INFLUENCE OF VARIETY AND WATER DEFICIENCY ON THE GROWTH AND YIELD OF BORO RICE

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INFLUENCE OF VARIETY AND WATER DEFICIENCY ON THE GROWTH AND YIELD OF BORO RICE

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CERTIFICATE

*This is to certify that the thesis entitled **"INFLUENCE OF VARIETY AND WATER DEFICIENCY ON THE GROWTH AND YIELD OF BORO RICE"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS)** in **AGRONOMY,** embodies the results of a piece of bona fide research work carried out by **PALLAB KUMAR BAGCHI,** Registration No. **11-04408** under my supervision and guidance. No part of this 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:

Dhaka, Bangladesh

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DEDICATED

TO

MY PARENTS

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ABSTRACT

A field experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University (SAU) farm, Dhaka, during the period from October 2016 to May 2017 to study the influence of variety and water deficiency on the growth and yield of boro rice under the Modhupur Tract (AEZ-28). The experiment consisted of 2 rice varieties {BRRI dhan74 (V_1) and Heera-2 (V_2)} and 7 levels of water deficiency {No deficiency (S_0), Deficiency at 15-35 DAT (S_1), Deficiency at 55-75 DAT (S_2), Deficiency at 85-105 DAT (S_3), Deficiency at 15-35 DAT and 55-75 DAT (S_4), Deficiency at 15-35 DAT and 85-105 DAT (S_5) and Deficiency at 55-75 DAT and 85-105 DAT (S_6)}. The experiment was laid out in a split-plot design with three replications having variety in the main plots and water deficiency in the sub-plots. In this experiment, all the genotypes varied significantly for all the parameters by their interaction with water deficiency. The highest plant height (88.31 cm) was recorded in V_2S_2. The lowest plant height (75.33 cm) recorded in V_1S_4. At 97 DAT, the highest dry matter hill^{-1} was observed in V_2S_4 (39.00 g) and the lowest dry matter hill^{-1} was observed in V_2S_6 (29.43 g). For grain yield, V_2S_2 showed the highest grain yield (7.52 t ha^{-1}) which was statistically similar with V_2S_0, V_2S_1, V_2S_3 and V_2S_6 but V_1S_4 showed the lowest grain yield (4.51 t ha^{-1}).

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LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
CF	=	Continuously flooding
cm	=	Centimeter
CRD	=	Completely Randomised Design
CS	=	Continuously saturated
CV%	=	Percentage of coefficient of variance
et al.	=	And others
FAO	=	Food and Agriculture Organization
g	=	Gram
GDP	=	Gross domestic product
ha	=	Hectare
ha^{-1}	=	Per hectare
HI	=	Harvest index
$Hill^{-1}$	=	Per hill
HYV	=	High yielding variety
IRRI	=	International Rice Research Institute
kg	=	Kilogram
LAI	=	Leaf area index
LCC	=	Leaf color chart
LSD	=	Least significant difference
m^{-2}	=	Per meter square
mg	=	Miligram
MoP	=	Muriate of potash
NPK	=	Nitrogen, Phosphorus and Potassium
NS	=	Non-significant
$Panicle^{-1}$	=	Per panicle
$Plant^{-1}$	=	Per plant
S	=	Sulfur
SCMR	=	SPAD Chlorophyll Meter Reading
SPAD	=	Soil Plant Analytical Development
SRDI	=	Soil Resources Development Institute
SRI	=	System of Rice Intensification
TSP	=	Triple super phosphate
$Unit^{-1}$	=	Per unit
Wt.	=	Weight
Zn	=	Zinc

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa L.)* is the principal food crop in Bangladesh and about 11,421,000 ha of the total arable lands are used for rice (aus, aman and boro) cultivation (BRRI, 2014-2015). Boro is the most important crop in Bangladesh in respect of volume of production and it has been persistently contributing to higher rice production in last successive years. The weather condition for boro cultivation was favorable in the growing stage in 2012. Total area under boro crop has been estimated 1,17,62,572 acres (47,60,055 ha) in 2012 as compared to 1,18,86,052 acres (48,10,025 ha) of the last year (2013). The harvested area has decreased by 1.04% in 2013 (BBS, 2013-2014). Approximately 28.48 km^3, or 79 percent of the total water withdrawal, comes from groundwater and 7.39 km^3, or 21 percent, from surface water. Most of that water is used in boro rice cultivation in our country. About 88% of withdrawal water is used for irrigation and livestock (FAO, 2015). In boro season most of the land is covered by modern variety of rice, which uptake more water from soil moisture.

Bangladesh is an agrarian country, where 76% of the people live in rural areas, and 47.5% of the total manpower is involved in agriculture. In Bangladesh, agriculture contributes 14.79% of the gross domestic product (GDP) of the country (Bangladesh Finance Bureau, 2017). Bangladesh has a long history of rice cultivation. Rice is grown throughout the country except in the southeastern hilly areas and the agro-climatic conditions of the country are suitable for growing rice year-round. However, the national average rice yield is much lower (2.94 t ha^{-1}) than that of other rice-growing countries. Rice is the staple food for about 156 million people of the country and the population growth rate is 2 million per year, and if the population increases at this rate, the total population will reach 238 million by 2050 (BBS, 2012). An increase in total rice production is required to feed this ever-increasing population and at the same time, the total cultivable land is decreasing at a rate of more than 1% per year owing to the construction of industries, factories, houses, roads, and highways. On the other hand, due to urbanization, food habits tend to change, demanding the cultivation of new crops that must share land used for rice cultivation.

Therefore, attempts should be made to increase the yield per unit area of rice. Moreover, due to climate change, agriculture is facing different adverse conditions, such as drought, flood, salinity, extreme temperature deficiency, and low soil fertility. In these circumstances, policies should be implemented to increase rice production in a sustainable manner for the food and nutritional security of this highly populated country.

The world rice production area is 15,98,07,722 ha in which only 7.12% area is shared by Bangladesh. The world total rice production is 74,09,61,445 ton in which only 7.1% production is shared by Bangladesh and 90.8% production is shared by Asia. The Asian total rice production is 58,48,10,184.17 ton in which only 8.99% production is shared by Bangladesh. But Bangladesh ranks the 4th position in terms of production. The yield of rice is low in Bangladesh (4.62 t ha^{-1}) compared to Australia (10.29 t ha^{-1}). On the other hand the yield of rice in India was (3.69 t ha^{-1}), Japan (5.44 t ha^{-1}), China (6.93 t ha^{-1}) and Philippines (3.87 t ha^{-1}) (FAO, 2016).

