Ministry of Science and Technology, the People's Republic of Bangladesh for providing him National Science and Technology (NST) fellowship.

The author would like to express his last but not least profound and grateful gratitude to his beloved parents, friends and all of his relatives for their inspiration, blessing and encouragement that opened the gate of his higher studies in his life.

Date: June, 2021 ***The Author***
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ABSTRACT

A field experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University to find out the effect of transplanting date on yield and seed quality of T. aman rice varieties. cultivated during aman season (July 2019 to December 2019). The experiment comprised two factors *viz*, factor A: Variety – 3, i) V_1= BRRI dhan32, ii) BRRI dhan62 and iii) V_3 = BRRI dhan80; factor B: Date of transplanting – 4, T_1= 01 July; T_2= 15 July; T_3 = 30 July and T_4 = 15 August. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data were collected on different aspects of growth, yield attributes, yield and seed quality of T. aman rice. Results revealed that, BRRI dhan32 gave the highest grain yield (5.01 t ha^{-1}) and maximum seed germination percentage (87.06%). This may be attributed to the maximum number of effective tillers $hill^{-1}$ (14.83), longest panicle (28.64 cm), the highest number of filled grains $panicle^{-1}$ (114.16), highest 1000-grain weight (23.84 g) and highest vigor index (2067.54) in this variety. Out of 4 dates of transplanting treatment, T_3 (Transplanting on 30 July) produced the highest grain yield (5.23 t ha^{-1}) and maximum seed germination percentage (90.95%). This treatment also showed the maximum number of effective tillers $hill^{-1}$ (14.99), longest panicle (28.35 cm), the maximum number of filled grains $plant^{-1}$ (119.59), highest weight of 1000-seed (24.23 g) and highest vigor index (2232.91). Regarding the interaction of variety and date of transplanting, the interaction of V_1T_3 (BRRI dhan32 when transplanting on 30 July) was the highest yielder (5.82 tha^{-1}) among the other interactions which was attributed to higher 1000-seed weight. Besides this, the interaction V_1T_3 also gave maximum seed germination percentage (92.89%) and highest vigor index (2377.98). Considering the above result, it may be concluded that BRRI dhan32 transplanting on 30 July was found superior in producing the highest yield and best quality seed production.

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	**Full meaning**
AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
BRRI	Bangladesh Rice Research Institute
BINA	Bangladesh Institute of Nuclear Agriculture
BBS	Bangladesh Bureau of Statistics
BCPC	British Crop Production Council
cm	Centi-meter
CV	Coefficient of variation
^{o}C	Degree Celsius
d.f.	Degrees of freedom
DAT	Days After Transplanting
et al.	And others
FAO	Food and Agriculture Organization
G	Gram
ha	Hectare
CRSP	Collaborative Research Support Program
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
mg	Milligram
m^2	Meter Squares
MoP	Muriate of Potash
%	Per cent
SPD	Split Plot Design
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food for more than half of the world's population. About 90% of the world's rice is grown and produced (622 million tons from 142 million ha of land) in Asia. As in many other countries of Asia, rice is the staple food and the economy mainly depends on rice production in Bangladesh. Over 95% people depend on rice for their daily diets and it engages over 85% of the total agricultural labour force in Bangladesh. Among the rice-growing countries, Bangladesh ranks third in area and fourth in production for rice cultivation. In Bangladesh, rice covered an area of 28.21 thousand acres with a production of 36.60 million metric tons while the average yield of rice is around 2.74 t/ha (BRRI, 2020) whereas the transplant aman rice covers the largest area of 13165 acres with a production of 13940 thousand M. ton rice grain during 2019-20 (BBS, 2020). BRRI has developed 106 rice varieties among which 46 is of aman varieties (BRRI, 2021). In Bangladesh, the rice-growing environment is classified into three major ecosystems based on physiography and land types: irrigated, rainfed, and floating or deep-water. Transplant aman rice varieties are cultivated in rainfed ecosystem which covers about 49.82% of total rice area and contributes to 38.80% of total rice production in the country (BBS, 2020). Modern varieties of T. aman cover about 88% of rice area in the aman season (BBS, 2020). Bangladeshi agriculture is now at crossroads. Over the past five decades the strategies, policies and actions were guided by the goals of 'self-sufficiency' in food grain production with main focus on rice. In the self-sufficiency of rice, the dominant cropping pattern T. aman (wet season rice)-fallow-boro (dry season rice) plays an important role which covers about 1.8 million hectares (about 22%) of the total land (USAID, 2012). But, unfortunately, the national average rice yield in Bangladesh (4.2 t ha^{-1}) is very low considering the other rice-growing countries like South Korea and Japan where the average yield is 7.50 and 6.22 t/ha, respectively (FAO. 2013). On the other hand, Bangladesh lacks arable land to extend rice production. Besides, rice production is decreasing day by day due to high population pressure, continuing drought and flood in farming areas, and conversion of farmlands to grow cash crops instead of rice. Therefore, it is an urgent need of the time to increase rice yield in Bangladesh. The reasons for low yield of rice are manifold; some are varietals, others are technological and rests are climatic. Undoubtedly, with the introduction of high yielding varieties the yield of rice has been increased, but the trend of increase is not linear. The yield can be increased by using improved cultural practices like use of quality seed, high yielding varieties, adopting plant protection measures, optimum seedling age, optimum number of seedling hill^{-1}, seedling raising technique, judicious application of fertilizers, etc. For the selection of right type of variety, suitable date of transplanting is the most important factors for maximizing rice seed production. Response to planting date varies with change in varieties for high yield. The yield of rice changes with the environment, such as different locations, seasonal fluctuations, different dates of planting etc. (Sarker, 2002).

Aman rice productivity is highly influenced by planting date. The optimum planting date as recommended by BRRI is July 15 to August 15 for T. aman rice. July transplanting in many cases is not practicable as the land remains occupied by other crops. When these varieties are transplanted in the late season during September-October, their sensitivity of flowering in the months of November-December mostly depends on the planting dates. The late transplanting exposes the reproductive phase as well as phenological events of crop, is very much sensitive to day length and lower temperature regime, thereby, causing high spikelet sterility and poor growth of the plant and finally reduction of grain yield through the reduction of yield contributing characters. The yield contributing characters especially the number of effective tillers hill^{-1}, number of grains panicle^{-1}, grain yield and straw yield were significantly affected when compared to late transplanting. Many of them obtained better results from early transplanting than late transplanting (Darko *et al.,* 2013; Ali *et al.,* 2012; Tamanna, 2007; Pandey *et al.,* 2001). When rice is planted under ideal conditions with favorable air and soil temperatures and appropriate soil moisture, the performance of the crop drastically improves. Planting too late can expose the crop to cold temperatures and result in poor germination, low seeding vigor, and seedling mortality (Dou *et al.,* 2016; Saichuk *et al.,* 2014). Planting too late often causes reduced yields and grain quality as the reproductive phase coincides with the height of the summer heat and rice grain yield and quality are negatively affected (Lanning *et al.,* 2012; Wu *et al.,* 2019).

Transplanting dates have been shown to provide differential growth conditions such as temperature, precipitation and growth periods. Different author(s) reported the benefits of choosing optimum planting dates rice and in most of the cases, neither too early nor too late transplanting proved to give better yield response by offering prolonged or shorter growth period while eliminating chances of escaping heat stress during reproductive growth (Safdar *et al.,* 2008 and Hossain, 2007). Temperature is the key factor to be affected by transplanting dates in rice. Different authors used different planting dates to check contrasting temperature regimes in various rice varieties (Laborte *et al.,* 2012; Rahman *et al.,* 2003 and Rahman *et al.,* 2007). They concluded that late transplanting dates coincided with reproductive phase temperature stress while early planting helps to escape from temperature stress. Therefore, late planting is considered as the vector to reduce growth and yield. But early planting could not be possible all the time due to existing cropping patterns, climate change, and socio-economic conditions. A compromise is therefore, needed between sacrificing grain yield by adjusting the transplanting date (Basal *et al.,* 2009 and Rauf *et al.,* 2007).

Variety is one of the most important factors which contribute much to producing the yield and yield component of rice. The yield of the variety is directly related to the environment in which it grows. Higher yield could be achieved from the suitable cultivar if an appropriate sowing date is used (Akhter *et al.,* 2007).

In light of the scenarios discussed above, the present study was undertaken with the following objectives:

- To observe the varietal performance on yield and quality of T. aman rice seed;
- To select appropriate transplanting date for higher yield with good seed quality of T. aman; and
- To observe the combination effect of variety and transplanting date on yield and seed quality of T. aman.

CHAPTER II

REVIEW OF LITERATURE

The high-yielding varieties of rice play an important role in achieving a higher yield. The growth and development of rice plants are greatly influenced by the environmental factors (i.e., day length or photoperiod, temperature etc.), variety, and agronomic practices (i.e., planting time, spacing, depth of planting, fertilizer etc.). Among these factors, planting time and variety itself are very important, especially for T. aman rice. Some of the pertinent works on the response of different T. aman rice varieties to date of transplanting have been reviewed in this chapter.

2.1 Effect of varieties on the growth, yield, and seed quality of rice

Hossain (2007) experimented during the aman season of 2006 with five varieties of T. aman (viz. BRRI dhan30, BRRI dhan32, BRRI dhan34, BRRI dhan39, and Naizershail). The varieties showed a significant variation on total tillers and also other yield contributing characters.

Marambe (2005) observed that the tiller number varied from 14-18 per plant with 6-9 panicles plant^{-1}. There were more unproductive tillers on weedy rice plants than on the cultivated variety. BRRI (2012) reported that the number of productive tillers by modern varieties ranged from 15 to 25, which significantly differs in varieties. It was also observed that total tillers^{-1} and the number of grains panicle^{-1} differed significantly among the varieties.

Kumar *et al.* (2005) observed the effect of varietal differences of modern transplanted aman rice. Among different varieties (viz. Jaya, Rasi, IR20, and Margala) IR20 has given the yield of 7.9 t ha^{-1} and Rasi 6.2 t ha^{-1}. The highest yield was in Jaya 8.4 t ha^{-1}. Diaz *et al.* (2001) noted wide variation in panicle length, grains panicle^{-1} and panicle weight, and secondary branches panicle^{-1} among the varieties which are responsible for variation in grain yield. Shriname and Muley (2003) studied the heritability and correlation studies of different biotic and morphological plant characters with grain yield in rice hybrid and cultivars and observed that grain yield exhibited a strong positive correlation with harvest index.

Rajaul (2005) stated that straw yield was significantly affected due to varieties. The highest straw yield might be contributed by the taller plant and total tillers m^{-2} in improved varieties. Ghosh *et al.* (2001) studied the performance of hybrid and high yielding cultivars and observed hybrids were superior over inbreed in straw weight.

Mia (2003) reported that plant height different significantly aman BR3, BR11, BR22, Naizershail, Pajam and Badshabhog varieties in aman season. Kumari *et al.* (2003) reported that plant height showed high heritability coupled with modern genetic advances. Ghosh *et al.* (2001) worked with four rice hybrids (CNHR3, Pro Agro 6201, PDSH 35 and GK 5006) and four high yielding cultivars (MW10, IET4786, IR50 and Parija), and concluded that hybrids have higher plant height as compared to HYV.

Neerja and Sharma (2002) experimented on non-aromatic (cvs.IR8, PR113, PR103, PR106) and aromatic (cvs. Basmati 370, Basmati 385, Basmati 386, Pusa Basmati No, 1) rice, and found that the highest 1000 kernel weight of brown rice was recorded for PE113. Hossain (2007) reported that the weight of thousand grains varied from 22.1 g to 27.3 g among BRRI dhan33, BRRI dhan39 and BRRI dhan49.

Singh and Singh (2002) conducted an experiment with rice cultivars Swarna and PR-108 in split-plot design in Varanasi, Uttar Pradesh, India and reported that Swarna was significantly superior to PR-108 in grains panicle^{-1}.

Bhowmik and Nayak (2000) found that CNHR2 produced more panicles (413.4 m^{-2}) and maximum grains panicle^{-1} (111.0) than another variety, whereas IR36 has given the highest test weight (21.7 g) and (15.2 g) of panicle m^{-2} and grains panicle^{-1}.

2.2 Effect of date of transplanting on the growth, yield and seed quality of rice

Cerioli *et al.* (2021) experimented at the Louisiana State University from 2011 to 2018 to quantify the effect of planting date, genotype and year on key agronomic traits. Planting date was strongly associated with yield across every year, explaining 55.6% of the overall phenotypic variation. A clear relationship was observed between later plantings and reduced yields; and the highest yields were observed during plantings between 11 and 31 March. Rice planted after the optimal planting window displays a yield reduction following a cubic regression trend. Planting date was associated with milling yield, explaining 28.6% of the phenotypic variation, however the effect size varied year to year. Milling yields were highest with the early and late planting dates, while reduced milling yields were observed in plantings between mid-

April and early June. Days to heading and days to seedling emergence were strongly associated with planting date; with planting date explaining, on average, 86 and 96% of the variation, respectively. Plant height was less influenced by planting date, with genotype being the largest source of variation. The results from this study highlight the importance of choosing the optimal planting date and identify an optimal planting window to maximize grain and milling yield for Southwest Louisiana.

Rice being an important staple food crop of the world, sowing date significantly influenced on growth and yield of rice crop, it has been studied by the number of research workers from various parts of India and abroad. The sowing time of the rice crop is important for three major reasons. Firstly, it ensures that vegetative growth occurs during a period of satisfactory temperatures and total sunshine hours. Secondly, the optimum sowing time for each cultivar ensures the cold-sensitive stage occurs when the minimum night temperatures are historically the warmest. Thirdly, sowing on-time guarantees that grain filling occurs when milder autumn temperatures are more likely, hence good grain quality is achieved (Patel *et al.*, 2019).

Tahsin *et al.* (2017) conducted an experiment July to December 2016 to determine the effect of transplanting dates on yield and yield attributes of different T. aman rice. The experimental treatments comprised of three transplanting dates viz. 25 July, 10 August and 25 August and four T. aman rice varieties *viz*. BR23, BRRI dhan41, BRRI dhan49, and BRRI dhan72. They found that BRRI dhan49 gave the highest grain yield and 25 August was the most suitable transplanting date.

Reza *et al.* (2016) carried out an experiment from June 2013 to December 2013 to study the yield and grain dimensions of transplant aman rice varieties as influenced by the date of transplanting. The experimental factors comprised of two factors namely, date of transplanting and variety. Most of the yield parameters were significantly affected by the date of transplanting. The yield and yield contributing characters were highest at 19 August transplanting and lowest at 18 September transplanting. Variety had a significant effect on most of the yield and yield contributing characters. BR11 gave the highest grain yield (4.47 t ha^{-1}) and the lowest value was obtained in BRRI dhan57. Among the grain dimensions, Binadhan-7 with 18 July transplanting gave the highest grain length (9.64 mm) whereas BR11 with 18 September transplanting gave the lowest value (7.82mm). Results showed that yield components were highest at 19

August transplanting and after that the reduction occurred on 18 September may be due to low temperature and short-day length at flowering stage.

Sharma *et al.* (2013) carried out an experiment during two consecutive transplanted aman seasons (2011 and 2012) at Rangpur, Dinajpur, Gaibandha, situated in a medium drought-affected area in Northern Bangladesh. Mostly traditional rice varieties were cultivated during the T. aman season in this area. Three sets of experiment were conducted in different transplanting dates using seven varieties and one local check-in both the seasons with three replications. In the first season, the highest yield was obtained from BRRI hybrid dhan4 (5.53 t ha^{-1}) then Binadhan-7 (4.9 t ha^{-1}), BRRI dhan49 (4.5 t ha^{-1}) followed by BRRI dhan56 and BRRI dhan57 (4.7 t ha^{-1}); and the lowest yield was obtained from BRRI dhan33 and BRRI dhan39 (3.5 t ha^{-1}) in 1st set respectively. On the other hand, the highest yield was observed in Binadhan-7 (5.2 t ha^{-1}) followed by BRRI dhan57 and BRRI dhan49 (4.9 t ha^{-1}); BRRI dhan33 (3.8 t ha^{-1}) followed by BRRI dhan39 (3.6 t ha^{-1}), and BRRI dhan56 (4.6 t ha^{-1}) followed by BRRI Hybrid dhan4 (4.8 t ha^{-1}) in 2nd set respectively in the following season. In the case of the date of transplanting, the highest yield was observed on 15 July (2nd set) seeding ranged from 2.4 to 4.8 t ha^{-1} and 4.2 to 5.8 t ha^{-1} among the tested varieties in the 1st and 2nd season, respectively. The second highest yield was obtained on 24 June (1st set) seeding ranged from 1.5 to 4.3 t ha^{-1} and 3.5 to 5.6 t ha^{-1} in the 1st and 2nd season, respectively. But the late sowing, 3rd set (mid-August) demonstrated lower yield ranging from 1.8 to 3.5 t ha^{-1} and 2.5 to 4.0 t ha^{-1} in 1st and 2nd season, respectively. The investigation suggested that modern rice varieties i.e. BRRI dhan56, BRRI dhan57, BRRI hybrid dhan4, and Binadhan-7 will be adaptable in this area and can double the rice production, and also first to mid-July will be the optimum transplanting date of T. aman rice for this area.