Variety is the key component to produce higher yield of rice depending upon their differences in genotypic characters, input requirements and response, growth process and off course the prevailing environmental conditions during the growing season and also the growth process of rice plants under a given agro-climatic condition differs with variety. So variety is the most important factor in rice production. As well as selection of potential variety, planting in appropriate method and application of optimum amount of nutrient elements, can play an important role in increasing yield and national income. It was the farmers who have gradually replaced the local indigenous low yielding rice varieties by HYV of rice developed by BRRI only because of getting 20% to 30 % more yield unit^{-1} land area (Shahjahan, 2007). The population of Bangladesh is still growing and will require about 27.26 million tons of rice for the year 2020. But the average yield of rice is poor (4.34 t ha^{-1}) in Bangladesh (BRRI, 2011). On the other hand, rice production area is decreasing day by day due to high population pressure. The possibility of horizontal expansion of rice production area has come to stand still (Hamid, 1991). Therefore, attempts should be taken to increase the yield per unit area through use of comparatively high yielding varieties along with judicial fertilizer management and the introduction of hybrid rice is an important step towards augmentation of rice yields. Hybrid rice out yielded the existing conventional high yielding varieties (HYVs) by 15-20% in India, Bangladesh and Vietnam (Janaiah *et al.*, 2002).

BRRI dhan74 is one of the HYV released by BRRI. It contains 8.3% protein, 24.2 mg Zn kg^{-1}, which is 8.2 mg kg^{-1} more than other varieties but 0.2 mg kg^{-1} more than BRRI dhan64. It has capability to yield 7.1 t ha^{-1} (BRRI, 2015). Heera-2 is one of the major hybrids is used by farmer. In Bangladesh there are three growing seasons of rice namely aus, aman and boro. About 36.44% of the total rice area of Bangladesh is devoted to boro rice which contributes 49% to the national rice production (BBS, 2004). Boro rice grows during dry winter which is fully depends on irrigation. The crop used to be grown in areas with available irrigation facilities so the water management is the most considerable factor for boro rice cultivation. In Bangladesh, the increased rice production has come mostly from the expansion of Boro rice area but currently only about 40% of the potentially irrigable area of 7.56 million ha has irrigation facilities. About 70% of the irrigated area use ground water as the source and remaining area received water from surface sources (FAO, 1996). The development of economic strategy of using water is a major driving force for increasing rice production. But water shortage will become a more severe limitation to increase production in future and most farmers maintained standing water in the rice crop to control weeds, but this benefit comes at the expense of substantial water loss by percolation and seepage. So the gap between the “actual need” and “current use” of water producing rice is very large (Bhuiyan, 1999). Water use in irrigated rice culture can be reduced by 30-50% when the soil maintained saturation level throughout the cropping season, compared with the general practice of continuous flooding (Tabbal *et al.*, 1992 and Dhar, 2006). The HYV of rice can be grown much economically at saturated condition thus saving a lot of water lost through percolation and evaporation (Kanwar *et al.*, 1974 and Rahman *et al.*, 1978). In saturated condition, 30% water was saved during normal irrigation period over the amount used in farmer’s water management practice with continuous 5-7 cm standing water without any significant yield reduction (Sattar and Bhuan, 1994).

Under this circumstance the present research work has been taken with the following objectives:

- to find out the effect of variety and water deficiency on the growth and yield of boro rice
- to find out the tolerable limit water deficiency for rice production
- to find out the best interactive treatments of variety and water deficiency

CHAPTER 2

REVIEW OF LITERATURE

2a: Rice Variety

Variety is the most important factor for successful cultivation of boro rice. It affects the phenological characters, growth & yield of rice plant and nutrient status of the soil. Rice-rice system and rice fallows are no longer productive in Southeast Asia. Crop and varietal diversification of the rice based cropping systems may improve the productivity and profitability of the systems. Diversification is also a viable option to mitigate the risk of climate change. Implementation of suitable crop or varietal diversification is thus very much vital to achieve this objective. To assess the yield performance of rice varieties under timely and late sown conditions and to evaluate the performance of dry season. Highest system productivity and profitability under timely sown rice may be due to higher dry matter remobilization from source to sink. Many scientists and researchers have reported the rice varieties and their effects on the yield and yield contributing characters in boro rice. Some of their findings are summarized below.

2a.1 Growth parameters

2a.1.1 Plant height

BRRI (2014) reported that average plant height (92 cm) was obtained from BRRI dhan74. But plant height of BRRI dhan69 was 95-100 cm and of BRRI dhan81 was 100 cm.

Alam *et al.* (2009) investigated the growth pattern of three high yielding rice varieties under different phosphorus levels and found that the differences among the varieties in respect of plant height. He showed that at all the growth stages, the highest plant height was observed with BRRI dhan29 which was followed by Aloran and also two hybrid varieties 'Aloron' and 'Heera-2' resulted statistically similar plant height up to 100 days after transplanting. Hoque *et al.* (2013) reported similar effects of variety on the plant height of rice.

Azam (2010) studied the influence of methods of nitrogenous fertilizer and varieties on growth and yield of boro rice. Significant influence was remarked in terms of plant height as influenced by different varieties at different growth stages. He showed that BRRI hybrid dhan2 showed the highest plant heights (16.42, 64.96, 105.30 and 108.00 cm at 25, 50, 75 DAT and at harvest, respectively). Whereas ACI hybrid dhan1 showed the shorter plant (14.6, 55.04, 98.92 and 102.50 cm at 25, 50, 75 DAT and at harvest, respectively) which was statistically similar with BRRI dhan29 at 75 DAT and at harvest.

Debnath (2010) studied the influence of planting material and variety on yield of boro rice and showed significant variation of plant height was found due to different varieties. His results revealed that the tallest plant (86.33 cm) was obtained from the BRRI dhan29 and statistically followed by the ACI 1 (83.14 cm), BRAC aloron (82.58 cm), Sonarbangla-6 (81.40 cm) and Heera-5 (81.20 cm). The shortest plant height (79.81 cm) was given by BRRI hybrid dhan2 that statistically similar with the ACI 1 (83.14 cm), BRAC aloron (82.58 cm), Sonarbangla-6 (81.40 cm) and Heera-5 (81.20 cm). The inbred variety was about 13.41% taller at harvest compared to the hybrid variety.

Ahmed (2006) studied on the influence of different cultivation methods on growth and yield of hybrid and inbred rice and showed that the plant height of boro rice was significantly influenced by different varieties at 30, 50 and 70 days after transplanting (DAT) and at harvest. His result revealed that at 30 DAT, the hybrid variety Sonarbangla-1 produced the tallest plant (46.37 cm) and the inbred variety BRRI dhan29 gave the shortest plant (39.84 cm) and the same trend of plant height for hybrid variety over inbred variety was obtained at 50 and 70 DAT. However, at harvest, the highest plant height (106.31 cm) was obtained from the BRRI dhan29 and the lowest height (102.22 cm) was recorded in Sonarbangla-1. In the initial stage of growth, the increase of plant height was very slow and then the crop remained in vegetative stage. The rapid increase of plant height was observed from 30 to 70 DAT. After reaching the highest vegetative stage, the growth of plant became very slow. The inbred variety was about 4% taller at harvest compared to the hybrid variety.