Bashir *et al.* (2010) conducted a field experiment to evaluate the effect of different sowing dates on yield and yield components of the direct sown coarse rice during the Kharif season of 2008. The experiment comprised of six sowing dates i.e. 31^{st} May, 10^{th} June, 20^{th} June, 30^{th} June, 10^{th} July and 20^{th} July. Results revealed that direct-seeded rice sown on 20th June proved to be the best for obtaining maximum grain yield and net return. 20th June sowing also gave the maximum number of productive (panicle bearing) tillers, number of kernels per panicle, 1000-grain weight, and benefit-cost ratio.

Rice yields may reduce by planting too early and also by planting too late in the growing season. If rice is planted extremely early, it could run into: 1) slow emergence, poor growth, lack of seedling vigor due to unfavorable weather, 2) increased seedling disease damage, such as water mold, 3) increased bird predation, (Baloch *et al.*, 2006). If rice is planted too late: 1) yield potential decreases, 2) panicle blight problems associated with temperature stress during pollination and grain fill occurs, 3) increased potential for disease and insect problems, 4) decrease in grain quality, 5) problems in ratoon crop timing (Habibullah *et al.*, 2007).

Hossain and Sikdar (2009) experimented to determine the optimum transplanting date to get maximum yield and quality of three local and two modern aromatic rice varieties of Bangladesh during aman season of 2005. The varieties Kataribhog, Radhunipagal, Badshabhog, BRRI dhan 34 and BRRI dhan 38 were transplanted from 15 July to 14 August with 10-day intervals. All the varieties gave the maximum grain yield when transplanted on 15 July. Among the aromatic rice varieties, the highest grain yield was obtained from BRRI dhan 34 followed by Kataribhog and the lowest grain yield was obtained from Radhunipagal. Milling outturn (%), head rice outturn (%), grain elongation ratio, and protein content (%) are affected by the date of transplanting in T. aman season.

Rahman (2004) experimented during the period from June 2002 to April 2003. He investigated the influence of four different transplanting dates viz. 18 July, 28 July, 7 August and 17 August. Transplanting on 28 July which was optimum produced the highest grain yield for T. aman rice and 17 August transplanting showed the lowest grain yield.

Mumin (2002) studied the influence of planting times on the yield and yield components of three aman rice varieties. Planting time exerted a significant influence on most of the crop characters. Crop transplanted on 25 July produced a maximum number of bearing tillers m^{-2} compared to other planting times. The highest grain (4.16 t ha^{-1}) and straw (5.09 t ha^{-1}) yields were observed from July transplanting.

Pattar *et al.* (2001) conducted a field experiment in India, to study the effect of planting date and seedling age on rice yield. Seedling of 25, 35, and 45 days old was planted on the first and second fortnight of August and the first fortnight of

September. Planting on the first fortnight of August had a higher yield than those planted on later dates. In general, there was a drastic reduction in yield when planting was done in the first fortnight of September.

Muthukrishnan *et al.* (2000) determined the optimum time of planting (5, 15 and 25 July) for four rice hybrids. Grain yield of rice decreased progressively with delay in transplanting. The crops transplanted on 5 July and 15 July were comparable. Grain yield was reduced by 9 %, from 5.14 t ha^{-1} on 5 July to 4.69 t ha^{-1} on 25 July.

Pardashty *et al.* (2000) studied the effect of transplanting date on yield and yield components in four rice cultivars. Treatment comprised four genotypes Taron, Neamat, Shel (7325 line) and Fajar (7328 line), and their transplanting dates with 10-day intervals from 13 March to 1 June 1998. Traits such as grain yield, biomass and harvest index, tiller number, grain number ear^{-1}. Ear fertilized percentage and 1000 seed weight at different transplanting dates were evaluated. The delay in transplanting date decreased tiller number, ear fertilized percentage, grain number ear^{-1}, the grain yield and harvest index, but the different transplanting dates did not show any significant differences in 1000 - seed weight and biomass. Neamat had a higher tiller number and 1000 - seed weight compared to the other varieties.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted in the research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from July 2019 to December 2019 to study the effect of transplanting date on yield and seed quality of T. aman varieties. This chapter will deal with a brief description of the experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording, and data analysis. The details are presented below under the following headings:

3.1 Experimental site

The study was conducted at the central research field of Sher-e-Bangla Agricultural University, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28. The location of the site is $23^{0}74/N$ latitude and $90^{0}35/E$ longitude with an elevation of 8.2 meters from sea level. The location of the experimental field was presented in Appendix I.

3.2 Climate

The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April, and monsoon period from May to October. Details of the meteorological data of air temperature, relative humidity, and rainfall during the period of the experiment were collected from the Bangladesh Meteorological Department, Agargaon, Dhaka presented in Appendix II.

3.3 Soil

The soil belongs to "The Modhupur Tract", AEZ – 28. Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish-brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium-high land. The details were presented in Appendix III.

3.4 Planting material

In this research work, three inbreed varieties i.e. BRRI dhan32, BRRI dhan62, and BRRI dhan80 were used as planting materials. BRRI varieties were collected from the Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh.

3.5 Experimental details

3.5.1 Treatments

The experiment consists of 2 factors, they were

Factor A: Variety-3

V_1 = BRRI dhan32

V_2 = BRRI dhan62

V_3 = BRRI dhan80

Factor B: Date of transplanting-4

T_1 = 01 July 2019

T_2 = 15 July 2019

T_3 = 30 July 2019

T_4 = 15 August 2019

Treatment Combination

V_1T_1 = BRRI dhan32 × 01 July 2019

V_1T_2= BRRI dhan32 × 15 July 2019

V_1T_3= BRRI dhan32 × 30 July 2019

V_1T_4= BRRI dhan32 × 15 August 2019

V_2T_1 = BRRI dhan62 ×01 July 2019

V_2T_2= BRRI dhan62 × 15 July 2019

V_2T_3= BRRI dhan62 × 30 July 2019

V_2T_4= BRRI dhan62 × 15 August 2019

V_3T_1 = BRRI dhan80 × 01 July 2019

V_3T_2= BRRI dhan80 × 15 July 2019

V_3T_3= BRRI dhan80 × 30 July 2019

V_3T_4= BRRI dhan80 × 15 August 2019

3.5.2 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Each block was divided into twelve-unit plots. The total number of plots was 36. The plot size was 4 m × 2.0 m. The distance between plots was 0.5 m and replication to replication was 1.0 m.

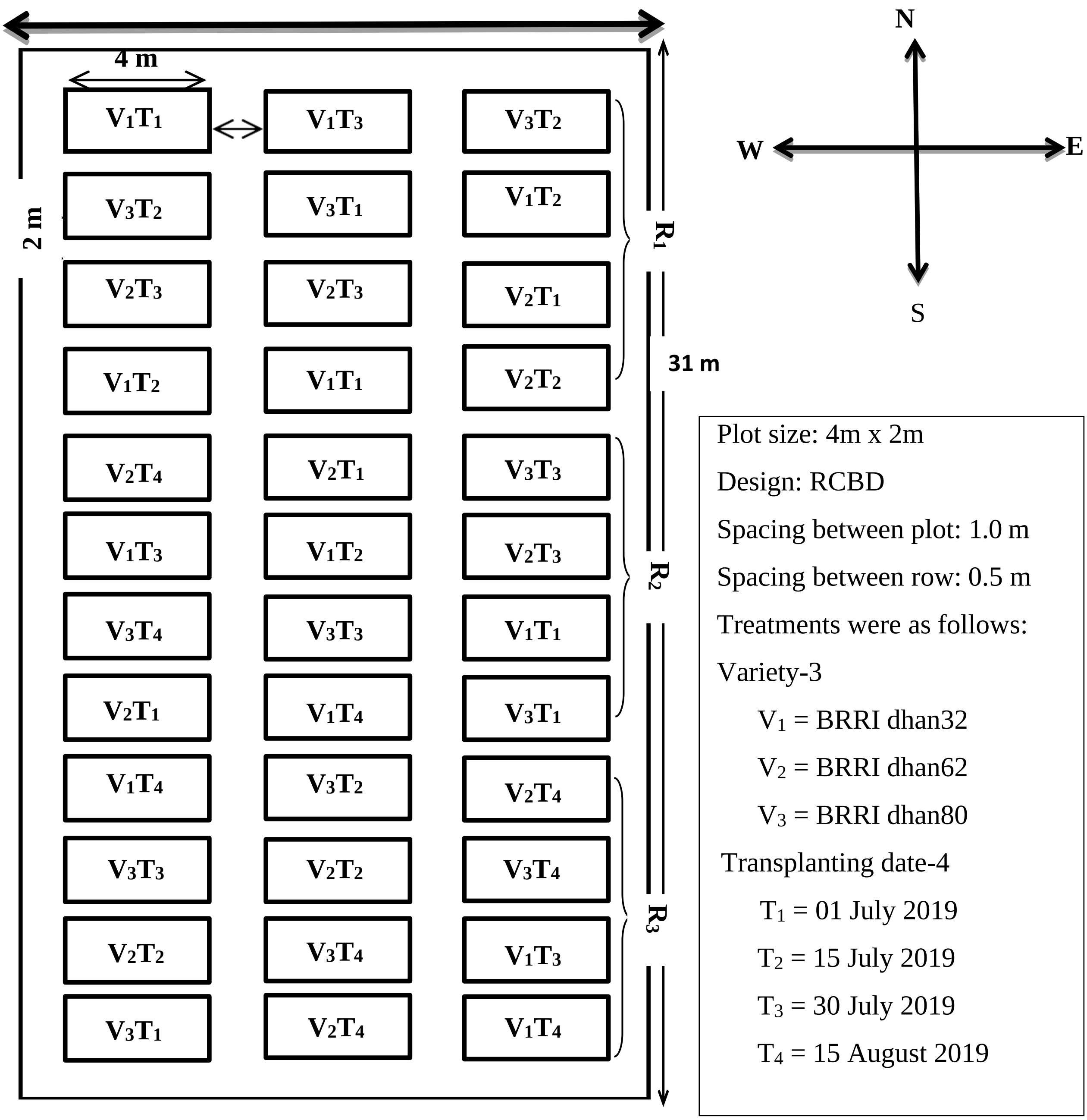


Figure 1: Layout of the experimental plot

3.6 Growing of crops

3.6.1 Preparation of seedling nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared 1m wide adding nutrients as per the requirement of soil. Seeds were sown in the seed bed on 10 June 2019, 25 June 2019, 10 July 2019 and 25 July 2019 to have 21 days old seedlings to transplant in the main field.

3.6.2 Preparation of the main field

The plot selected for the experiment was opened in the third week of June 2019 with a power tiller and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed, and finally obtained a desirable tilth of soil for transplanting of seedlings.

3.6.3 Fertilizer application

The fertilizers N, P, K, S and B fertilizers were applied in the form of urea, TSP, MP, Gypsum and borax, at the rate of 160, 100, 100, 60 and 10 kg ha^{-1}, respectively. Full amounts of TSP, MoP, Gypsum and borax were applied as basal dose before transplanting of rice. Urea was applied in 3 equal splits: one-third was applied at basal before transplanting, the second one-third at the active tillering stage (30 DAT) and the remaining one-third was applied at the panicle initiation stage (60 DAT). The dose and method of application of fertilizers are shown in Table 1.

Table 1. Dose and method of application of fertilizers in the rice field

Fertilizers	Dose (kg/ha)	Application (%)		
		Basal	1st installment	2nd installment
Urea	160	33.33	33.33	33.33
TSP	100	100	-	-
MP	100	100	-	-
Gypsum	60	100	-	-
Borax	10	100	-	-

Source: Adunik Dhaner Chase, BRRI, Joydebpur, Gazipur.

3.6.4 Uprooting and transplanting of seedlings

Seedlings were uprooted carefully from the nursery bed. Before uprooting the seedlings, the nursery bed was slightly irrigated for easier uprooting. Uprooted seedlings were transplanted in the unit plots on 01 July 2019, 15 July 2019, 30 July 2019, and 15 August 2019, respectively using two seedlings hill^{-1} maintaining spacing of 25 cm × 15 cm.

3.6.5 Intercultural operations

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

3.6.5.1 Gap filling and bund repair

Gap filling was done for all of the plots 10 days after transplanting (DAT) by planting same-aged seedlings. The bunds around individual plots were repaired as and when necessary, so that water does not move between plots.

3.6.5.2 Irrigation

Necessary irrigations were provided to the plots as and when required during the growing period of the rice crop. Fifteen days before harvest, the plots were dried to ensure the maturation of the crop.

3.6.5.3 Weeding

The plots were infested with some common weeds, which were removed by uprooting them from the field three times at 15, 30, and 45 DAT during the period of the cropping season.

3.6.5.4 Insect and pest control

There was no infestation of diseases in the field but leaf roller (*Chaphalocrosis medinalis*, Pyralidae, Lepidoptera) was observed in the field and they were controlled by applying Malathion @ 1.12 L per ha.

3.7 Crop harvest

The rice plant was harvested depending upon the maturity of grains and harvesting was done with the help of sickle from each plot. The maturity of crop was determined when 80-90% of the grains become golden yellow. Enough care was taken for harvesting, threshing and also cleaning of rice seed. Crops of the central 1 m^2 area were harvested in each plot for taking grain and straw yield. For taking yield attributes data, 10 hills were collected from each plot outside the harvested area. Fresh weight of grain and straw were recorded plot-wise. Finally, the weight was adjusted to a moisture content of 14%. The straw was sun-dried and the yields of grain and straw $plot^{-1}$ were recorded and converted to t ha^{-1}.

3.8 Seed quality test

Seed quality test was under taken in the agronomy laboratory of SAU. Dried and clean seeds were collected from each plot and used for quality tests. For the quality test, 50 seeds of each plot were set in Petridis using sand media.

3.9 Data collection

The following data was recorded-

A. Plant characters data

i. Plant height (cm)
ii. Tillers hill^{-1} (no.)

B. **Yield attributes and yield data**

i. Effective tillers hill^{-1} (no.)
ii. Non-effective tillers hill^{-1} (no.)
iii. Total tillers hill^{-1} (no.)
iv. Panicle length (cm)
v. Filled grain panicle^{-1} (no.)
vi. Unfilled grain panicle^{-1} (no.)
vii. Total grain panicle^{-1} (no.)
viii. Weight of 1000 grain (g)
ix. Grain yield (t ha^{-1})
x. Straw yield (t ha^{-1})
xi. Biological yield (t ha^{-1})
xii. Harvest index (%)

C. Seed quality parameters data

Dried and clean seeds of each plot were taken separately from which the following seed quality parameters data were taken-

i. Germination percentage
ii. Seedling root and shoot length (cm)
iii. Seedling root and shoot dry weight (g)
iv. Vigor index

3.9.1 Detailed data recording

3.9.1.1 Plant height

The height of the plant was recorded in centimeter (cm) at the time of 30, 60, 90 DAT, and the harvesting stage. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the leaf.

3.9.1.2 Tillers hill^{-1}

The number of tillers hill^{-1} was recorded at the time of 30, 60, 90 DAT, and at harvest by counting total tillers. Data were recorded as the average of 5 hills selected at random from the inner rows of each plot.

3.9.1.3 Effective tillers hill^{-1}

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

3.9.1.4 Non-effective tillers hill^{-1}

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

3.9.1.5 Total tiller hill^{-1}

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

3.9.1.6 Panicle length

The length of the panicle was measured with a meter scale from 10 selected panicles and the average value was recorded to have the length of the panicle in cm.

3.9.1.7 Filled grains panicle^{-1}

Filled grain panicle^{-1} was taken from 20 randomly selected panicles of each plot. The grains which have something inside were considered as filled grain. The average number of grains of 20 panicles was recorded to have grains panicle^{-1}.

3.9.1.8 Unfilled grains panicle^{-1}

The numbers of unfilled grains were counted randomly from selected 20 panicles of each plot and averaged them to have unfilled grain panicle^{-1}. The grain which has nothing inside was considered as unfilled grain panicle^{-1}.

3.9.1.9 Total grains panicle^{-1}

The total numbers of filled and unfilled grains were counted from randomly selected 20 panicles of each plot and average them to have total grains panicle^{-1}. The number of filled and unfilled grains was termed as total grains panicle^{-1}.

3.9.1.10 Weight of 1000 grain

One thousand grains were counted randomly from the harvested grains of each plot and then weighed with an electric balance in grams and recorded.

3.9.1.11 Grain yield

The grains of the central 1 m^2 harvested area were cleaned and dried properly. Then weighted in an electric balance and converted the weight to t ha^{-1}. The grain weight was adjusted at 14% moisture content of grains.

3.9.1.12 Straw yield

The straw of the harvested 1 m^2 area was sundried properly and then weighted. The weight was then converted into t ha^{-1}.

3.9.1.13 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.

3.9.1.14 Harvest index

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

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

3.9.1.15 Germination percentage

After harvesting germination test was done in the laboratory of the Department of Agronomy, SAU. Fifty seeds were placed in a Petri dish and replicated thrice. The normal seedling was counted. Finally, the total number was converted as a percentage. Germination percentage was calculated by using the following formula:

$$\text{Germination (\%)} = \frac{\text{Number of normal seedlings}}{\text{Number of seeds set for test}} \times 100$$

3.9.1.16 Shoot length and root length

From the germinated seedling, shoot length and root length were measured using a measuring scale and recorded as a centimeter (cm). Average values of 10 shoot and root were used for determining shoot and root length. Shoot and root length were taken at 14 days of seedling age.

3.9.1.17. Vigor index

Vigor index was computed by using the following formula as suggested by Baki and Anderson (1973) and expressed in number.

Vigor index = Germination (%) x (Shoot length + Root length) in cm

3.9.1.18 Shoot weight and root weight

From the germinated seedling, after taking shoot length and root length the dry weight of shoot and root was measured separately. Fourteen days old seedlings were used for this estimation. As the weight was very low, the recorded data was measured as milligram (mg).