Samsuzzaman (2007) worked on the varietal characterization and yield evaluation of six rice hybrids grown in Bangladesh and reported that the plant height of the hybrids ranged from 82.46 cm in Richer to 100.31 cm in BRRI dhan28 with a mean of 89.58 cm. For the checks the value ranged from 97.5 cm (BRRI dhan29) to 101.5 cm (BRRI dhan28), with a mean of 99.52 cm. He showed plant height of hybrids was lower than the checks. Among the 8 genotypes, BRRI dhan28 showed the highest plant height of 101.5 cm and Richer showed the lowest plant height of 82.5 cm. The grand mean value for this trait was 92.06 cm. The group of genotypes that showed higher plant height was constituted by BRRI dhan28 (101.5 cm), BRRI hybrid dhan1 (100.3 cm) and BRRI dhan29 (97.5 cm). The group of genotypes that showed lower plant height was constituted by BRRI dhan28 (82.5 cm) and Jagoron (85.5 cm) respectively.

Hussain *et al.* (2014) studied on the evaluation of different rice varieties for growth and yield characteristics and observed that plant length increased in all varieties steadily from transplanting to full heading stage. The rate of increase was higher from panicle initiation to full heading stage in all varieties. The length became constant from full heading to maturity for all varieties except IR-28 whose length increased upto grain development stage but the rate of increase was lower than previous stages. The rapid increase of plant length was an indication of changing vegetative to reproductive phase of crop growth. Koshihikari was the tallest variety with plant length 117.0 cm followed by IR-28 (111.8). The lowest plant length among all varieties was achieved by Nipponbare (102.5). The increase of plant length was due to elongation of stem internodes.

Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that plant height was significantly influenced by variety and the highest plant height was 90.27 cm which was found in BRRI dhan29 at 100 DAT and the lowest plant height was 68.52 cm which was found in Binadhan-14. Variable effect of variety on plant height was also reported by Om *et al.* (1998) and Krisna (2002) who also recorded variable plant height among varieties.

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

Ghosh (2001) worked with four rice hybrids and four high yielding rice cultivars and showed that hybrids have higher plant height as compared with high yielding varieties.

2a.1.2 Number of tillers hill^{-1}

Haque and Biswash (2014) worked on characterization of commercially cultivated hybrid rice in Bangladesh. Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid1 and two checks are BRRI dhan28 and BRRI dhan29. They found that among all the genotypes, Heera showed highest no. of effective tillers (17.7) and Sonarbangla-1 showed least no. of effective tillers (13.3) with a grand mean of 15.87. The group of genotypes that showed higher no. effective tillers per plant was constituted by Aloron (16.3) and Heera (17.7). The group of genotypes which showed least number of effective tillers per plant was constituted by Sonarbangla-1 (13.3) and Jagoron (15.3), respectively.

Debnath (2010) showed that there was no significant difference among BRRI dhan29, ACI-1, BRAC aloron, Sonarbangla-6, Heera-5 and BRRI hybrid dhan2 in case of number of effective tillers m^{-2}, number of ineffective tillers m^{-2} and number of total tillers m^{-2}.

Azam (2010) showed that number of tillers hill^{-1} was significantly influenced by different varieties used in his research. He showed that BRRI hybrid dhan2 showed the highest number of tillers hill^{-1} (1.73, 24.16, 23.98 and 23.98 at 25, 50, 75 DAT and at harvest, respectively). ACI Hybrid dhan1 also showed significantly same result compared to the variety of BRRI hybrid dhan2 at 25 DAT. Comparing tiller producing capacity of tillers hill^{-1} among the three varieties, BRRI dhan29 showed the lowest number of tillers hill^{-1} (1.02, 17.68, 17.56 and 17.54 at 25, 50, 75 DAT and at harvest, respectively). ACI Hybrid dhan1 gave intermediate result which was statistically similar with BRRI dhan29 at 50, 75 DAT and at harvest, respectively.

Samsuzzaman (2007) showed that among all the genotypes, Heera showed highest no. of effective tillers (17.7) and Sonarbangla-1 showed least no. of effective tillers (13.3) with a grand mean of 15.87. The group of genotypes that showed higher no. effective tillers plant^{-1} was constituted by Aloron (16.3) and Heera (17.7). The group of genotypes which showed least number of effective tillers plant^{-1} was constituted by Sonarbangla-1 (13.3) and Jagoron (15.3), respectively.

Hussain *et al.* (2014) studied on the evaluation of different rice varieties for growth and yield characteristics and observed that number of tillers per unit area increased from transplanting to the highest tillering stage in all varieties. However, NERICA-4 produced significantly lower numbers m^{-2} (403) as compared to other varieties. Nipponbare produced the highest numbers (790) but it was statistically at par with Koshihikari and IR-28. After the highest tillering stage, tillers decreased in all varieties but rate of decline was lower in NERICA-4 than other varieties. The number diminished up to full heading stage in NERICA-4 while in other varieties mortality of tillers continued up to maturity stage. This was due to high competition among tillers in Japonica and Indica varieties as compared to NERICA-4.

Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that the number of tillers hill^{-1} was significantly influenced by variety and the highest number of tillers hill^{-1} was 7.24 which was found in BRRI dhan29 at 100 DAT and the lowest number of tillers hill^{-1} was 6.06 which was found in Binadhan-14. Variable effect of variety on number of total tillers hill^{-1} was also reported by BINA (1998) and Nuruzzaman *et al.* (2000) who noticed that number of total tillers hill^{-1} differed among varieties.

2a.1.3 Leaf area index

Hussain *et al.* (2014) studied on the evaluation of different rice varieties for growth and yield characteristics and said that leaf area index (LAI) is a measure to know the size of photosynthetic machinery of a plant. Nipponbare exhibited higher LAI at all growth stages while NERICA-4 was the lowest one. IR-28 and Koshihikari were intermediate and statistically at par with each other. LAI increased with crop growth period and reached at the highest value at full heading stage in each variety. Afterwards, it started declining as crop moved towards maturity. The highest and the lowest values of LAI in Nipponbare and NERICA-4 respectively, were due to number of tillers m^{-2} exhibited by these varieties.

Rajput *et al.* (2017) studied on physiological parameters namely, leaf area index, crop growth rate, relative growth rate and net assimilation rate of different varieties of rice grown under different planting geometries and depths in SRI. The highest LAI in closer plant geometry might be due to more number of leaves produced per unit area and also the LAI is the photosynthetic area of the plant. It increased orderly up to growth stage and then declined slowly up to harvest under subtropical climatic condition. He showed that LAI was not significantly influenced by rice variety at 60 DAT and used varieties were MR-219, WGL-32100 and PS-3.

Haque *et al.* (2015) worked on comparative performance of hybrid and elite inbred rice varieties with respect to their source-sink relationship and stated that leaf area index (LAI) increased gradually in all the tested varieties in all the planting dates up to heading and in most of the cases the differences are non-significant. But the reduction of LAI is greater in inbred than that of hybrids and as an outcome, the hybrid varieties sustained higher LAI after heading to maturity over inbred BRRI dhan45 regardless of planting dates. However, the highest LAI was recorded from Heera2 (6.36) at heading stage followed by BRRI hybrid dhan2 (5.94) while it was significantly lower in BRRI dhan45 (5.10) at 20 December planting of 2008-09 and this result revealed that hybrid rice varieties maintained significantly greater LAI from heading to maturity stage compared to the inbred.

Mahato and Adhikari (2017) studied on the effect of planting geometry on growth of rice varieties and stated that the LAI significantly ($p<0.01$) influenced by the both plant spacing as well as varieties. They showed that in all observation, Sukhadhan-5 recorded the highest LAI and the highest LAI was found in 60 DAT and the lowest in 30 DAT followed by Sukhadhan4 and Radha-4.

2a.1.4 SPAD readings

Hussain *et al.* (2014) studied on the evaluation of different rice varieties for growth and yield characteristics and observed that SPAD value indicates chlorophyll contents and colour of crop. Japonica varieties achieved lower SPAD values at all growth stages as compared to indica and NERICA. SPAD value decreased sharply in Nipponbare and Koshihikari from active tillering to panicle initiation stage as compared to IR-28 and NERICA-4. It increased initially in Nipponbare from transplanting to active tillering stage but in IR-28 it remained constant for this period and then declined at P. I. stage for both varieties. At P. I. stage second dose of N and K_2O was top dressed which increased SPAD value at full heading stage and again it decreased reaching the lowest level at maturity stage in all varieties. NERICA-4 was the most responsive variety to increase SPAD value. It may be due to lower number of tillers and competition among tillers as compared to other varieties.

Figueiredo *et al.* (2015) stated that 60 % variation of the straw dry matter was depended on the SPAD-readings at reproductive stage.

Islam *et al.* (2009) worked on evaluation of SPAD and LCC based nitrogen management in rice and stated that the SPAD meter was a simple portable diagnostic tool used for monitoring crop N status in situ in the field. The SPAD reading was taken by a chlorophyll meter (SPAD-502, Minolta Camera Co., Japan). Also the SPAD and LCC readings were taken from the middle portion of the fully expanded youngest leaves from 5 randomly selected hills. They founded that the SPAD reading came down to critical value of 35.

2a.1.5 Days to 50% flowering and maturity

Samsuzzaman (2007) worked on the varietal characterization and yield evaluation of six rice hybrids grown in Bangladesh and studied the number of days taken for 50% flowering and it had significant difference with varieties. It took 96.0 days in case of Heera to 116.3 days in case of BRRI dhan29. He also showed that the grand mean for days to maturity of all the genotypes was 131.95 days. In which Heera took 130 days to mature.

Ganesan (2001) said that days to flowering, plant height, number of tillers plant^{-1}, and productive tillers plant^{-1} had both positive and negative indirect effects on yield. Padmavathi *et al.* (1996) suggested that days to 50% flowering had high positive direct effects of number of panicles plant^{-1} and panicle length on grain yield.

2a.2 Yield and yield contributing characters

2a.2.1 Number of effective tillers hill^{-1}

Samsuzzaman (2007) worked on the varietal characterization and yield evaluation of six rice hybrids grown in Bangladesh and showed that among all the genotypes, Heera showed highest no. of effective tillers (17.7) and Sonarbangla-1 showed least no. of effective tillers (13.3) with a grand mean of 15.87. He represented that the group of genotypes that showed maximum no. effective tillers plant^{-1} was constituted by Aloron (16.3) and Heera (17.7) and the group of genotypes which showed least number of effective tillers plant^{-1} was constituted by Sonarbangla-1 (13.3) and Jagoron (15.3), respectively.

Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that number of effective tillers hill^{-1} was significantly influenced by variety. He showed that BRRI dhan29 produced the highest number of effective tillers hill^{-1} (5.62) and Binadhan-14 produced the lowest number of effective tillers hill^{-1}**.**

Anon. (1992) reported that the effective tillers were more or less similar in BRRI dhan29 and Sonarbangla-6. However, Anon. (1998) suggested that high yielding variety had more effective tillers m^{-2} over the inbred variety.

2a.2.2 Number of ineffective tillers hill^{-1}

Debnath (2010) studied the influence of planting material and variety on yield of boro rice and showed that the number of ineffective tillers m^{-2} was not significantly influenced by variety.

Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that number of ineffective tillers hill^{-1} was not significantly influenced by variety. Ullah (2013) showed that non-effective tillers hill^{-1} exerted significant difference among the varieties. The highest number of non-effective tillers hill^{-1} (1.78) was obtained in BRRI dhan29 followed by Heera (1.18) and Sl8H (1.17) and the lowest number of non-effective tillers hill^{-1} was produced by BRRI dhan58 (1.11) which is statistically similar with Heera (1.18) and Sl 8H (1.17).

2a.2.3 Panicle length

Hussain *et al.* (2014) studied on the evaluation of different rice varieties for growth and yield characteristics and observed that Koshihikari produced smaller panicles (17.9 cm) as compared to other varieties which exhibited similar panicle lengths. The longest panicle lengths were observed in IR-28 (23.7 cm) followed by NERICA-4 and Nipponbare. Different panicle lengths were observed due to different genotype of the varieties.

Debnath (2010) studied the influence of planting material and variety on yield of boro rice and showed that the panicle length was varied significantly due to different variety. She showed that the highest (27.23 cm) and the lowest (22.33 cm) panicle length obtained from BRRI dhan29 and BRAC Aloron respectively.

Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that panicle length was significantly influenced by variety. He showed that BRRI dhan29 produced the highest panicle length (20.16) and Binadhan-14 produced the lowest panicle length.

Obaidullah (2007) stated that variety significantly influenced panicle length and the highest panicle length was 27.36 cm. Devaraju *et al.* (1998), BINA (1993) and Chowdhury *et al.* (1993) also said panicle length was significantly influenced by different rice varieties. Babiker (1986) also observed that panicle length differed due to the varietals variation.

2a.2.4 Rachis branches panicle^{-1}

Mo *et al.* (2012) worked on changes in the panicle-related traits of different rice varieties under high temperature condition and showed that number of primary branches panicle^{-1} was significantly differ with rice variety.

2a.2.5 Leaf area index

Azam (2010) showed that leaf area index was significantly influenced by different varieties used in his study. His results indicated that BRRI hybrid dhan2 showed the highest leaf area index (7.36, 7.19 and 7.12 at 50, 75 DAT and at harvest, respectively). Which was statistically similar with ACI Hybrid dhan1 at 50, 75 DAT and at harvest, respectively but at 25 DAT there was significant variation observed. Among the three varieties, BRRI dhan29 showed the lowest leaf area index.