3.10 Data analysis

The data obtained from the experiment on various parameters were statistically analyzed in the MSTAT-C computer program. The mean values for all the parameters were calculated and analysis of variance was performed. The significance of the difference among the treatment means was estimated by the Least Significant Different (LSD) at 5% levels of probability.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to observe the effect of sowing date on yield and seed quality of T. aman rice varieties. Data on different plant parameter, yield attributes, yield and seed quality parameters were recorded. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix IV-XX. The results have been presented and possible interpretations are given under the following headings:

4.1 Plant height

The plant height of T. aman rice was significantly influenced by varieties at different days after transplanting (DAT) (Fig. 2). The figure shows that plant height increased gradually with advances of growth stages irrespective of varieties. The highest/increase was found at the harvest stage. However, numerically at 30 DAT, the variety BRRI dhan32 produced the tallest plant (45.94 cm) and the variety BRRI dhan62 gave the shortest plant (39.44 cm). At 60 DAT, 90 DAT, and at harvest, BRRI dhan32 gave the highest plant height (90.45, 118.64 and 118.8 cm, respectively) and BRRI dhan62 produce the shortest plant (82.67, 95.50 and 98.04 cm, respectively). This variation in the plant height of the cultivars is probably due to the genetic make-up of the varieties. The results of the experiment are in agreement with Reza (2016), who observed the tallest plant at harvest (137.00 cm) in the case of Bashiraj and the lowest plant highest at harvest (87.05 cm) in the case of Bina dhan-7.

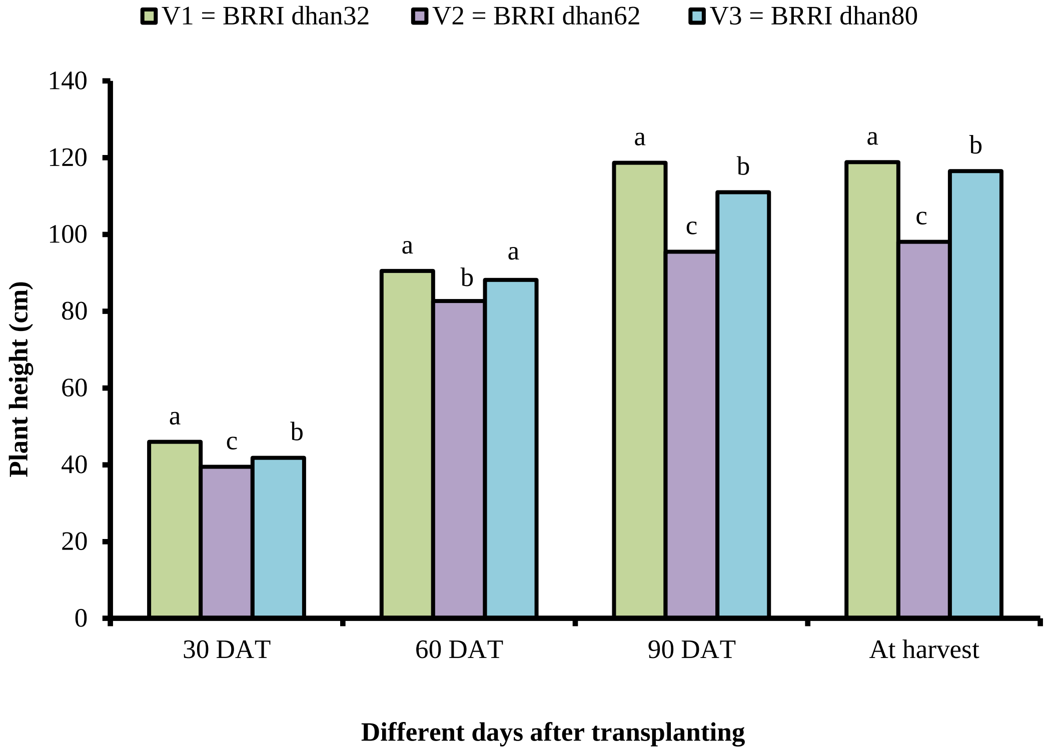


Figure 2. Effect of variety on plant height at different days after transplanting ($LSD_{0.05}$ = 1.28, 2.57, 1.74 and 4.79 at 30, 60, 90, and at harvest, respectively)

Date of transplanting exerted a significant effect on plant height at 30, 60, 90 DAT and at harvest (Fig. 3). At the different days after transplanting (DAT) the tallest plant (44.45 cm, 94.04 cm, 114.34 cm and 115.23 cm) of T. aman at 30, 60, 90 DAT and at harvest, respectively was observed for transplanting of seedling on 30 July (T_3). On the other hand, at the same DAT, the shortest plant (40.44 cm, 80.65 cm, 102.25 cm and 108.9 cm) was observed for transplanting on 15 August. Plant height was significantly influenced by the date of transplanting was also reported by Hossain and Sikdar (2009), who find that the earlier planting dates had a higher response, which gradually decreased with the delays in planting dates. The longest plant height (142.4 cm) was obtained from 15 July and the shortest (117.05 cm) from 14 August transplanting. This might be because the optimum date of transplanting (which in this case was 30 July) enables the crop to complete its vegetative phase in favorable climatic conditions.

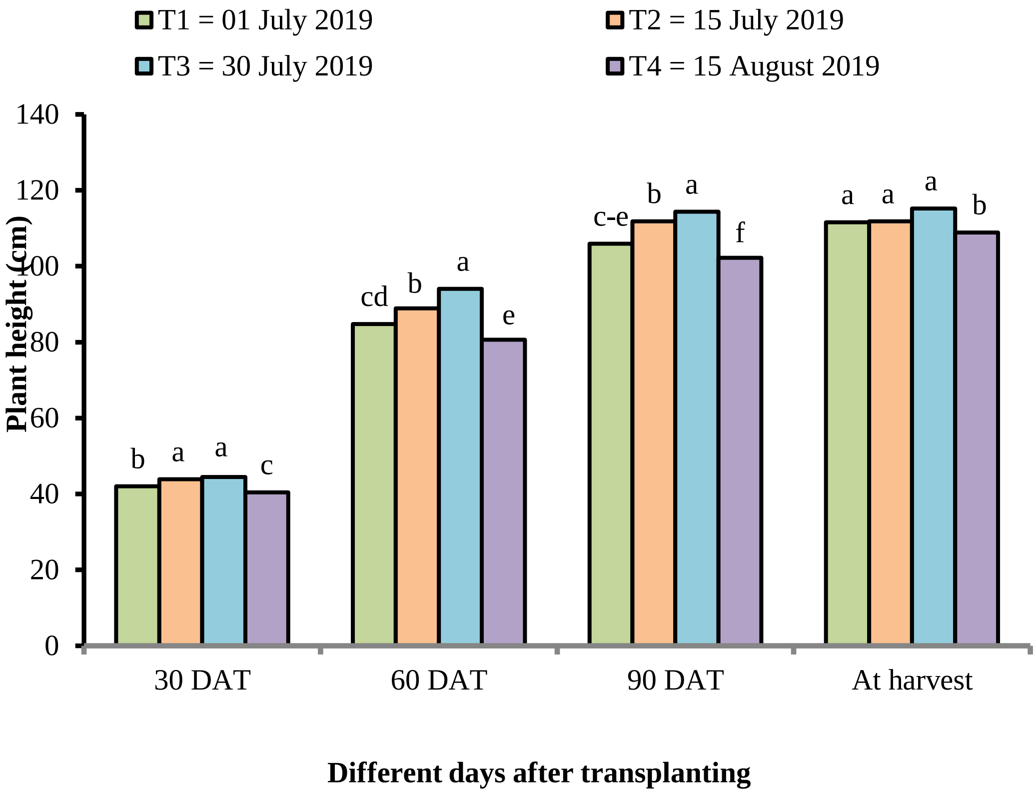


Figure 3. Effect of transplanting date on plant height of T. aman rice at different days after transplanting ($LSD_{0.05}$ = 1.47, 2.97, 2.01 and 5.53 at 30, 60, 90, and at harvest, respectively)

Interaction of variety and date of transplanting showed a significant variation on plant height of rice at 30 DAT, 60 DAT, 90 DAT and at harvest (Table 1). At 30 DAT, the longest plant (49.01 cm) was observed from the V_1T_3 (BRRI dhan32 transplanting on 30 July) treatment and the shortest plant (37.68 cm) was observed from V_2T_4 (BRRI dhan62 transplanting on 15 August) treatment. Similarly at 60 DAT, 90 DAT, and at harvest, the highest plant height (98.84 cm, 123.15 cm, and 124.52 cm, respectively) was observed from the V_1T_3 (BRRI dhan32 transplanting on 30 July) treatment and the lowest plant height (76.18 cm, 90.17 cm, and 92.58 cm, respectively) was observed from V_2T_4 treatment. The variation is due to varietal characters and also late transplanting. Late transplanting means adverse temperature and it leads to a short vegetative growth period which might have affected the plant height.

Table 1. Combined effect of variety and transplanting date on plant height of T. aman rice at different days after transplanting

Treatment	Plant height (cm)			
	30 DAT	60 DAT	90 DAT	Harvest
V_1T_1	45.25 bc	87.22 cd	116.67 bc	117.35 bc
V_1T_2	45.49 b	92.26 bc	121.51 a	122.53 a
V_1T_3	49.01 a	98.84 a	123.15 a	124.52 a
V_1T_4	44.02 b-d	83.47 de	113.24 cd	115.64 c
V_2T_1	39.39 fg	88.47 c	91.37 i	94.57 i
V_2T_2	39.94 fg	85.86 d	98.78 hi	102.45 gh
V_2T_3	40.76 ef	80.19 fg	102.27 fg	104.66 f
V_2T_4	37.68 g	76.18 g	90.17 i	92.58 j
V_3T_1	41.36 d-f	94.82 b	117.64 b	105.82 f
V_3T_2	42.66 c-e	88.71 c	115.32 c	109.25 d-f
V_3T_3	43.59 b-d	86.86 d	107.53 de	117.32 bc
V_3T_4	39.63 fg	82.31 f	103.34 f	91.19 j
LSD (0.05)	**2.50**	**3.94**	**3.40**	**5.58**
CV (%)	**3.56**	**3.98**	**1.86**	**1.85**

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

[V_1=BRRI dhan32; V_2=BRRI dhan62; V_3= BRRI dhan80; T_1= 01 July; T_2= 15 July; T_3 = 30 July; and T_4 = 15 August]

4.2 Tillers hill^{-1}

The number of tillers per hill of T. aman rice was significantly influenced by different varieties at 30, 60, and 90 DAT and at harvest (Table 2). The result revealed that at 30 DAT, the variety BRRI dhan32 (V_1) produced the highest number of tillers hill^{-1} (3.80) and the variety BRRI dhan62 (V_2) gave the lowest number of hill^{-1} (2.95). At 60 DAT, the variety BRRI dhan32 (V_1) produced the highest number of tillers hill^{-1} (13.38) which was at par with V_3 and the variety BRRI dhan62 (V_2) gave the lowest number of hill^{-1} (11.13) and the same trend was observed for those varieties at 90 DAT. At harvest, the variety BRRI dhan32 gave the highest number of tillers per hill (19.14) which was statistically similar with V_3 (17.57) treatment and the variety BRRI dhan62 gave the lowest (16.92). The number of tillers hill^{-1} can be different in different varieties due to genetic build-up of the varieties. Hossain and Sikdar (2009) found that, the number of tillers hill^{-1} at different days after transplanting varied significantly among the varieties up to harvest where the maximum number of tillers hill^{-1} was observed in Badshabhog and minimum in BRRI dhan34.

Statistically significant variation was recorded for the total number of tillers per hill of T. aman rice by the date of Transplanting on 30 DAT, 60 DAT, 90 DAT and at harvest (Table 2). At the different days after transplanting, the maximum number of total tillers per hill (4.01, 13.08, 17.59, and 20.76) was observed from T_3 (Transplanting on 30 July). Again, at the same DAT the minimum number of tillers per hill (2.84, 11.40, 12.56, and 15.36) was observed from T_4 (Transplanting on 15 August). These results are in conformity with the findings of Mahmud (2014) who found a marked effect of the total number of tillers m^{-2} due to different transplanting date. He found the highest number of tiller m^{-2} when transplanting on 26 July and lowest when Transplanting on 15 August. The optimum date of transplanting increases the vegetative growth and enhances the rice plant to produce more tillers. In case of 30 July was the optimum date of transplanting for all the varieties to produce the highest number of tillers per hill.

Interaction of varieties and date of transplanting showed a significant variation on the number of tillers hill^{-1} of T. aman rice at 30, 60, 90 DAT and at harvest (Table 2). At 30 DAT, the highest number of tiller hill^{-1} (4.82) was observed from the V_1T_3 (BRRI dhan32 transplanting on 30 July) treatment, whereas, the lowest (2.51) was observed from V_2T_4 (BRRI dhan62 transplanting on 15 August) treatment, which was statistically similar with V_2T_1 (2.59) and V_3T_4 (2.62). Similarly, at 60 DAT, 90 DAT, and at harvest, the highest number of tillers hill^{-1} (14.56, 19.49, and 22.11) was observed from the V_1T_3 treatment respectively and the lowest (10.50, 11.36, and 14.38) was observed from V_2T_4 treatment.

Table 2. Effect of variety, date of transplanting and their interaction on tiller number per hill of T. aman rice at different days after transplanting (DAT)

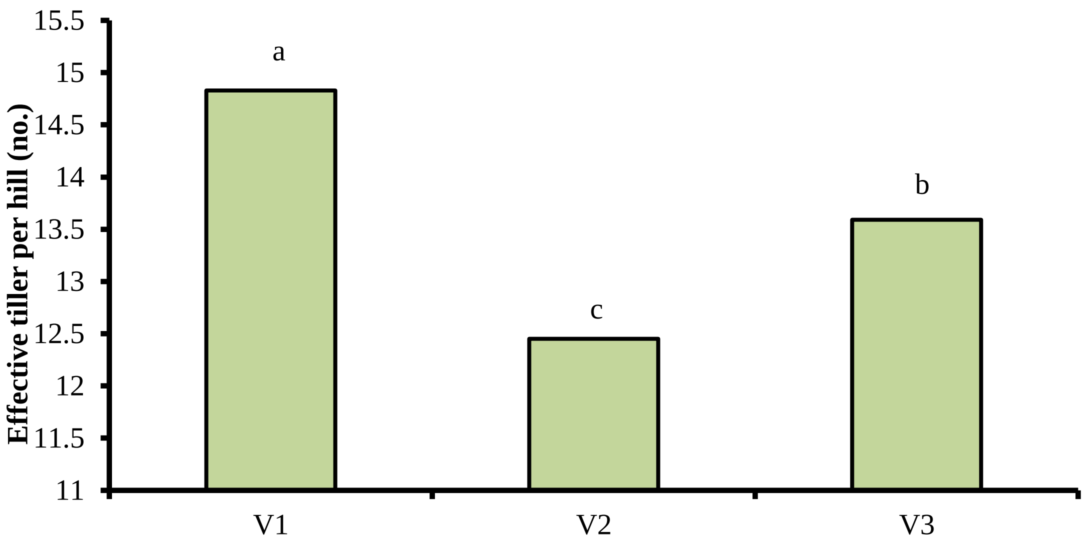
Treatment	Number of total tiller hill^{-1}			
	30 DAT	60 DAT	90 DAT	Harvest
Different T. aman rice variety				
V_1	3.87 a	13.38 a	16.05 a	19.14 a
V_2	2.95 c	11.13 b	13.38 b	16.92 b
V_3	3.30 b	11.99 ab	15.30 a	17.57 ab
LSD (0.05)	**0.16**	**0.53**	**0.64**	**0.78**
CV (%)	**5.42**	**5.84**	**5.09**	**5.79**
Date of transplanting				
T_1	3.21 bc	11.82 b	13.79 bc	16.53 c
T_2	3.43 b	12.36 ab	15.59 b	19.04 ab
T_3	4.01 a	13.08 a	17.59 a	20.76 a
T_4	2.84 c	11.40 b	12.56 c	15.36 d
LSD (0.05)	**0.18**	**0.61**	**0.74**	**0.90**
CV (%)	**5.42**	**5.48**	**5.09**	**5.79**
Combination of different variety and date of transplanting				
V_1T_1	3.74 b	13.26 b	14.89 d-f	17.81 b-d
V_1T_2	3.53 b-e	13.08 bc	16.67 bc	20.04 a-d
V_1T_3	4.82 a	14.56 a	19.49 a	22.11 a
V_1T_4	3.38 c-e	12.61 b-d	13.16 e-g	16.59 b-d
V_2T_1	2.59 f	10.66 ef	12.63 fg	15.58 b-d
V_2T_2	3.20 e	11.50 d-f	14.01 d-f	17.94 a-d
V_2T_3	3.49 b-e	11.85 c-e	15.13 c-f	19.77 a-c
V_2T_4	2.51 f	10.50 f	11.36 g	14.38 d
V_3T_1	3.30 de	11.53 d-f	13.83 c-e	16.20 b-d
V_3T_2	3.56 b-d	12.49 b-d	16.10 b-d	19.13 a-d
V_3T_3	3.71 bc	12.83 b-d	18.08 b	20.22 ab
V_3T_4	2.62 f	11.10 ef	13.15 d-f	15.12 cd
LSD (0.05)	**0.31**	**1.05**	**1.28**	**1.69**
CV%	**5.42**	**5.84**	**5.09**	**5.79**