Sitaramaiah *et al.* (1998) observed that high yielding hybrids also recorded higher harvest index and higher biomass yield. Kiniry *et al.* (2001) concluded that yield differences among cultivars were due to HI and the superiority of hybrids for biomass over conventional varieties is reported widely. Blanco *et al.* (1990) observed 10-20% superiority of hybrids for total biological yield and grain yield and Jiang *et al.* (1995) compared 10 varieties for yield components. He showed that the yield increase of dwarf over tall varieties mainly resulted from higher harvest index, while the yield increase of hybrid rice over the dwarf varieties was mainly from higher biomass production. Takeda *et al.* (1983) also observed that high yielding rice varieties had higher LAI.

2a.2.6 Filled grains panicle^{-1}

Samsuzzaman (2007) worked on the varietal characterization and yield evaluation of six rice hybrids grown in Bangladesh and showed that the mean of hybrids for number of filled grains panicle^{-1} was 130.96, with the range being 118.0 (Jagoron) to 148.7 (BRRI hybrid dhan1) in which Heera showed 140 grains panicle^{-1}.

Debnath (2010) studied the influence of planting material and variety on yield of boro rice and showed that the filled grains panicle^{-1} differed significantly for variation of the variety. She represented that the highest number of filled grains panicle^{-1} (162.57) was found in the hybrid variety BRRI hybrid dhan2 that similar to the all other varieties except ACI 1 which resulted the lowest number of filled grains panicle^{-1} (136.95) and the filled grains panicle^{-1} of ACI 1 was similar to BRRI dhan29, BRAC aloron and Heera 5.

Obaidullah (2007) stated that variety significantly influenced filled grains panicle^{-1} and the highest filled grains panicle^{-1} was 156.84.

2a.2.7 Unfilled grains panicle^{-1}

Debnath (2010) studied the influence of planting material and variety on yield of boro rice and showed that the unfilled grains panicle^{-1} was significantly differed among the varieties. She represented that the highest number of unfilled grains panicle^{-1} (27.37) was counted in the inbred variety BRRI dhan29 and the lowest number of unfilled grains panicle^{-1} (6.60) was counted in the hybrid variety BRAC aloron.

Akbar (2004) also found the highest number of unfilled grains panicle^{-1} in Sonarbangla-6. BINA (1993) reported that varieties differed significantly in respect of unfilled grains panicle^{-1}.

2a.2.8 Total number of grains panicle^{-1}

Samsuzzaman (2007) worked on the varietal characterization and yield evaluation of six rice hybrids grown in Bangladesh and showed that there was a significant difference among rice varieties. He showed that the mean of hybrids for this character was 158.83 with the range being 133.7 (Jagoron) to 213.3 (BRRI hybrid dhan1).

Debnath (2010) studied the influence of planting material and variety on yield of boro rice and showed that the total number of grains panicle^{-1} was not significantly influenced by the variety though the highest number of grains panicle^{-1} (179.33) was obtained from the inbred variety BRRI dhan29 and the lowest number of grains panicle^{-1} (149.23) was obtained from the hybrid variety BRAC aloron. The inbred variety showed 14.50% higher number of total grains panicle^{-1} compared to hybrid variety BARC aloron.

Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that the number of grains panicle^{-1} was significantly influenced by variety. He showed that BRRI dhan29 produced the highest number of grains panicle^{-1} (95.03) and Binadhan-14 produced the lowest number of grains panicle^{-1}**.**

Hossain and Alam (1991) reported that the growth characters like total tillers hill^{-1} and the number of grains panicle^{-1} differed significantly among BR3, BRll, BR14 and Pajam varieties in boro season. Obaidullah (2007) also stated that variety significantly influenced number of total grains panicle^{-1} which was 196.75 panicle^{-1}.

Ashrafuzzaman (2006) observed that variety significantly influenced the number of grains panicle^{-1} and showed that the higher number of grains panicle^{-1} (147.59) was counted in the inbred variety and the lower number of grains panicle^{-1} (111.98) number were counted in the hybrid variety.

2a.2.9 Weight of 1000-grain

Samsuzzaman (2007) worked on the varietal characterization and yield evaluation of six rice hybrids grown in Bangladesh and showed that there was a significant difference among rice varieties. He showed that the highest 1000-grain weight was observed in Aloron (28.82 g) and the lowest in Heera (25.82 g) among the hybrids, with a mean of 27.67 g.

Akter *et al.* (2015) studied on seed treatment for improving quality of hybrid seeds of rice. They found that moisture content of collected hybrid seed samples varied significantly from one to another, while the lowest (12.20%) and the highest (14.37%) records were made in Moyna and Meghna, respectively. In respect of 1000-seed weight, the varieties of hybrid rice were also found to vary significantly from one to another, where the lowest 1000-seed weight (20.00 g) was found in variety Aloron and Heera-1, but the highest weight (26.00 g) was recorded in Heera-4.

Debnath (2010) studied the influence of planting material and variety on yield of boro rice and showed that the weight of 1000-grain was significantly influenced by the variety and the highest weight of 1000-grain (35.68 g) was obtained from the hybrid variety BRAC Aloron and the lowest weight of 1000-grain (24.98 g) was obtained from the inbred variety BRRI dhan29.

Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that 1000 grains weight was significantly influenced by variety. He showed that BRRI dhan29 produced the highest 1000 grains weight (20.74) and Binadhan-14 produced the lowest 1000 grains weight.

Obaidullah (2007) reported that variety significantly influenced 1000 grains weight and the highest 1000 grains weight was 27.40 g. Rahman (2001) found highest weight of 1000-grain in Sonarbangla variety than the other studied varieties.

Ashrafuzzaman (2006) observed that variety significantly influenced the 1000 grains weight and showed that the higher 1000 grains weight (27.12 g) was counted in the inbred variety and the lower 1000 grains weight (21.89 g) number were counted in the hybrid variety.

2a.2.10 Grain yield

Samsuzzaman (2007) worked on the varietal characterization and yield evaluation of six rice hybrids grown in Bangladesh and showed that among the hybrids, grain yield ha^{-1} significantly differ by varieties. He showed that highest yield was 7.45 t ha^{-1} (Aloron) but yield of Heera was 6.2 t ha^{-1}.

Debnath (2010) showed that the grain yield was significantly influenced by the variety and the highest grain yield (6.33 t ha^{-1}) was obtained from the hybrid variety BRAC aloron that followed by hybrid variety, Sonarbangla-6, BRRI hybrid dhan2, ACI 1 and Heera-5. She also showed that the lowest fresh grain yield (4.16 t ha^{-1}) was found in inbred variety BRRI dhan29.

Munoz *et al.* (1996) showed that IR8025A hybrid rice cultivar produced an average yield of 7.1 t ha^{-1} which was 16% higher than the commercial variety Oryzica Yacu-9. Bisne *et al.* (2006) also showed that grain yield was significantly influenced by different varieties.