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

[V_1=BRRI dhan32; V_2=BRRI dhan62; V_3= BRRI dhan80; T_1= 01 July; T_2= 15 July; T_3 = 30 July; and T_4 = 15 August]

4.3 Effective tillers hill^{-1}

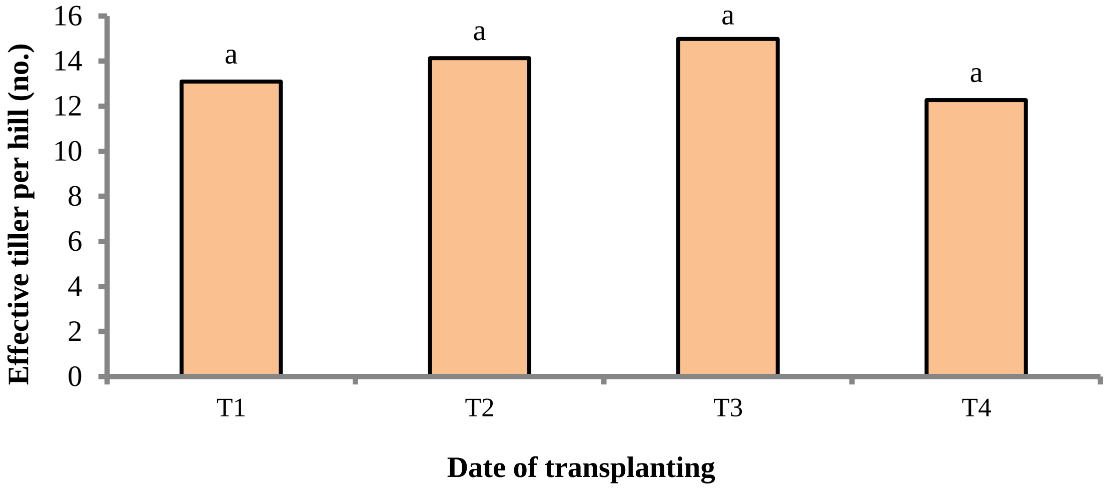
The number of effective tillers hill^{-1} of T. aman rice was significantly influenced by the three tested varieties (Fig. 4). The result revealed that the variety BRRI dhan32 produced the highest number of effective tillers hill^{-1} (14.83) and the variety BRRI dhan62 gave the lowest number of effective tillers hill^{-1} (12.45) which was statistically similar with BRRI dhan80 (13.59). Differences in the number of effective tillers per hill may perhaps be the differences in the genetic makeup of the varieties. Reza *et al.* (2016) have seen the same results in four aman varieties cultivars of rice and have concluded that the effective tillers hill^{-1} was significantly influenced by variety.



V_1=BRRI dhan32; V_2=BRRI dhan62; V_3=BRRI dhan80

Figure 4. Effect of varieties on number of effective tillers per hill of T. aman rice ($LSD_{0.05}$ = 1.07)

The number of effective tillers hill^{-1} of T. aman rice was not significantly influenced by the date of transplanting (Fig. 5). However, numerically, the maximum number of effective tillers hill^{-1} (14.99) was found from T_3 (Transplanting on 30 July). On the other hand, the minimum number of effective tillers per hill (12.27) was recorded when the seedling was planted on 15 August. So, it can be concluded that transplanting on 15 August would reduce the number of effective tillers. The ability of the rice tiller to produce panicle or the panicle initiation (PI) stage greatly depends on both photoperiod and temperature. If the varieties are non-photosensitive the PI stage may not be influenced by photoperiod but as these varieties are highly susceptible to temperature stress and as both photoperiod and temperature greatly depends on the date of transplanting, this is why the optimum date of transplanting greatly influenced the production of the number of effective tillers hill^{-1}.



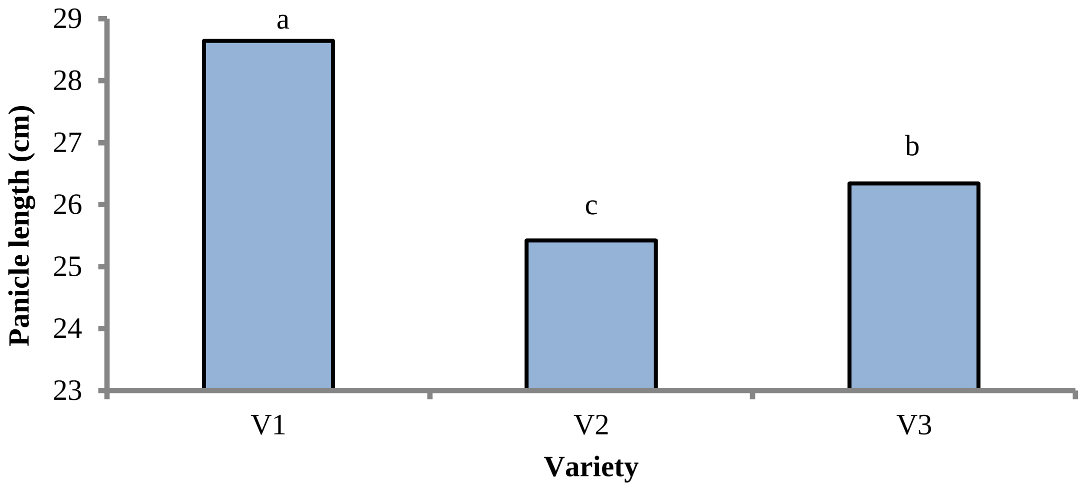
T_1= 01 July; T_2= 15 July; T_3 = 30 July and T_4 = 15 August

Figure 5. Effect of date of transplanting on number of effective tillers per hill of T. aman rice ($LSD_{0.05}$ = NS)

Interaction of varieties and date of transplanting showed significant variation in the number of effective tillers hill^{-1} of T. aman rice (Table 3). The highest number of effective tillers hill^{-1} (16.43) was observed from the V_1T_3 (BRRI dhan32 transplanting on 30 July) treatment which was statistically at par with V_3T_3 (15.10) and V_1T_2 (15.39) whereas, the lowest (11.32) was observed from V_2T_4 (BRRI dhan62 transplanting on 15 August).

4.4 Panicle length

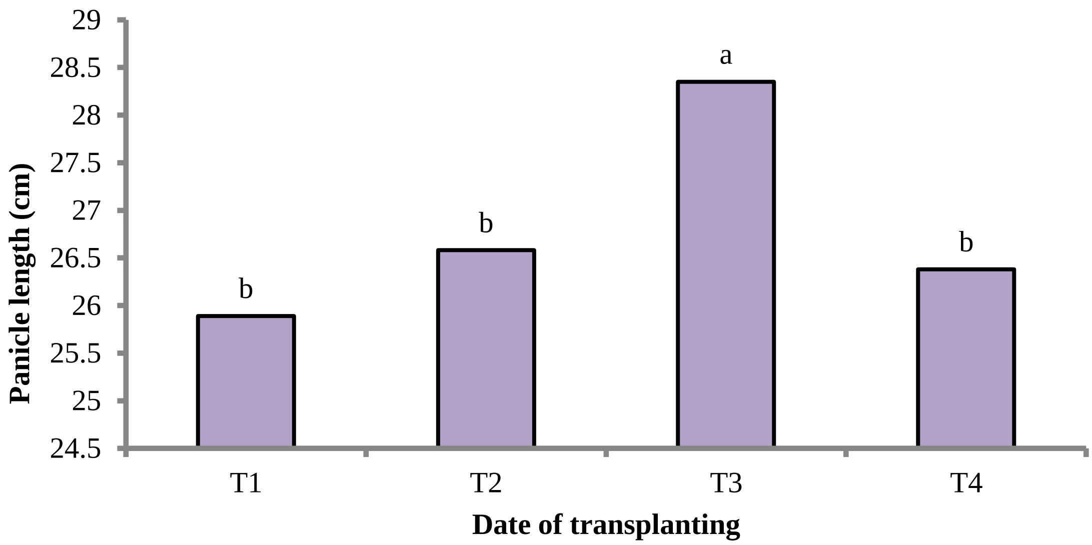
The panicle length of T. aman rice was significantly influenced by different varieties (Fig. 6). The longest panicle (28.64 cm) was observed in the V_1 (BRRI dhan32) which was statistically at par with V_3 (27.14 cm) and the shortest (25.42 cm) was obtained from the variety V_2 (BRRI dhan62). Mahmud (2014) have seen the same results in seven aman cultivars of rice in rainfed condition and have concluded that the panicle length was not significantly influenced by variety.



V_1=BRRI dhan32; V_2=BRRI dhan62; V_3=BRRI dhan80

Figure 6. Effect of variety on panicle length of T. aman rice ($LSD_{0.05}$ = 1.14)

The panicle length (cm) of T. aman rice was statistically significant due to different date of transplanting (Fig. 7). The longest panicle (28.35 cm) was recorded from T_3 (Transplanting on 30 July) treatment. On the other hand, the lowest length of the panicle (25.89 cm) was observed from T_1 (Transplanting on 01 July). Mahmud (2014) have seen similar results in seven aman cultivars of rice in rainfed condition and have concluded that the panicle length was not significantly influenced by the date of transplanting.



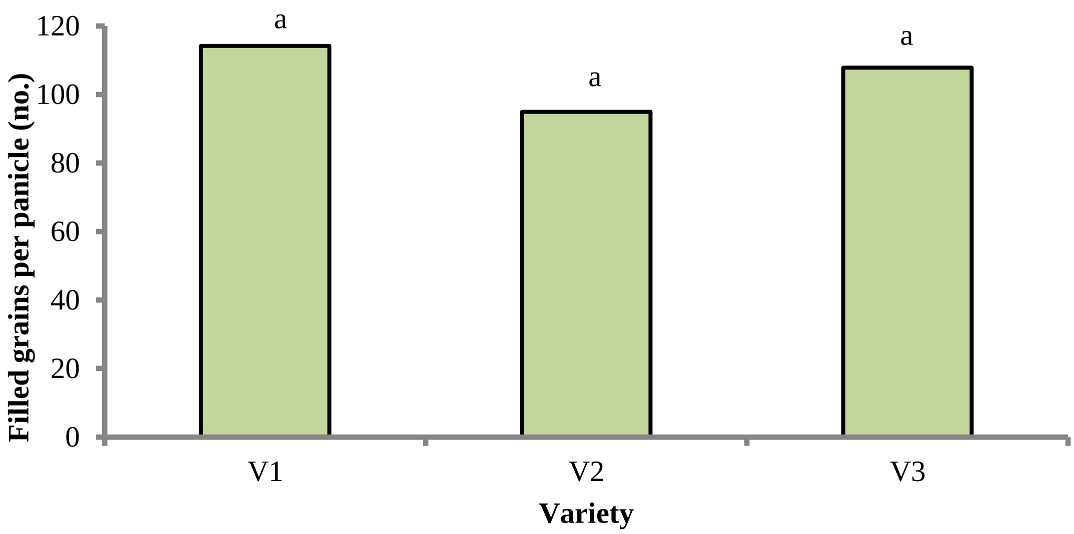
T_1= 01 July; T_2= 15 July; T_3 = 30 July and T_4 = 15 August

Figure 7. Effect of date of transplanting on panicle length of T. aman rice ($LSD_{0.05}$ = 1.32)

Significant influence was observed on panicle length due to the different combination of varieties and the date of transplanting of T. aman rice (Table 3). The highest length of panicle (30.84 cm) was obtained from V_1T_3 (BRRI dhan32 when transplanting on 30 July). In contrast, the lowest number of panicle length (22.95 cm) was recorded from the treatment combination V_2T_4 (BRRI dhan62 when transplanting on 15 August).

4.5 Filled grains panicle^{-1}

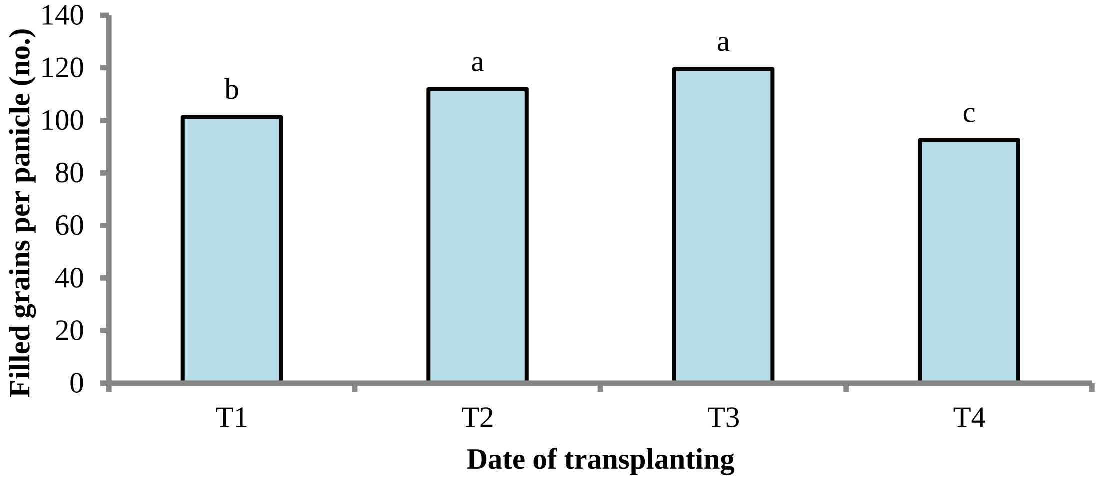
The number of filled grains panicle^{-1} of T. aman rice was not significantly influenced by different varieties (Fig. 8). Numerically, the result revealed that the variety BRRI dhan32 produced the highest number of filled grains panicle^{-1} (114.16) and the variety BRRI dhan65 gave the lowest number of filled grains panicle^{-1} (94.98). This may be due to varietal difference. Reza *et al.* (2016) reported a variable number of grains panicle^{-1} among varieties. Varietal differences regarding the number of grains panicle^{-1} might be due to varietal differences in photosynthetic assimilate accumulation especially after heading.



V_1=BRRI dhan32; V_2=BRRI dhan62; V_3=BRRI dhan80

Figure 8. Effect of different T. aman rice varieties on number of filled grains panicle^{-1} ($LSD_{0.05}$ =NS)

The number of grains panicle^{-1} of T. aman was significantly affected by different dates of transplanting (Fig. 9). The maximum number of filled grain per panicle (119.59) was found from T_3 (Transplanting on 30 July) which was statistically identical with T_2 (119.59). On the other hand, the minimum (92.50) was recorded from T_4 (Transplanting on 15 August) treatment. The optimum date of transplanting increases assimilate accumulation in grains.



T_1= 01 July; T_2= 15 July; T_3 = 30 July and T_4 = 15 August

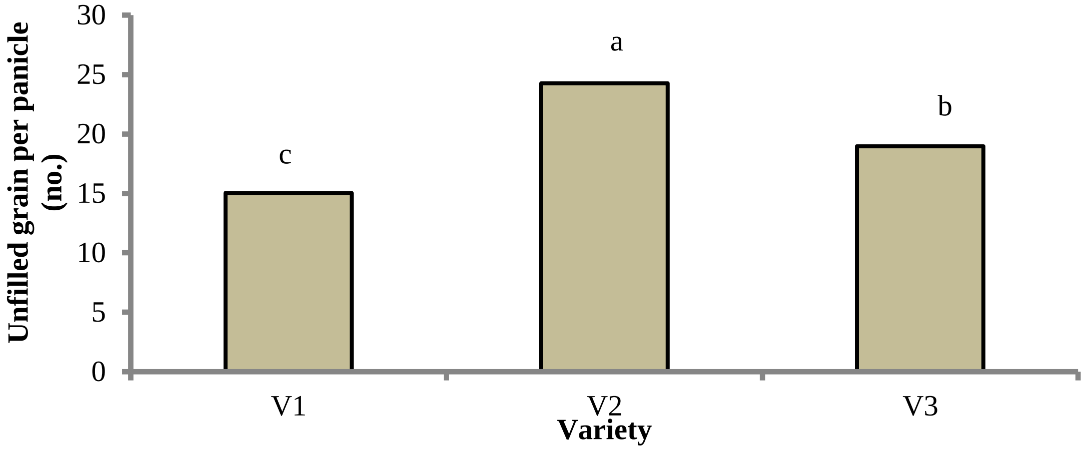
Figure 9. Effect of different date of transplanting on number of filled grains panicle^{-1} of T. aman rice ($LSD_{0.05}$ =8.41)

Significant influence was observed on the number of filled grains panicle^{-1} due to the combination of variety and different dates of transplanting of T. aman rice (Table 3). The highest number of filled grains (132.18) panicle^{-1} was observed from V_1T_3 which was statistically similar to V_3T_3 and V_1T_2, V_2T_3, V_2T_3, V_3T_4, V_3T_2, and V_2T_2 (120.75 and 122.46, respectively), and the lowest (82.87) was recorded from combination V_2T_4 treatment which was at par with V_1T_1, V_3T_4 and V_1T_4. Filled grains panicle^{-1} is one of the most important yield contributing parameters in the case of grains panicle^{-1}. In this study it was observed that BRRI dhan32 gave higher filled grains panicle^{-1} among the three varieties. On the other hand, T. aman rice transplanting on 30 July perform better in the case of the number of filled grains panicle^{-1}. These results were consistent with those of Naha (2007) and Kamal (2006) who also observed significant variation among the interaction effects of varieties and transplanting date.