2a.2.11 Straw yield

Debnath (2010) showed that the straw yield was significantly influenced by the variety and the highest straw yield (6.70 t ha^{-1}) was obtained from the inbred variety BRRI dhan29 and the lowest yield (4.86 t ha^{-1}) from the of hybrid variety BRAC Aloron. All the hybrid 55 varieties showed the similar straw yield. The straw yield of BRRI dhan29 was 32.1% higher compared to the hybrid variety BARC aloron.

Main *et al.* (2007) stated that there was no significant variation of straw yield and harvest index observed between the two varieties.

2a.2.12 Grain straw ratio

Debnath (2010) showed that there was no significant difference among the variety in respect of grain straw ratio though the increased grain straw ratio (1.32) was obtained from the hybrid variety BRAC Aloron and the lowest grain straw ratio (0.66) was obtained from inbred variety BRRI dhan29.

2a.2.13 Biological yield

Samsuzzaman (2007) worked on the varietal characterization and yield evaluation of six rice hybrids grown in Bangladesh and showed that among the hybrids, biological yield $plant^{-1}$ ranged from 28.0 g in Heera to 46.45 g in BRRI dhan29, with a mean value of 33.89 g.

Debnath (2010) showed that variety had no effect on biological yield though the highest biological yield (12.22 t ha^{-1}) was found from the hybrid variety Sonarbangla-6 and the lowest biological yield (10.85 t ha^{-1}) was found from the inbred variety BRRI dhan29.

Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that biological yield was significantly influenced by variety. He showed that BRRI dhan29 produced the highest biological yield (11.77 t ha^{-1}) and Binadhan-14 produced the lowest biological yield.

2a.2.14 Harvest index

Samsuzzaman (2007) worked on the varietal characterization and yield evaluation of six rice hybrids grown in Bangladesh and showed that the mean of harvest index of the hybrids was recorded 57.43% and range varied from 48.0% (BRRI hybrid dhan1) to 64.0 (Jagoron). But harvest index of Heera was 52.5%.

Debnath (2010) showed that Harvest index was significantly influenced by the variety and the highest harvest index (56.50%) was found from the hybrid variety BRAC Aloron and the lowest harvest index (37.67%) was found from the inbred variety BRRI dhan29 and it was 18.8 % different.

Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that harvest index was significantly influenced by variety. He showed that BRRI dhan29 produced the highest harvest index (43.79 %) and Binadhan-14 produced the lowest harvest index.

2a.2.15 Dry weight hill^{-1}

Azam (2010) showed that significant variation was observed by different varieties used in his study in terms of dry weight hill^{-1}. He showed that BRRI hybrid dhan2 showed the highest dry weight hill^{-1}. ACI also showed significantly similar result compared to the variety of BRRI hybrid dhan2 at 25 DAT. Among the three varieties, BRRI dhan29 showed the lowest number dry weight hill^{-1}.

Alam *et al.* (2009) investigated the growth pattern of three high yielding rice varieties under different phosphorus levels and found that the significant effect of variety on total dry matter production in plant was observed at 75 DAT and 100 DAT but at 25 DAT and 50 DAT, dry matter plant^{-1} was influenced non-significantly across the varieties. At 75 DAT and At 100 the highest dry weight (17.28 g) and (42.2 g) plant^{-1} was found with Heera-2 variety followed by Aloron (16.06 g) and (39.91 g) respectively.

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

2a.2.16 Dry matter of shoot hill^{-1}

Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that the dry matter of shoot hill^{-1} was significantly influenced by variety and the highest dry matter of shoot hill^{-1} was 26.38 g which was found in BRRI dhan29 at 100 DAT and the lowest dry matter of shoot hill^{-1} was found in Binadhan-14.

2a.2.17 Dry matter of root hill^{-1}

Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that the dry matter of root hill^{-1} was significantly influenced by variety and the highest dry matter of root hill^{-1} was 11 g which was found in BRRI dhan29 at 100 DAT and the lowest dry matter of root hill^{-1} was found in Binadhan-14.

2b: Water deficiency:

2b.1. Growth parameters

2b.1.1 Plant height

Sarvestani *et al.* (2008) conducted a field experiment during 2001-2003 to evaluate the effect of water deficiency on the yield and yield components of four rice cultivars commonly grown in Mazandaran province, Iran. Local and improved cultivars used were Tarom, Khazar, Fajr and Nemat. He used water deficiency during vegetative, flowering and grain filling stages and well watered was the control. He showed that water deficiency at vegetative stage significantly reduced plant height of all cultivars.

Dhar (2006) studied on the growth and yield of boro rice as influence by water level and seedling number hill^{-1} plant height of boro rice. He showed that plant height was significantly influenced by different water levels but it was insignificant at 30 days after transplanting. His results revealed that at 15 DAT, the tallest plant (24.98 cm) was obtained from continuous submergence and the shortest plant (20.20 cm) was at continuous saturation. At 30 DAT, there was no significant difference in plant height due to water levels was observed. The tallest plant height (72.81 cm) was recorded at 45 DAT maintaining water continuously submergence followed by irrigation applied at saturated condition and similar trend of plant height was observed at 60 & 75 DAT and even at harvest, the tallest plant height was 109.88 cm and the shortest plant height was 105.10 cm. He estimated that plant height increased over saturated to submerged condition was 23.66 %, 12.52%, 14%, 11.25%, 6.98% and 4.55 % at 15, 30, 45, 60, 75 DAT and at harvest respectively.

Zain *et al.* (2014) studied on the impact of cyclic water deficiency on growth, physiological responses and yield of rice grown in tropical environment and showed that the water deficiency have remarkable influence on growth and yield components of rice. He showed that plant height was not significantly influenced by continuously flooding (CF) and continuously saturated conditions.

Cruj *et al.* (1975) who concluded that plant height was greater under submerged condition than other treatments and decreased plant height in saturated condition might be due to enormous weeds which suppressed plant growth and development and such trend was higher at early stage due to highest infestation of weed as suggested by (Reddy and Raju, 1987).

2b.1.2 Number of tillers hill^{-1}

Mostajeran and Rahimi-Eichi (2009) studied on effects of drought deficiency on growth and yield of rice cultivars. They showed that the number of tillers per hill was decreased with decreased soil moisture level. The reduction of tillers production under lower soil moisture levels might be the fact that under water deficiency, plants were not able to produce enough assimilates for inhibited photosynthesis. It might be also happened for less amount of water uptake to prepare sufficient food and inhibition of cell division of meristematic tissue.

Dhar (2006) studied on the growth and yield of boro rice as influence by water level and seedling number hill^{-1} plant height of boro rice. He showed that the production of total tiller hill^{-1} was significantly influenced by different water levels. He showed that at 45 days after transplanting, the highest (21.07) and the lowest (18.80) number of tiller was observed from submerged and saturated condition respectively and the highest number of tiller hill^{-1} was counted in this stage comparing the entire growing period.