4.6 Unfilled grains panicle^{-1}

The number of unfilled grains panicle^{-1} of T. aman rice was significantly influenced by different varieties (Fig. 10). The result revealed that the variety BRRI dhan62 produced the highest number of unfilled grains panicle^{-1} (24.27) and the variety BRRI dhan32 gave the lowest number of unfilled grains panicle^{-1} (15.05). Mahmud (2014) observed that BRRI dhan56 produced the highest number of unfilled grains panicle^{-1}

(21.71) followed by BRRI dhan33 (19.88), and BRRI hybrid dhan4 (19.21) which correlates with the present finding in the unfilled grains panicle^{-1} among the varieties.



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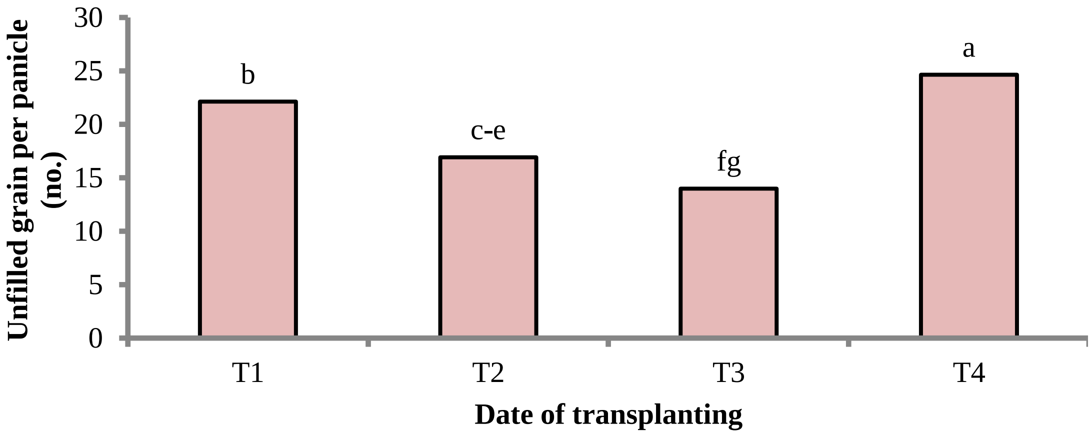
V_1=BRRI dhan32; V_2=BRRI dhan62; V_3=BRRI dhan80

Figure 10. Effect of different T. aman rice varieties on number of unfilled grains panicle^{-1} ($LSD_{0.05}$ = 3.53)

The number of unfilled grains panicle^{-1} of T. aman rice showed statistically significant variation due to different dates of transplanting (Fig. 11). The minimum number of unfilled grains pancle^{-1} (13.99) was recorded from T_3 (Transplanting 30 July). On the other hand, the maximum number of unfilled grains per panicle (24.65) was recorded from T_4 (Transplanting 15 August). These results are in conformity with the findings of Mumin (2002) who found a marked effect of date of transplanting to the number of unfilled grains panicle^{-1}.



T_1= 01 July; T_2= 15 July; T_3 = 30 July and T_4 = 15 August

Figure 13. Effect of different date of transplanting on number of unfilled grain per panicle of T. aman rice ($LSD_{0.05}$ =0.61)

The combination of variety and date of transplanting showed significant influence on the number of sterile or unfilled grains panicle^{-1} (Table 3). From the interaction of V_2T_4 (BRRI dhan62 when transplanting on 15 August), the highest number of unfilled grain panicle^{-1} (31.07) was obtained whereas the lowest (10.73) was recorded from the interaction of V_1T_3 (BRRI dhan32 when transplanting on 30 June). BRRI dhan32 gave lower unfilled grains panicle^{-1} among the three varieties. On the other hand, 30 July transplanting may enhance suitable condition to produce enough photosynthates to fill the grain and BRRI dhan32 produced the highest photosynthates for grain fillings. 15 August transplanting reduced the amount of assimilates of photosynthesis, transportation and storing of assimilates in the grain drastically reduced than 30 July transplanting.

Table 3. Combined effect of variety and different date of transplanting on effective tillers hill^{-1}, panicle length, filled grains panicle^{-1} and unfilled grains panicle^{-1} of T. aman rice

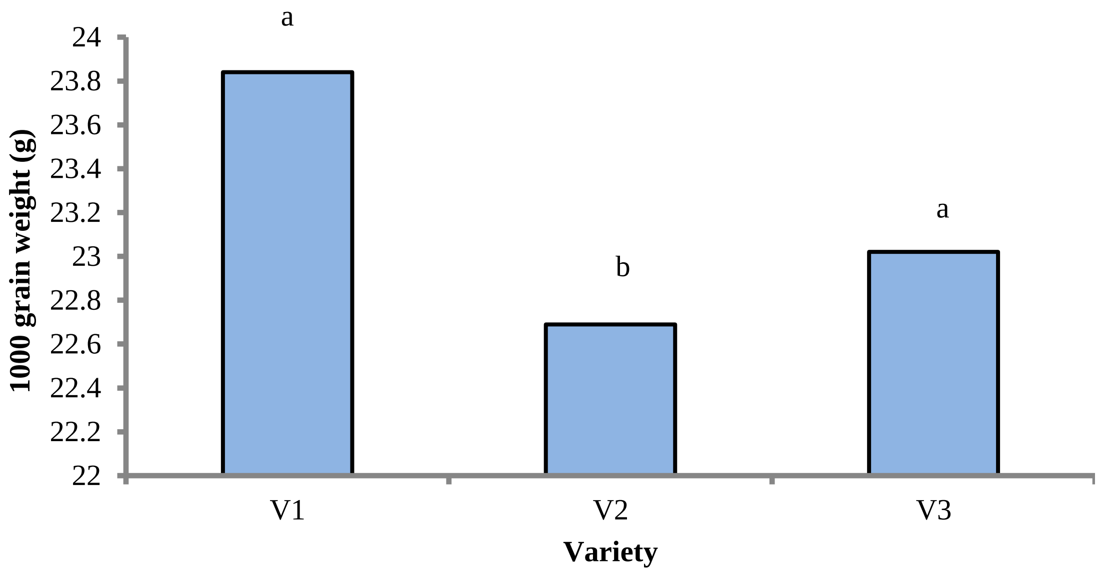
Treatment	Effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)
V_1T_1	14.09 c-e	27.64 bc	110.53 b	17.26 kl
V_1T_2	15.39 a	28.32 b	122.46 a	13.90 mn
V_1T_3	16.43 a	30.84 a	132.18 a	10.73 o
V_1T_4	13.41 de	26.75 bc	99.45 bc	18.29 k
V_2T_1	12.05 c-e	23.86 de	90.55 c	27.89 b-e
V_2T_2	12.98 b-d	24.97 b-e	100.67 b	26.79 f
V_2T_3	13.45 bc	25.92 b-d	105.83 b	17.31 kl
V_2T_4	11.32 e	22.95 e	82.87 c	31.07 a
V_3T_1	13.14 c-e	26.09 b-e	102.95 b	21.28 ij
V_3T_2	14.03 b-d	26.57 b-d	112.53 b	16.10 l
V_3T_3	15.10 a	27.27 b-d	120.75 a	13.93 mn
V_3T_4	12.09 e	25.42 c-e	95.17 bc	24.60 gh
LSD (0.05)	**1.36**	**2.26**	**17.54**	**1.03**
CV%	**6.05**	**5.08**	**6.56**	**2.94**

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

[V_1=BRRI dhan32; V_2=BRRI dhan62; V_3= BRRI dhan80; T_1= 01 July; T_2= 15 July; T_3 = 30 July; and T_4 = 15 August]

4.7 Weight of 1000-grain

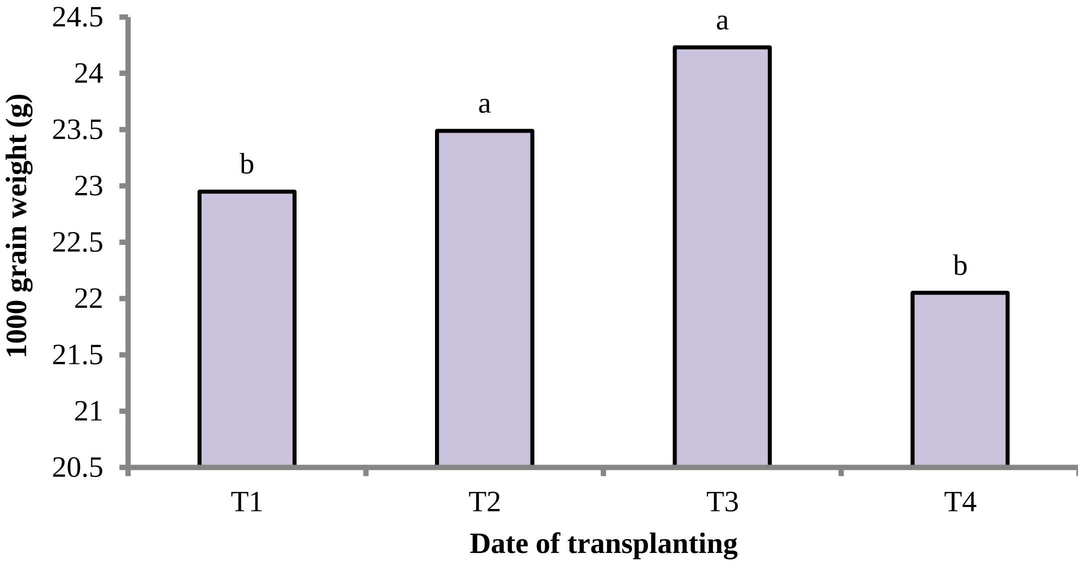
The weight of 1000-grain of T. aman rice was significantly influenced by different varieties (Fig. 12). The result revealed that the variety BRRI dhan32 produced the highest 1000-grain weight (23.84 g) and the variety BRRI dhan62 gave the lowest 1000-grain weight (22.69 g). Mahmud (2014) observed that the highest 1000 grain weight was recorded from BRRI dhan33 (21.64 g) and the lowest from BRRI dhan57 (21.64 g). Islam *et al.* (1999) stated that the weight of thousand grains of modern high-yielding T. aman varieties does not differ significantly.



V_1=BRRI dhan32; V_2=BRRI dhan62; V_3=BRRI dhan80

Figure 12. Effect of variety on 1000-grain weight of T. aman rice ($LSD_{0.05}$ =1.03)

The weight of 1000-grain of T. aman rice showed statistically significant variation due to different date of transplanting (Fig. 13). The highest weight of 1000 seeds (24.23 g) was obtained when transplanting was done on 30 July. On the other hand, the minimum weight of 1000 grains (22.05 g) was observed from T_4 (Transplanting on 15 August).



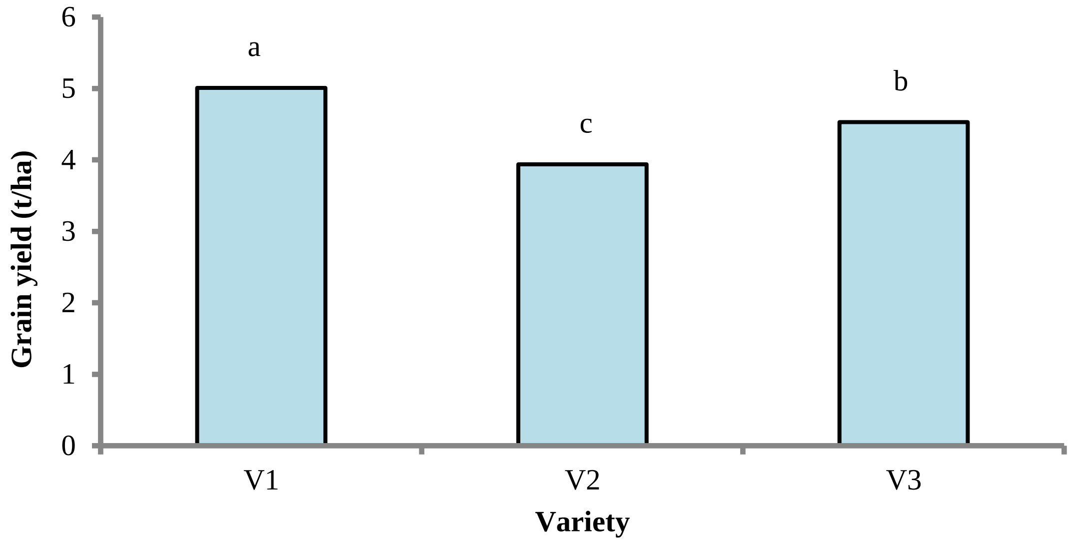
T_1= 01 July; T_2= 15 July; T_3 = 30 July and T_4 = 15 August

Figure 13. Effect of transplanting date on 1000 grains weight of T. aman rice ($LSD_{0.05}$ = 1.19)

The thousand grain weight of T. aman rice is significantly influenced by the combined effect of variety and date of transplanting (Table 4). The height 1000-grain weight (24.88 g) was recorded from V_1T_3 (BRRI dhan32 when transplanting on 30 July). On the other hand, the lowest 1000-grain weight was obtained from V_2T_4 (BRRI dhan62 when transplanting on 15 August) treatment.

4.8 Grain yield

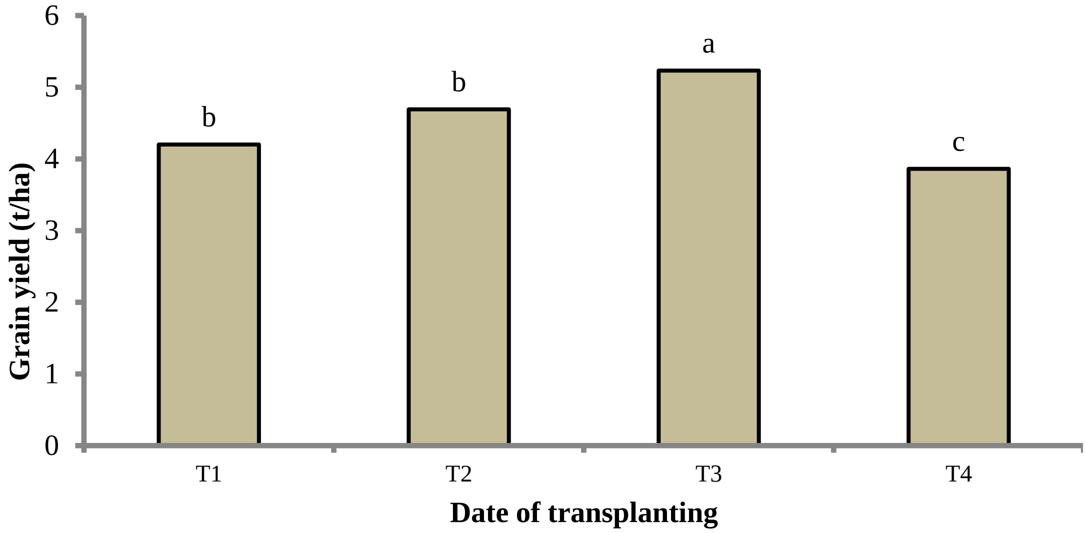
Grain yield (t ha^{-1}**)** of T. aman rice was significantly influenced by different varieties (Fig. 14). The result revealed that the variety BRRI dhan32 produced the highest grain yield (5.01 t ha^{-1}) and the variety BRRI dhan62 gave the lowest grain yield (3.94 t ha^{-1}), which indicates that BRRI dhan32 out yielded over BRRI dhan80 and BRRI dhan62 by producing 10.60% and 27.15% higher yield, respectively. Hossain and Sikdar (2009) observed that the highest number of effective tillers $hill^{-1}$ (11.42) eventually contributed to higher grain yield (2.59 t ha^{-1}) of BRRI dhan34, which indicates that yield variation among the varieties may be attributed to the genetic makeup of the varieties.



V_1=BRRI dhan32; V_2=BRRI dhan62; V_3=BRRI dhan80

Figure 14. Effect of variety on grain yield of T. aman rice ($LSD_{0.05}$ =0.49)

Grain yield was significantly affected by different dates of transplanting. The highest grain yield of 5.23 t ha^{-1} was obtained at 30 July transplanting (Fig. 15). The second highest grain yield of 4.69 t ha^{-1} was obtained with 15 July transplanting which was statistically similar to 01 July transplanting. Yield decreased by delay in transplanting. The lowest (3.86 tha^{-1}) yield was obtained from the 15 August transplanting. This happened probably due to optimum temperature and moisture received by the plants on 30 July transplanting than 15 August transplanting and stress condition was apparent for 15 August transplanting. This might be because 15 July transplanting rice completed its vegetative phase in favorable climatic condition and then started panicle initiation while in late transplanted (15 August) crops seed filling was less due to decrease in temperature at that stage. Optimum vegetative and reproductive period resulted in better yield of 30 July transplanting, while in delay transplanting there was a drastic reduction in yield due to short growth period and adverse temperature might have affected the yield in late transplanting. The higher grain yield in optimum transplanting was owing to favorable yield attributing parameters. But the gradual decrease in the yield with delay in transplanting might be due to the relatively low temperature at the vegetative phase which could have adversely affected the plant growth and development. The results are in agreement with the findings of Mahmud (2014), Shaon (2006), and Rahman (2004).



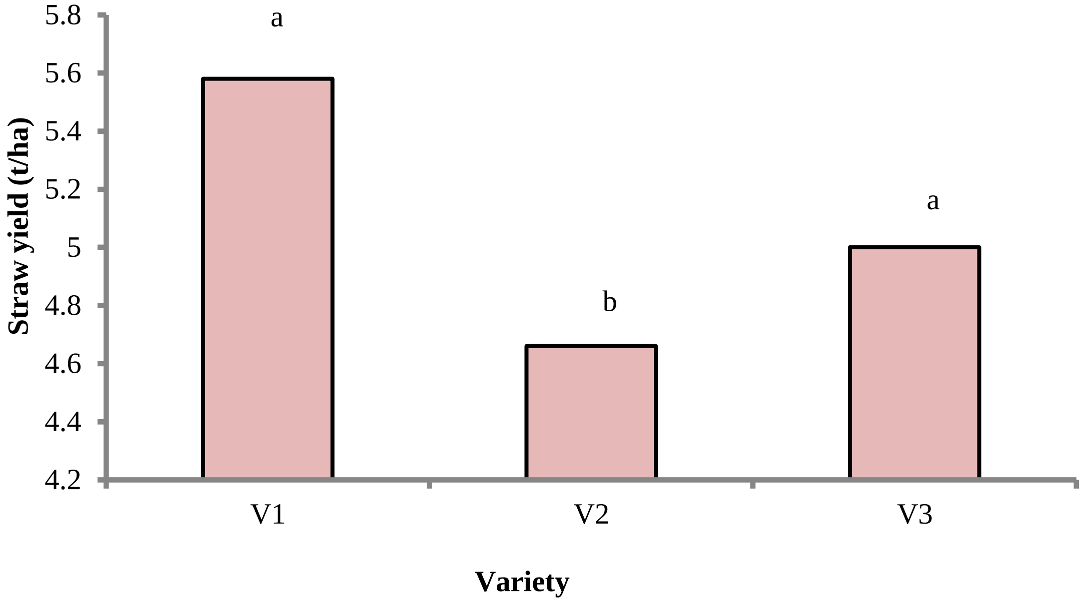
T_1= 01 July; T_2= 15 July; T_3 = 30 July and T_4 = 15 August

Figure 15. Effect of transplanting date on grain yield of T. aman rice ($LSD_{0.05}$ =0.52)

The grain yield was significantly influenced by the interaction of variety and the date of transplanting (Table 4). The highest grain yield (5.82 t ha^{-1}) was obtained from the V_1T_3 treatment. On the other hand, V_2T_1 showed the lowest result (3.53 t ha^{-1}) which was statistically similar to V_2T_1 (3.71 t ha^{-1}) and V_3T_4 (3.79 t ha^{-1}). Hossain and Sikdar (2009) found that all the cultivars gave the maximum grain yield when transplanted on 15 July. BRRI dhan34 gave the highest yield (3.4 t ha^{-1}) when transplanted on 15 July. Kataribhog (2.73 t ha^{-1}), Radhunipagal (2.5 t ha^{-1}), Badshabhog (2.53 t ha^{-1}) and BRRI dhan38 (2.77 t ha^{-1}) gave the highest yield on 15 July. A delay transplanting on 14 August reduced the yield compared with the transplanting on dates. Such a reduction was attributed mainly due to restricted tillering and crop growth.

4.9 Straw yield

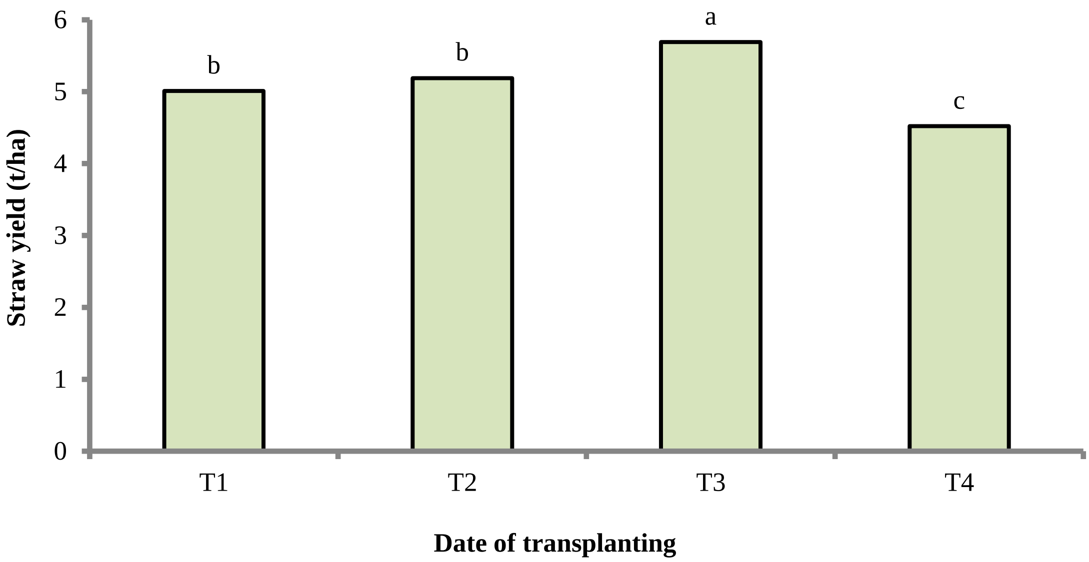
There was significant variation among the varieties in respect of straw yield. The highest straw yield (5.58 tha^{-1}) was produced by BRRI dhan32 (Fig. 16) which is statistically similar to BRRI dhan80. BRRI dhan80 has given the second-highest straw yield (5.00 tha^{-1}). The lowest (4.66 tha^{-1}) straw yield was produced by BRRI dhan62. These results were consistent with those of Mahmud (2014) and Khisha (2002) who also observed significant variation among the varieties. The variation of straw yield is probably due to the genetical make-up of the varieties.



V$_1$=BRRI dhan32; V$_2$=BRRI dhan62; V$_3$=BRRI dhan80

Figure 16. Effect of variety on straw yield of T. aman rice ($LSD_{0.05}$ =0.53)

The straw yield of T. aman rice varied significantly due to different date of transplanting (Fig. 17). The highest straw yield (5.69 t ha^{-1}) was obtained from T$_3$ (transplanting on 30 July). On the other hand, the lowest straw yield (4.52 t ha^{-1}) was found from T$_4$ (transplanting on 15 August).



T$_1$= 01 July; T$_2$= 15 July; T$_3$ = 30 July and T$_4$ = 15 August

Figure 17. Effect of date of transplanting on straw yield of T. aman rice ($LSD_{0.05}$ =0.47)

The effect of the combination of variety and date of transplanting of straw yield of T. aman was significant (Table 4). The highest straw yield (6.13 t ha^{-1}) was obtained from V_1T_3 (BRRI dhan32 when transplanting on 30 July) treatment which was statistically similar to V_3T_3 (5.72 tha^{-1}), V_1T_2 (5.68 tha^{-1}) and V_1T_1 (5.64 tha^{-1}). On the other hand, V_2T_4 (BRRI dhan62 when transplanting on 15 August) treatment showed the lowest result (4.28 t ha^{-1}). All the varieties have shown the lowest straw yield in 15 August planting.

Table 4. Combined effect of variety and different date of transplanting on 1000 grain weight, grain yield, and straw yield of rice

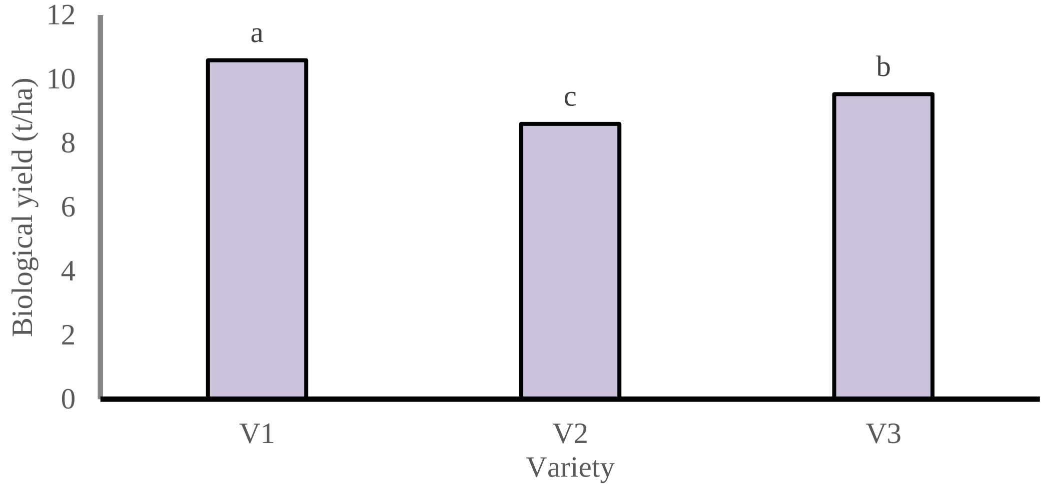
Treatment	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
V_1T_1	23.61 b	4.66 c-d	5.64 a
V_1T_2	24.14 a	5.27 b	5.68 a
V_1T_3	24.88 a	5.82 a	6.13 a
V_1T_4	22.91 bc	4.27 e	4.85 c
V_2T_1	22.46 bc	3.71 f	4.46 c
V_2T_2	23.00 ab	4.07 e	4.70 c
V_2T_3	23.74 ab	4.52 c-d	5.21 b
V_2T_4	21.01 c	3.53 f	4.28 d
V_3T_1	22.79 bc	4.23 e	4.92 e
V_3T_2	23.32 ab	4.74 c-d	5.19 b
V_3T_3	24.06 a	5.34 b	5.72 a
V_3T_4	21.89 bc	3.79 f	4.42 c
LSD (0.05)	**1.93**	**0.46**	**0.63**
CV%	**5.79**	**5.85**	**7.02**

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

[V_1=BRRI dhan32; V_2=BRRI dhan62; V_3= BRRI dhan80; T_1= 01 July; T_2= 15 July; T_3 = 30 July; and T_4 = 15 August]

4.10 Biological yield

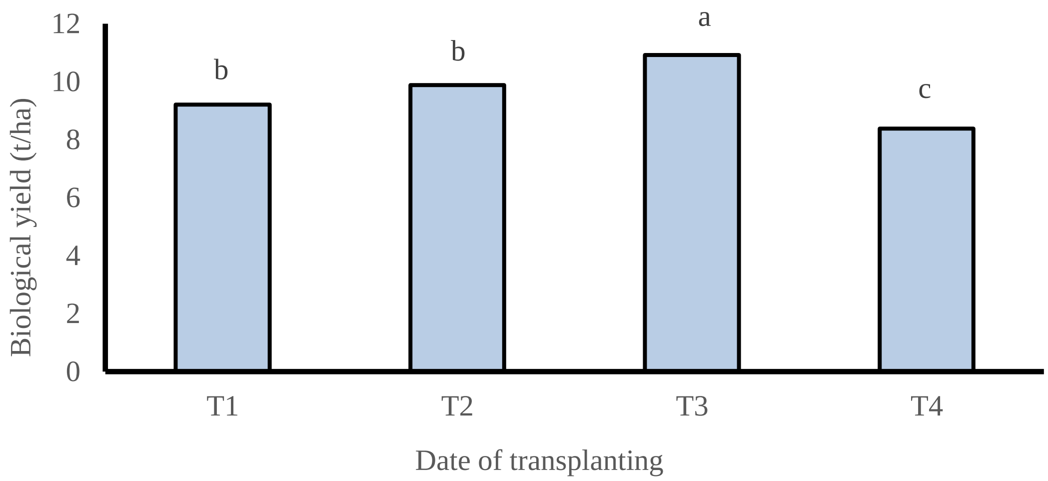
The biological yield was significantly influenced by variety. The highest biological yield (10.59 t ha^{-1}) was obtained from BRRI dhan32 and the lowest one (8.6 tha^{-1}) was produced from BRRI dhan62 (Fig. 18). It is probably due to the highest number of tillers, moderate plant height, highest grain and straw yield moderate crop duration possessed by BRRI dhan32. Lamberts *et al.* (2007) have seen the similar result and concluded that different varieties of transplant aman rice show variation in biological yield and generally the longest variety with the highest number of effective tillers produce the highest biological yield.



V_1=BRRI dhan32; V_2=BRRI dhan62; V_3=BRRI dhan80

Figure 18. Effect of variety on biological yield of T. aman rice ($LSD_{0.05}$ = 0.82)

The biological yield of T. aman rice showed statistically significant variation due to different date of transplanting (Fig. 19). The highest biological yield (10.92 t ha^{-1}) was obtained from T_3 (Transplanting on 30 July). On the other hand, the lowest biological yield (8.38 t ha^{-1}) was found from T_4 (Transplanting on 15 August).



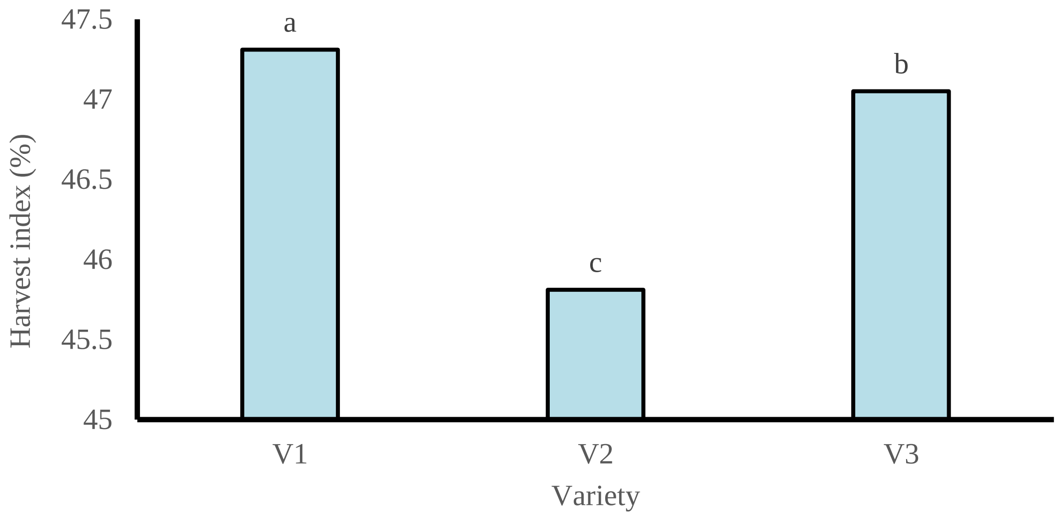
T_1= 01 July; T_2= 15 July; T_3 = 30 July and T_4 = 15 August

Figure 19. Effect of date of transplanting on biological yield of T. aman rice ($LSD_{0.05}$ = 0.49)

The combination between variety and date of transplanting exerted a significant effect on biological yield (Table 5). The highest biological yield (11.95 t ha^{-1}) was produced by V_1T_3 (BRRI dhan32 when transplanting on 30 July). The lowest biological yield (7.81 t ha^{-1}) was produced by the transplanting on 15 August of the variety BRRI dhan62. All the varieties have shown a drastic reduction in biological yield for 15 August planting. This is due to the short growth period and reproductive period and adverse temperature.

4.12 Harvest index

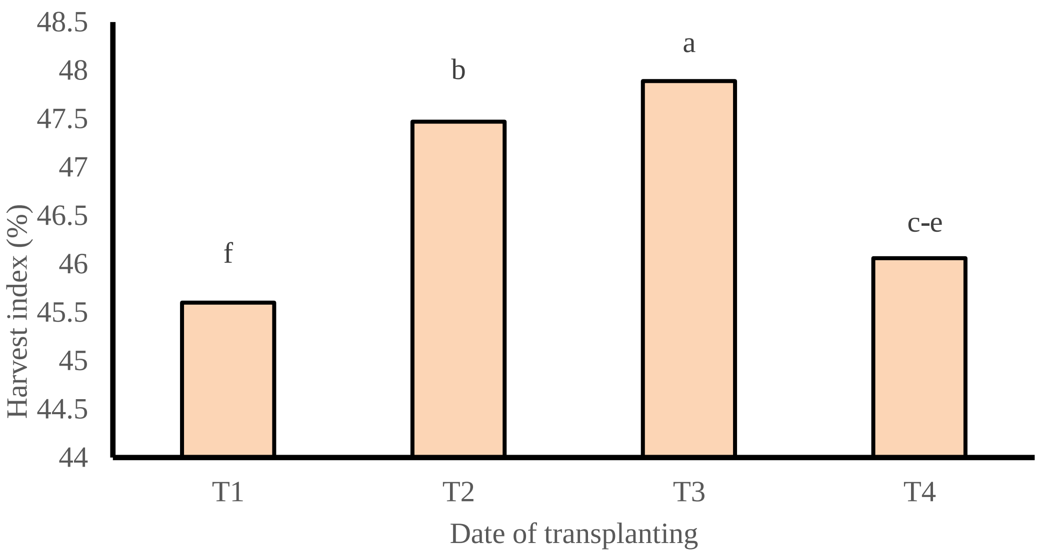
Varieties exerted a significant effect on the harvest index. The highest harvest index (47.31 %) was produced by BRRI dhan32. The lowest (45.81 %) was produced by BRRI dhan62 (Fig. 20). It is the genetical attributes that have shown variation in the harvest index of different varieties. Tyeb, A. (2012) has seen similar results and concluded that harvest index depends on inherent genetical attributes on the same environmental condition.



V_1=BRRI dhan32; V_2=BRRI dhan62; V_3=BRRI dhan80

Figure 20. Effect of variety on harvest index of T. aman rice ($LSD_{0.05}$ =0.17)

The harvest index of T. aman rice was influenced significantly due to different dates of transplanting (Fig. 21). The highest harvest index (47.89 %) was found from T_3 (Transplanting on 30 July) which was followed by T_2 (47.47 %). On the other hand, the lowest harvest index (45.60 %) was observed from T_1 (Transplanting on 01 July).