Zain *et al.* (2014) studied on the impact of cyclic water deficiency on growth, physiological responses and yield of rice grown in tropical environment and showed that the water deficiency have remarkable influence on growth and yield components of rice. He showed that number of tiller hill^{-1} was significantly influenced by continuously flooding (CF) and continuously saturated conditions.

Biswas and Salokhe (2001) who mentioned that tillering in rice increases up to 30 to 40 days after transplanting. Statistically the highest (17.34) and the lowest (15.78) tillers hill^{-1} at 75 DAT was recorded under submerged and saturated condition, respectively and at harvest, significantly higher (14.78) number of tiller hill^{-1} was counted at irrigation applied in continuous standing (3-5 cm) water and lower (13.39) number was at saturated condition. Islam (1997) who showed that in submergence condition 7.06 % more tiller was produced over saturated condition. Singh and Pandey (1972) reported greater tiller production under continuous submergence that decreased with decreasing soil moisture.

2b.1.3 Leaf area index

Amano *et al.* (1993) who showed that leaf area index (LAI) was the highest in heading stage (61 DAT) and then decreased. At 60 DAT, significantly higher (7.57) and lower (5.72) LAI was found under submerged and saturated condition respectively. Tanaka (1976) and Farugue (1996) also showed the similar kind of result.

2b.1.4 SPAD readings

Stephan *et al.* (2010) worked on effect of abiotic deficiencyes on the non-destructive estimation of rice leaf nitrogen concentration and concluded that non-destructive estimation of rice crop nitrogen status (e.g., chlorophyll meter [SPAD] or leaf color chart [LCC]) are an established technology for improved N management in irrigated systems, but their value in rainfed environments with frequent abiotic deficiencyes remains untested. Therefore, they studied the effect of drought, salinity, phosphorus (P) deficiency, and sulfur (S) deficiency on leaf N estimates derived from SPAD and LCC measurements in a greenhouse experiment. Linear relations between chlorophyll concentration and leaf N concentration based on dry weight between SPAD values adjusted for leaf thickness and between LCC scores adjusted for leaf thickness and could be confirmed for all treatments and varieties used. Leaf spectral reflectance measurements did not show a deficiency-dependent change in the reflectance pattern, indicating that no specific element of the photosynthetic complex was affected by the deficiencyes and at the deficiency level applied. They concluded that SPAD and LCC were potentially useful tools for improved N management in moderately unfavorable rice environments.

2b.1.5 Days to flowering and maturity

Sikuku *et al.* (2010) showed that the varieties had significant difference ($P \leq 0.05$) in days to flowering. The watering regimes affected the number of days taken by the plants to reach 50% flowering. He used the plants watered daily (control) took the least days to attain 50% flowering while plants watered after every six days which were the most deficiencyed plants took the longest duration to attain 50% flowering. NERICA 2 was the least affected by water deficit because it took the least number of days to attain 50% flowering in the plants watered after every 2, 4 and 6 days and NERICA 11 was the most affected by water deficit and took the most number of days to reach 50% flowering in plants watered after six days.

Dhar (2006) showed that, days to flowering was significantly influenced by water levels and duration of flowering was earlier (103.83 DAT) at submerged condition whereas the highest duration (105.75 DAT) was taken at continuous saturated condition.

2b.2 Yield and yield contributing characters

2b.2.1 Number of effective tillers hill^{-1}

Krishnamurty *et al.* (1980) who observed that submergence of rice field increased number of productive tillers compared to under saturation condition but the difference was not significant. Chowdhury (1988) also showed that the highest number of effective tillers m^{-2} with continuous flooding that was significantly different from that obtained with continuous saturation.

Zubaer *et al.* (2007) showed that the number of tiller per hill was decreased with decreased soil moisture level. Reduced tiller production under lower soil moisture levels might be the fact that under water deficiency, plants were not able to produce enough assimilates for inhibited photosynthesis and it might be also happened for less amount of water uptake to prepare sufficient food and inhibition of cell division of meristematic tissue. Murty (1987), Castilo *et al.* (1987), Cruz *et al.* (1986), IRRI (1974) and Islam *et al.* (1994) also showed the similar kind of result.

2b.2.2 Number of ineffective tillers hill^{-1}

Su-Mei *et al.* (2016) worked on effect of water deficiency on growth and yield of rice and said water control may increase rice tiller amount but the tiller reduces fast in the late stage of tillering as drought period becomes longer, the ineffective tiller will increase and effective tiller will decrease.

2b.2.3 Panicle length

Bhuiyan (1999) showed that rice plant did not suffer from water deficiency if soil was saturated and there was no standing water but this result was disagreed with Khare *et al.* (1970) who reported that the panicle length was highest at 5 cm flooding than that's of continuous saturation.

Venkatesan *et al.* (2005) stated that water deficiency in various stages of crop growth reduced panicle length, number of grains panicle^{-1} and weight of 1000 grains. However the yield components were not much affected in the deficiency treatment given in tillering stage only and it seems that plant tolerated to deficiency conditions when the deficiency was imposed in the vegetative stage than other stages.

Dhar (2006) showed that the panicle length was not varied significantly due to water levels and the highest (28.42 cm) and the lowest (28.10 cm) panicle length was obtained under submerged and saturated condition respectively which was statistically similar.

2b.2.4 Rachis branches panicle^{-1}

Wu *et al.* (2011) worked on effect of water deficiency on physiological traits and yield in rice backcross lines after anthesis and concluded that primary branches panicle^{-1} significantly differed with water deficiency.

2b.2.5 Flag leaf length

Yan *et al.* (2012) worked on Rice flag leaf physiology, organ and canopy temperature in response to water deficiency and concluded that the photosynthetic ability was higher in W2 (mild water deficiency), yielding a higher soluble sugar in the flag leaf. There was a significant difference in soluble sugar content between the plants in W2 and W3 (severe water deficiency) ($P<0.05$). The free proline content was significantly higher in W2 than in W3.

2b.2.6 Filled grains panicle^{-1}

Bhatia and Dastane (1971) conducted an experiment over a two year period with three rice varieties grown on soil submergence under 4 or 4-8 cm of water or irrigated at 0.4 atm. The yields of rice, number of productive tillers and filled grains panicle^{-1} and 1000-grain weight were higher with a water depth of 4cm than with a depth of 4-8 cm or with irrigation to 0.4 atm tension.

Dhar (2006) studied on the growth and yield of boro rice as influence by water level and seedling number hill^{-1} plant height of boro rice. He showed that the filled grains panicle did not differ significantly for water levels and the highest number of filled grains (145.35) was found in submerged condition and the minimal number (137.20) of grains panicle^{-1} at saturated condition. The filled grains were 89.50% and 90.05% of total grains under saturated and submerged condition respectively.