T_1= 01 July; T_2= 15 July; T_3 = 30 July and T_4 = 15 August

Figure 21. Effect of date of transplanting on harvest index of T. aman rice ($LSD_{0.05}$ =0.08)

The combination effect of variety and date of transplanting on harvest index was significant. The highest harvest index (48.70 %) was observed in BRRI dhan32 with 30 July transplanting and the lowest harvest index (45.20 %) was obtained from BRRI dhan62 with 15 August transplanting (Table 5). BRRI dhan32 showed the highest harvest index among other varieties in different planting date respectively. Planting on 30 July has shown the highest harvest index for all the varieties. BRRI dhan32 has given the highest grain yield and 30 July is the most suitable transplanting date in terms of producing grain yield. So, the harvest index of BRRI dhan32 on 30 July transplanting was highest and it was the most suitable combination among all other experimental treatments.

Table 5. Combined effect of variety and different date of transplanting on biological yield and harvest index of rice

Treatment	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
V_1T_1	10.3 ab	45.24 l-n
V_1T_2	10.95 a	48.13 c
V_1T_3	11.95 a	48.70 a
V_1T_4	9.12 cd	46.82 e-h
V_2T_1	8.17 d	45.41 l-n
V_2T_2	8.77 d	46.41 ij
V_2T_3	9.73 c	46.45 ij
V_2T_4	7.81 e	45.20 o
V_3T_1	9.15 cd	46.23 k
V_3T_2	9.93 b	47.73 de
V_3T_3	11.06 a	48.28 b
V_3T_4	8.21 d	46.16 k
LSD (0.05)	**1.07**	**0.27**
CV%	**6.43**	**0.35**

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

[V_1=BRRI dhan32; V_2=BRRI dhan62; V_3= BRRI dhan80; T_1= 01 July; T_2= 15 July; T_3 = 30 July; and T_4 = 15 August]

4.12 Germination percentage

The germination (%) showed a statistically significant impact due to a different variety of rice (Table 6). It can be inferred from the table that the value of germination (%) was higher (87.06 %) in the V_1 variety (BRRI dhan32). However, the minimum germination percentage (85.67 %) was recorded in V_2 (BRRI dhan62).

The germination (%) exerted a significant effect due to different days of transplanting in rice (Table 6). The highest germination (%) (90.95 %) was recorded in T_3 (transplanting on 30 July) treatment. On the other hand, the lowest germination percentage (81.29 %) was found in T_4 (Transplanting on 15 August).

The combined effect of variety and date of transplanting produced statistically significant variation in germination (%) of rice (Table 6). The germination (%) ranges from 78.77 % to 92.89 % among the combination. The maximum germination (%) was found in V_1T_3 (BRRI dhan32 when transplanting on 30 July) which was statistically at par with V_3T_3 (92.23 %) and the minimum germination (%) was found in V_2T_4 (BRRI dhan62 when transplanting on 15 August) treatment combination.

Table 6. Effect of variety, date of transplanting and their interaction on germination percentage of T. aman rice

Treatment	Germination (%)
Variety	
V_1	87.06 a
V_2	85.67 b
V_3	86.49 a
LSD $_{(0.05)}$	**1.30**
CV%	**0.49**
Date of transplanting	
T_1	84.76 c
T_2	87.17 b
T_3	90.95 a
T_4	81.29 d
LSD $_{(0.05)}$	**2.16**
CV%	**0.49**
Combination of variety and date of transplanting	
V_1T_1	84.81 lm
V_1T_2	87.80 b-i
V_1T_3	92.89 a
V_1T_4	82.74 op
V_2T_1	86.03 k
V_2T_2	86.79 j
V_2T_3	87.72 b-i
V_2T_4	78.77 q
V_3T_1	83.45 n
V_3T_2	86.93 j
V_3T_3	92.23 a
V_3T_4	82.36 op
LSD $_{(0.05)}$	**0.70**
CV%	**0.49**

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

[V_1=BRRI dhan32; V_2=BRRI dhan62; V_3= BRRI dhan80; T_1= 01 July; T_2= 15 July; T_3 = 30 July; and T_4 = 15 August]

4.13 Root length

The root length showed a statistically significant impact due to the different varieties of rice (Table 7). The highest root length (8.71 cm) was recorded in the V_1 variety (BRRI dhan32) while the lower root length (7.73 cm) was in the V_2 variety (BRRI dhan62).

The root length of T. aman rice showed statistically significant variation due to different dates of transplanting (Table 7). The highest value of root length (8.92 cm) was recorded in T_3 (Transplanting on 30 July) treatment, which was statistically similar with T_1 and T_2 treatment. On the other hand, the lowest value of root length 7.35 cm was found from T_4 (Transplanting on 15 August).

The combined effect of variety and date of transplanting produced statistically significant root length in rice (Table 7). The maximum root length (9.40 cm) was found from the V_1T_3 (BRRI dhan32 when transplanting on 30 July) treatment, which was statistically at per with V_3T_1 (9.39 cm). Whereas, the minimum root length (6.83 cm) was found in the V_2T_4 treatment.

4.14 Shoot length

The shoot length showed a statistically non-significant impact due to the different varieties of rice (Table 7). However, numerically the highest shoot length (14.96 cm) was recorded in the V_1 variety (BRRI dhan32) while the lowest shoot length (13.40 cm) was in the V_2 variety.

The shoot length of T. aman rice was influenced significantly due to different date of transplanting (Table 7). The highest value of shoot length (15.40 cm) was recorded in the T_3 (Transplanting on 30 July) treatment, which was statistically similar to the T_2 treatment. On the other hand, the lowest value of shoot length 12.94 cm was found from the T_4 treatment which was statistically similar to T_1 treatment.

The combined effect of variety and date of transplanting produced statistically significant shoot length in rice (Table 7). The maximum shoot length (16.20 cm) was found from the V_1T_3 (BRRI dhan32 when transplanting on 30 July) which was statistically similar to the V_3T_3 treatment. Whereas, the minimum root length (12.33 cm) was found in V_2T_4 (BRRI dhan62 when transplanting on 15 August) treatment combination.

4.15 Shoot dry weight of seedling

The varietal difference on rice showed significant variations for shoot dry weight of seedling (Table 7). The maximum value of shoot dry weight (16.25 mg) was found in V_1 (BRRI dhan32) and the minimum value of shoot weight (14.27 mg) was recorded in the V_2 variety (BRRI dhan62).

The shoot dry weight showed significant variations due to different dates of transplanting on rice (Table 7). The highest value of shoot weight (17.67 mg) was recorded in T_3 (Transplanting on 30 July) treatment, which was statistically similar to the T_2 treatment. On the other hand, the lowest value of shoot weight 13.67 mg was found from T_4 (Transplanting on 15 August).

The combined effect of variety and date of transplanting exerted significant shoot dry weight of rice (Table 7). The maximum shoot dry weight (17.98 mg) was found from the V_1T_3 (BRRI dhan32 when transplanting on 30 July) treatment. Whereas, the minimum shoot weight (11.87 mg) was found in the V_2T_4 treatment.

4.16 Root dry weight of seedling

The varietal difference on rice showed significant variations for the root weight of seedling (Table 7). The maximum value of root dry weight (18.72 mg) was found in V_1 (BRRI dhan32) and the minimum value of root dry weight (16.10 mg) was recorded in the V_2 variety (BRRI dhan62).

The root dry weight showed significant variations due to different date of transplanting on rice (Table 7). The highest value of root weight (19.42 mg) was recorded in T_3 (Transplanting on 30 July) treatment, which was statistically similar to T_2 (18.27 mg). On the other hand, the lowest value of shoot weight 15.77 mg was found from T_4 (Transplanting on 15 August).

The combined effect of variety and date of transplanting produced statistically significant root weight of rice (Table 7). The maximum root dry weight (19.66 mg) was found from the V_1T_3 (BRRI dhan32 when transplanting on 30 July) treatment. Whereas, the minimum root weight (14.10 mg) was found in the V_2T_4 treatment.

4.17 Vigor index

The vigor index showed statistically significant impact due to the different variety of rice (Table 7). The highest vigor index (2067.54) was recorded in the V_1 variety (BRRI dhan32) while the lower vigor index (1797.11) was in the V_2 variety (BRRI dhan62).

The vigor index showed significantly variation due to different date of transplanting on rice (Table 7). The highest value of vigor index (2232.91) was recorded in T_3 (Transplanting on 30 July) treatment and the lowest value of vigor index 1662.36 was found in T_4 (Transplanting on 15 August).

The combined effect of date of transplanting and variety produced statistically significant vigor index in rice (Table 7). The maximum vigor index (2377.98) was found from the V_1T_3 (BRRI dhan32 when transplanting on 30 July) treatment. Whereas, the minimum vigor index (1509.23) was found in the V_2T_4 treatment.

Table 7. Effect of variety, days of transplanting and their combination on seedling characteristics of different T. aman rice cultivars

Treatment	Seedling Characteristics				
	Root length (cm)	**Shoot length (cm)**	**Shoot dry weight (mg)**	**Root dry weight (mg)**	**Vigor index**
Variety					
V_1	8.71 a	14.96	16.25 a	18.72 a	2067.54 a
V_2	7.73 b	13.40	14.27 b	16.14 b	1797.11 b
V_3	8.45 a	14.34	15.18 a	17.77 ab	1972.46 a
LSD (0.05)	**0.92**	**NS**	**0.74**	**0.66**	**264.6**
CV%	**5.92**	**6.42**	**6.20**	**6.52**	**6.04**
Days of transplanting					
T_1	8.14 a	13.56 b	15.00 b	17.67 ab	1851.58 b
T_2	8.35 a	14.87 a	16.52 a	18.27 a	2035.96 a
T_3	8.92 a	15.40 a	17.14 a	19.42 a	2232.91 a
T_4	7.35 b	12.94 b	13.67 b	15.77 b	1662.36 c
LSD (0.05)	**1.52**	**1.15**	**0.85**	**0.76**	**197.9**
CV%	**5.92**	**6.42**	**6.20**	**6.52**	**6.04**
Interaction of different variety and date of transplanting					
V_1T_1	8.87 ab	14.42 b	15.36 bc	18.09 a-c	1975.22 c
V_1T_2	8.93 ab	15.77 a	16.89 ab	18.44 a-c	2168.66 b
V_1T_3	9.40 a	16.20 a	17.98 a	19.66 a	2377.98 a
V_1T_4	7.73 d	13.40 bc	14.77 c	16.49 c-d	1748.30 d
V_2T_1	7.48 d	13.03 cd	14.77 c	17.24 b-d	1764.48 d
V_2T_2	8.04 bc	13.87 b	16.33 a-c	18.13 a-c	1901.57 c
V_2T_3	8.58 b	14.37 b	17.11 ab	19.20 a	2013.17 b
V_2T_4	6.83 e	12.33 d	11.87 d	14.10 e	1509.23 e
V_3T_1	8.08 bc	13.67 bc	14.87 c	17.73 a-d	1815.04 c
V_3T_2	8.47 b	14.97 b	16.33 a-c	18.15 a-c	2037.64 b
V_3T_3	9.39 a	15.63 a	17.63 a	19.41 a	2307.59 a
V_3T_4	7.90 c	13.10 b-d	14.67 c	15.77 de	1729.56 d
LSD (0.05)	**0.82**	**1.48**	**1.70**	**1.83**	**191.9**
CV%	**5.92**	**6.42**	**6.20**	**6.52**	**6.04**

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

[V_1=BRRI dhan32; V_2=BRRI dhan62; V_3= BRRI dhan80; T_1= 01 July; T_2= 15 July; T_3 = 30 July; and T_4 = 15 August]

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from July 2019 to December 2019 to study the effect of transplanting date on yield and seed quality of T. aman variety. The three varieties included in this study were BRRI dhan32, BRRI dhan62, and BRRI dhan80. There were four dates of transplanting. Such as T_1= 01 July; T_2= 15 July; T_3 = 30 July and T_4 = 15 August. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data on growth, yield attribute, yield, and seed quality was recorded.

At 30, 60, 90 DAT, and at harvest the tallest plant (45.94 cm, 90.45 cm, 118.64 cm, and 118.8 cm) was found in BRRI dhan32 and the lowest (39.44 cm, 82.67 cm, 95.5 cm, and 98.04 cm) was found in BRRI dhan62. At 30, 60, 90 DAT, and at harvest the maximum number of tillers per hill (3.80, 13.18, 16.05, and 19.14) was recorded from V_1 and again the minimum (2.95, 11.13, 13.38, and 16.92) was observed from V_2.

At 30, 60, 90 DAT, and at harvest, the tallest plant (44.45 cm, 94.04 cm, 114.34 cm, and 115.23 cm) was recorded from T_3 (transplanting on 30 July) treatment and the shortest (40.44 cm, 80.65 cm, 102.25 cm, and 108.9 cm) was found in T_4 (Transplanting on 15 August). At 30, 60, 90 DAT, and at harvest the maximum number of tillers per hill (4.01, 13.08, 17.59, and 20.76) was recorded from T_3 and again the minimum (2.84, 11.40, 12.56, and 15.36) was observed from T_4.

In most of the cases, the interaction effect between variety and date of transplanting was significant. At 30, 60, 90 DAT, and at harvest the tallest plant (49.01 cm, 98.84 cm, 123.15 cm, and 124.52 cm) was recorded from V_1T_3 (BRRI dhan32 transplanting on 30 July) and the lowest (37.68 cm, 76.18 cm, 90.17 cm, and 92.58 cm) was found in V_2T_4 (BRRI dhan62 transplanting on 15 August). At 30, 60, 90 DAT, and at harvest the maximum number of tillers per hill (4.82, 14.56, 19.49, and 22.11) was recorded from V_1T_3 and again the minimum (2.51, 10.50, 11.36, and 14.38) was observed from V_2T_4.

The number of effective tillers, length of panicle, number of filled grains, the weight of 1000-grains, grain yield, straw yield, and biological yield were influenced by different varieties. The maximum number of effective tillers $hill^{-1}$ (14.83), longest panicle (28.64 cm), highest number of filled grains $panicle^{-1}$ (114.16), highest 1000-grain weight (23.84 g), highest grain yield (5.01 t ha^{-1}), highest straw yield (5.58 t ha^{-1}), and maximum biological yield (10.59 t ha^{-1}) was observed in the V_1 (BRRI dhan32). Similarly, maximum seed germination percentage (87.06%), highest root length (8.71 cm), highest shoot length (14.96 cm), highest vigor index (2067.54), maximum shoot dry weight (16.25 g), maximum root dry weight (18.72 g) was observed in the V_1 (BRRI dhan32) variety.

The minimum number of effective tillers $hill^{-1}$ (12.45), shortest panicle (25.42 cm), lowest number of filled grains $panicle^{-1}$ (94.98), lowest 1000-grain weight (22.69 g), lowest grain yield (3.94 t ha^{-1}), lowest straw yield (4.66 t ha^{-1}), minimum biological yield (8.60 t ha^{-1}), minimum germination percentage (85.67%), lowest root length (7.73 cm), lowest shoot length (13.40 cm), lowest vigor index (1797.11), lowest shoot dry weight (14.25 g), and lowest root dry weight (16.14 g) was obtained from the variety V_2 (BRRI dhan62) variety.

The number of effective tillers per hill, length of panicle, number of filled grains, the weight of 1000-grains, grain yield, straw yield, and biological yield was significantly influenced by different date of transplanting. The maximum number of effective tillers per hill (14.99), longest panicle (28.35 cm), maximum number of filled grain per plant (119.59), highest weight of 1000-seeds (24.23 g), highest grain yield (5.23 t/ha), highest straw yield (5.69 t/ha), highest biological yield (10.92 t/ha), maximum seed germination percentage (90.95%), highest root length (8.92 cm), highest shoot length (15.40 cm), highest vigor index (2232.91), maximum shoot dry weight (17.14 g), maximum root dry weight (19.42 g) was found from T_3 (Transplanting on 30 July).

The minimum number of effective tillers per hill (12.27), lowest length of panicle (25.89 cm), minimum number of filled grain per plant (92.50), minimum weight of 1000-grains (22.05 g), lowest grain yield (3.86 t/ha), lowest straw yield (4.52 t/ha), lowest biological yield (8.38 t/ha), minimum germination percentage (81.29%), lowest root length (7.35 cm), lowest shoot length (12.94 cm), lowest vigor index (1662.36), lowest shoot dry weight (13.67 g), and lowest root dry weight (15.72 g) was recorded from T_4 (Transplanting on 15 August).

All the parameters were significantly influenced by the interaction of varieties and the date of transplanting. The highest number of effective tillers hill^{-1} (16.43), highest length of panicle (30.84 cm), highest number of filled grains (132.18) panicle^{-1}, height 1000-grain weight (24.88 g), highest grain yield (5.82 t ha^{-1}), highest straw yield (6.13 t/ha), highest biological yield (11.95 t/ha), maximum seed germination percentage (92.89%), highest root length (9.40 cm), highest shoot length (16.20 cm), highest vigor index (2377.98), maximum shoot dry weight (17.98 g), maximum root dry weight (19.66 g) was observed from the V_1T_3 (BRRI dhan32 when transplanting on 30 July) treatment whereas, the lowest (16.43), lowest number of panicle length (30.84 cm), lowest number of filled grains per panicle (132.18), lowest grain yield (3.53 t/ha), lowest straw yield (4.28 t/ha), lowest biological yield (7.81 t/ha), minimum seed germination percentage (78.77%), lowest root length (6.83 cm), lowest shoot length (12.33 cm), lowest vigor index (1509.23), lowest shoot dry weight (11.87 g), and lowest root dry weight (14.91 g)was observed from V_2T_4 treatment.

The result of the present study generated some information that may help to increase the yield and seed quality of T. aman rice. Hence, the present study may be concluded as follows:

Among the T. aman rice varieties, BRRI dhan32 produced the tallest plant, maximum effective tiller, longest panicle, maximum filled grains, highest grain yield, highest straw yield, highest biological yield, maximum seed germination percentage, highest shoot and root length, highest vigor index, and maximum shoot and root dry weight.

Transplanting of BRRI dhan32 seeding on 30 July gave the tallest plant, maximum effective tiller, longest panicle, maximum filled grains, highest grain yield, highest straw yield, highest biological yield, maximum seed germination percentage, highest shoot and root length, highest vigor index, and maximum shoot and root dry weight.

Considering the above result of this experiment the following conclusions can be drawn:

- Among the T. aman rice varieties, BRRI dhan32 gave a higher yield and best seed quality seed,
- The optimum transplanting date for higher grain yield and the best quality seed of T. aman rice was 30 July.
- BRRI dhan32 transplanted on 30 July gave the best result for grain yield and quality seed in aman season.

However, the study might be conducted at the different Agro-ecological condition for the conformation of the result. Further study should be needed in different AEZ of Bangladesh for accuracy of the results obtained from the present experiment.

CHAPTER VI

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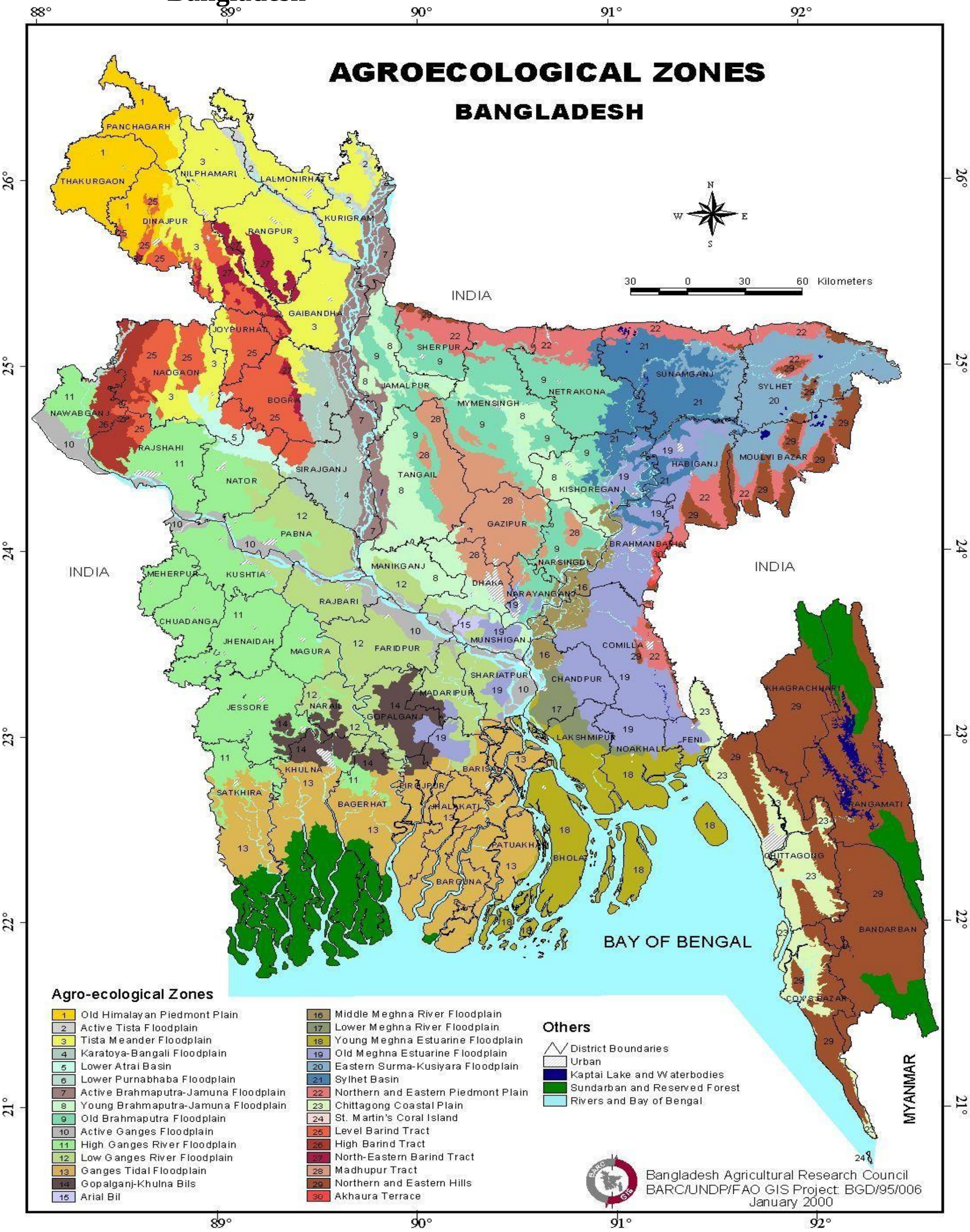
CHAPTER VII

APPENDICES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. Monthly recorded the average air temperature, rainfall, relative humidity, and sunshine of the experimental site during the period from June 2019 to December 2019.

Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
July 2019	31.4	25.8	81	542
August 2019	32.0	26.6	82	361
September 2019	32.7	26.0	81	514
October 2019	30.5	24.3	80	417
November 2019	29.0	19.8	72	3
December 2019	27.0	15.6	66	0

Source: Sher-e-Bangla Agricultural University Weather Station and Bangladesh Meteorological Department.

Appendix III. The physical and chemical characteristics of the soil of the experimental site as observed prior to experimentation (0-15 cm depth)

Constituents	Percent
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Source: Soil Resources Development Institute (SRDI)

Chemical composition:

Soil characters	Value
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.54
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.88 µg/g soil
Copper	1.64 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 meg/100g soil

Source: Soil Resources Development Institute (SRDI)

Morphological Characteristics of the Experimental Field

Morphology	Characteristics
Location	SAU farm, Dhaka
Agro-ecological zone	Madhupur Tract (AEZ-28)
General Soil Type	Deep Red Brown Terrace Soil
Parent material	Madhupur Clay
Topography	Fairly level
Drainage	Well drained
Flood level	Above flood level

(FAO and UNDP, 1988)

Appendix IV. Factorial ANOVA for plant height at 30 DAT

Source of variances	DF	SS	MS	F	P
Replication	2	0.156	0.078	0.0343	
Variety	2	259.730	129.865	57.1088	0.0000
Date of transplanting	3	48.294	16.098	7.0792	0.0017
Variety*Date of transplanting	6	35.000	5.833	2.5652	0.0489
Error	22	50.028	2.274		

Appendix V. Factorial ANOVA for plant height at 60 DAT

Source of variances	DF	SS	MS	F	P
Replication	2	3.278	1.639	0.2907	
Variety	2	1618.178	809.089	143.5087	0.0000
Date of transplanting	3	246.277	82.092	14.5608	0.0000
Variety*Date of transplanting	6	103.347	17.225	3.0551	0.0250
Error	22	124.034	5.638		

Appendix VI. Factorial ANOVA for plant height at 90 DAT

Source of variances	DF	SS	MS	F	P
Replication	2	9.909	4.955	1.1747	0.3276
Variety	2	3097.554	1548.777	367.1897	0.0000
Date of transplanting	3	61.042	20.347	4.8241	0.0099
Variety*Date of transplanting	6	408.271	68.045	16.1324	0.0000
Error	22	92.794	4.218		

Appendix VII. Factorial ANOVA for plant height at harvest

Source of variances	DF	SS	MS	F	P
Replication	2	9.909	4.955	1.1747	0.3276
Variety	2	3097.554	1548.777	367.1896	0.0000
Date of transplanting	3	61.042	20.347	4.8240	0.0099
Variety*Date of transplanting	6	408.272	68.045	16.1324	0.0000
Error	22	92.794	4.218		

Appendix VIII. Factorial ANOVA for tiller per hill at 30 DAT

Source of variances	DF	SS	MS	F	P
Replication	2	0.017	0.009	0.2575	
Variety	2	5.161	2.581	77.4842	0.0000
Date of transplanting	3	4.059	1.353	40.6193	0.0000
Variety*Date of transplanting	6	3.903	0.651	19.5332	0.0000
Error	22	0.733	0.033		

Appendix IX. Factorial ANOVA for tiller per hill at 60 DAT

Source of variances	DF	SS	MS	F	P
Replication	2	0.018	0.009	0.0183	
Variety	2	30.944	15.472	30.6948	0.0000
Date of transplanting	3	12.529	4.176	8.2855	0.0007
Variety*Date of transplanting	6	3.400	0.567	1.1243	0.3808
Error	22	11.089	0.504		

Appendix X. Factorial ANOVA for tiller per hill at 90 DAT

Source of variances	DF	SS	MS	F	P
Replication	2	0.017	0.008	0.0150	
Variety	2	27.655	13.828	25.0532	0.0000
Date of transplanting	3	43.567	14.522	26.3120	0.0000
Variety*Date of transplanting	6	13.012	2.169	3.9292	0.0081
Error	22	12.142	0.552		

Appendix XI. Factorial ANOVA for total tiller per hill at harvest

Source of variances	DF	SS	MS	F	P
Replication	2	0.021	0.010	0.0112	
Variety	2	46.092	23.046	24.8213	0.0000
Date of transplanting	3	25.797	8.599	9.2615	0.0004
Variety*Date of transplanting	6	13.840	2.307	2.4844	0.0547
Error	22	20.427	0.928		

Appendix XII. Factorial ANOVA for effective tiller per hill

Source of variances	DF	SS	MS	F	P
Replication	2	0.040	0.020	0.0299	
Variety	2	34.239	17.120	25.3627	0.0000
Date of transplanting	3	9.769	3.256	4.8241	0.0099
Variety*Date of transplanting	6	0.738	0.123	0.1822	
Error	22	14.850	0.675		

Appendix XIII. Factorial ANOVA for panicle length per plant

Source of variances	DF	SS	MS	F	P
Replication	2	0.014	0.007	0.0039	
Variety	2	65.817	32.909	17.7198	0.0000
Date of transplanting	3	30.921	10.307	5.5499	0.0054
Variety*Date of transplanting	6	9.882	1.647	0.8868	
Error	22	40.858	1.857		

Appendix XIV. Factorial ANOVA for number of grain per panicle

Source of variances	DF	SS	MS	F	P
Replication	2	9366.074	4683.037	41.8063	0.0000
Variety	2	447.390	223.695	1.9970	0.1596
Date of transplanting	3	2721.577	907.192	8.0987	0.0008
Variety*Date of transplanting	6	107.220	17.870	0.1595	
Error	22	2464.387	112.018		

Appendix XV. Factorial ANOVA for number of unfilled grain per panicle

Source of variances	DF	SS	MS	F	P
Replication	2	0.460	0.230	0.5971	
Variety	2	558.903	279.452	726.1025	0.0000
Date of transplanting	3	201.098	67.033	174.1721	0.0000
Variety*Date of transplanting	6	122.646	20.441	53.1121	0.0000
Error	22	8.467	0.385		

Appendix XVI. Factorial ANOVA for 1000 seed weight

Source of variances	DF	SS	MS	F	P
Replication	2	139.777	69.888	46.9058	0.0000
Variety	2	498.055	249.027	167.1354	0.0000
Date of transplanting	3	155.725	51.908	34.8358	0.0000
Variety*Date of transplanting	6	121.511	20.252	13.5920	0.0000
Error	22	32.779	1.490		

Appendix XVII. Factorial ANOVA for grain yield per plot

Source of variances	DF	SS	MS	F	P
Replication	2	7.466	3.733	49.1991	0.0000
Variety	2	1.518	0.759	10.0009	0.0008
Date of transplanting	3	2.189	0.730	9.6169	0.0003
Variety*Date of transplanting	6	4.096	0.683	8.9985	0.0001
Error	22	1.669	0.076		

Appendix XVIII. Factorial ANOVA for straw yield per plot

Source of variances	DF	SS	MS	F	P
Replication	2	10.625	5.313	37.6963	0.0000
Variety	2	1.714	0.857	3.0791	0.0079
Date of transplanting	3	11.685	3.895	27.6348	0.0000
Variety*Date of transplanting	6	0.808	0.135	0.9560	
Error	22	3.101	0.141		

Appendix XIX. Factorial ANOVA for biological yield

Source of variances	DF	SS	MS	F	P
Replication	2	35.929	17.964	42.9298	0.0000
Variety	2	0.948	0.474	1.1323	0.3404
Date of transplanting	3	18.937	6.312	15.0844	0.0000
Variety*Date of transplanting	6	6.360	1.060	2.5333	0.0511
Error	22	9.206	0.418		

Appendix XX. Factorial ANOVA for harvest index

Source of variances	DF	SS	MS	F	P
Replication	2	0.053	0.027	1.0000	0.3840
Variety	2	117.144	58.572	2195.5335	0.0000
Date of transplanting	3	205.713	68.571	2570.3384	0.0000
Variety*Date of transplanting	6	83.189	13.865	519.7149	0.0000
Error	22	0.587	0.027		

PLATES

Plate 1: Plot preparation

Plate 2: Seedling transplanting in main field

Plate 3: Intercultural operation in the experimental field

Plate 4: Growing seedling in the main field

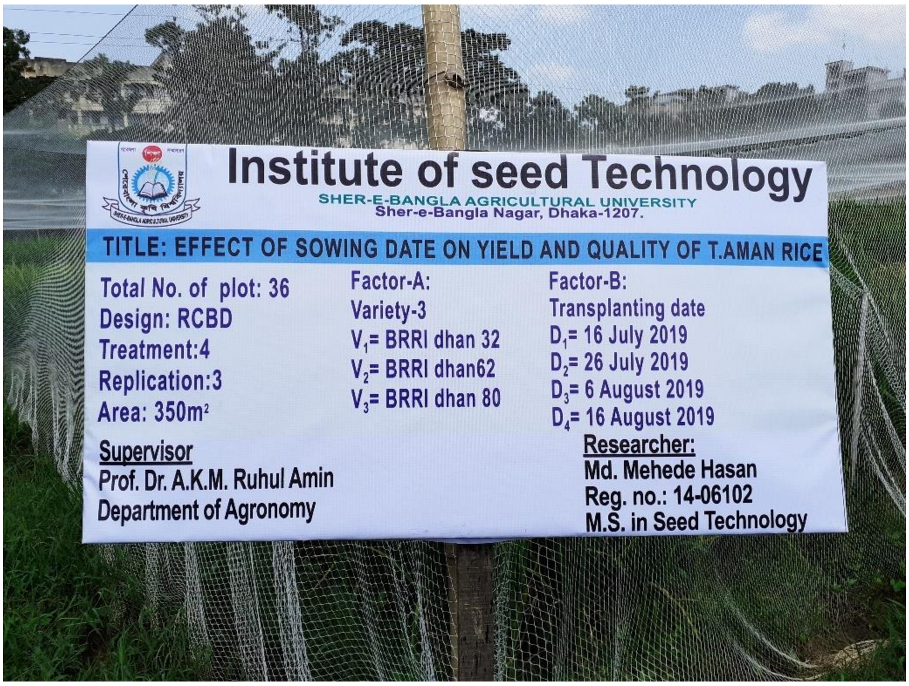


Plate 5: Signboard of the experiment

Plate 6: Crop ready to harvest


Plate 7: Data collection

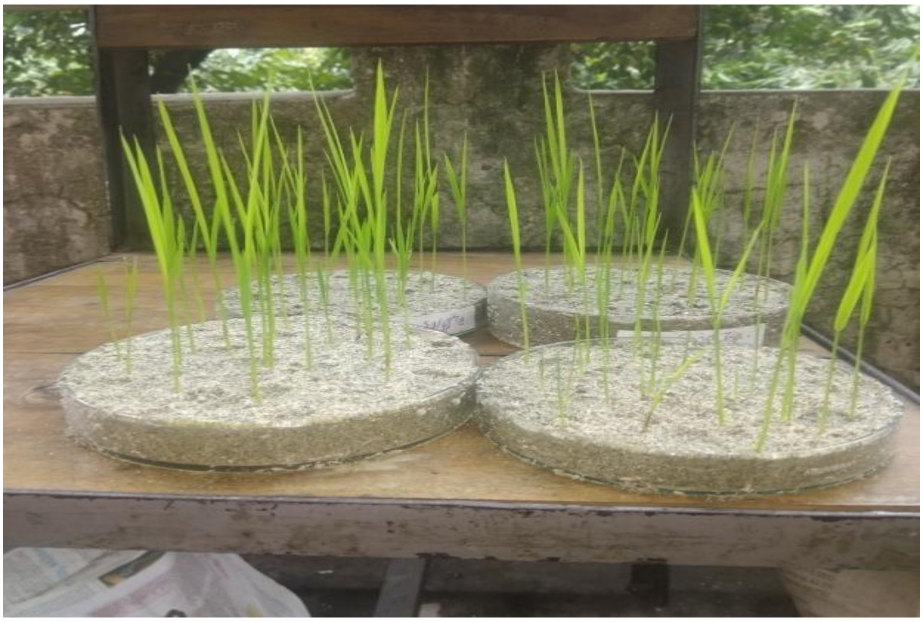


Plate 8: Data collection for seed quality analysis