2b.2.7 Unfilled grains per panicle

Zubaer *et al.* (2007) showed the interaction effect of soil moisture levels and rice genotypes on the number of unfilled grains per panicle, was significant. In all the rice genotypes, number of unfilled grains was increased with reduced soil moisture levels but the degree of increment was different in different genotypes. Increased unfilled grains per panicle under lower soil moisture level might be due to inactive pollen grain for dryness, incomplete development of pollen tube; insufficient assimilates production and its distribution to grains. Hossain (2001), Yambo and Ingram (1988), Begum (1990) and Islam *et al.* (1994) also showed the similar kind of result.

Dhar (2006) studied on the growth and yield of boro rice as influence by water level and seedling number hill^{-1} plant height of boro rice. He represented that analysis of variance showed that number of unfilled grain panicle^{-1} was not statistically differed due to different water levels and the highest (16.07) and the lowest (15.96) number of unfilled grains panicle^{-1} was recorded under continuous submergence and saturated condition respectively.

2b.2.8 Total number of grains panicle^{-1}

Joseph and Havanagi (1987) who showed that number of grains panicle^{-1} under standing water was superior than that’s of under saturated condition and they also found 8.21% more grains panicle^{-1} over saturated to submerged condition.

2b.2.9 Weight of 1000-grain

Patel (2000) observed no significant difference of 1000 grains weight under saturated and submerged condition. Dhar (2006) studied on the growth and yield of boro rice as influence by water level and seedling number hill^{-1} plant height of boro rice. He represented that weight of 1000 grains was found statistically unaffected by the variation of water levels. He showed that comparatively heavier (19.86 g) 1000 grains weight was found under saturated condition which was similar with that of submerge condition.

2b.2.10 Grain yield

Sarvestani *et al.* (2008) conducted a field experiment during 2001-2003 to evaluate the effect of water deficiency on the yield and yield components of four rice cultivars commonly grown in Mazandaran province, Iran. Local and improved cultivars used were Tarom, Khazar, Fajr and Nemat. He used water deficiency during vegetative, flowering and grain filling stages and well watered was the control. He showed that water deficiency at flowering stage had a greater grain yield reduction than water deficiency at other times and the reduction of grain yield largely resulted from the reduction in fertile panicle and filled grain percentage. He also showed that water deficit during vegetative, flowering and grain filling stages reduced mean grain yield by 21, 50 and 21% on average in comparison to control respectively. Total biomass, harvest index, plant height, filled grain, unfilled grain and 1000 grains weight were reduced under water deficiency in all cultivars and water deficiency at vegetative stage effectively reduced total biomass due to decrease of photosynthesis rate and dry matter accumulation.

Dhar (2006) studied on the growth and yield of boro rice as influence by water level and seedling number hill^{-1} plant height of boro rice. He represented that grain yield of boro rice was not significantly influenced by water levels. The highest grain yield (6.44 t ha^{-1}) was obtained with continuous submerged condition that followed by continuous saturated condition. IRRI (1995) showed that maintaining a saturated soil throughout the growing season could save upto 40% of water in clay loam soil, without yield reduction.

Maity and Sarkar (1990) observed no significant yield difference under saturated and submerged condition. But the result was disagreed with Gowda (1995) who stated statistically higher grain yield at submerged condition than that of saturated condition.

Sattar and Bhuiyan (1994) revealed that yield from all the treatments of direct-seeded rice was significantly higher (0.6 t ha^{-1}) than transplanted one using 20% less amount of water. They showed that under continuous saturated condition, 30% water was saved during normal irrigation period over the amount used in farmers' water management practices (continuous 5-7 cm standing water) with the direct-seeded methods without any significant yield reduction. In case of transplanted rice 1,238 mm water used for farmers normal management practice whereas continuous saturated soil condition had the most water-saving regime requiring 917 mm (26% less) water for the whole growing season.

Jaggi *et al.* (1985) suggested that continuous submergence of soil was not essential for high yield. Continuous flooding needs more water than other water regimes and there are evidences that rice grown under saturation or with intermittent flooding save a lot of valuable water.

Patel (2000) conducted an experiment to find out the effect of water regimes, variety and biofertilizer (blue-green algee) on rice yield. His result indicated that water regimes affected grain yield of rice significantly. Saturation till tillering and submergence till ripening gave the highest yield compared with other treatments except the treatment of continuous submergence. The straw yield, 1000-grain weight, number of filled grains $panicle^{-1}$ and effective tillers $plant^{-1}$ also showed similar observation.

Tabbal *et al.* (1992) observed no significant yield difference between rice grown in standing water and that grown under saturated field condition in 1988-89 dry seasons. However, he showed yields under saturated soils were lower in 1990-91 dry seasons because of more weed growth compared with the previous dry seasons.

Islam (1992) observed that the highest grain yield of (5.19 t ha^{-1}) was obtained in plots maintaining 5 to 7 cm standing water and the lowest yield (3.85 t ha^{-1}) was noted in plot where water level was maintained from 1 cm to saturation. Singh and Mishra (1990) also obtained the highest yield under the continuous flooding regime and the lowest under the moist regime.

BINA (1988) showed that the highest yield achieved under continuous (8-10 cm) standing water whereas the lowest statistically identical yields were 2.81 and 2.76 t ha^{-1} from the treatments of alternate flooding and drying (0 to 5.0 cm) and continuous saturation condition.

Zain *et al.* (2014) studied on the impact of cyclic water deficiency on growth, physiological responses and yield of rice grown in tropical environment and showed that the water deficiency have remarkable influence on growth and yield components of rice. He represented that grain yield was highest under both in continuously flooding (CF) and continously saturated (CS) (10.40 t ha^{-1}) conditions. However grain yield of rice reduced by 14% for both 5 and 10 days of water deficiency cycle compared with CF and CS.

2b.2.11 Straw yield

Dhar (2006) studied on the growth and yield of boro rice as influence by water level and seedling number $hill^{-1}$ plant height of boro rice. He represented that irrigation treatments showed statistically similar effect on straw yield of boro rice and comparatively the highest (8.03 t ha^{-1}) and the lowest (7.69 t ha^{-1}) straw yield was found under irrigation applied at submerged condition and saturated condition respectively.

Venkatesan *et al.* (2005) stated that water deficiency in various stages of crop growth reduced grain yield and straw yield and had its impact on the growth of rice crop. Patel (2000) reported that, there was no significant difference of straw yield under saturated and submerged condition. Chowdhury (1988) opined that straw yield was significantly decreased whenever soil moisture dropped below saturation and Islam (1997) also observed significantly the highest straw yield in submerged condition than that of saturated condition.

2b.2.12 Biological yield

Dhar (2006) studied on the growth and yield of boro rice as influence by water level and seedling number hill^{-1} plant height of boro rice. He represented that biological yield was not significantly varied for the water levels and the highest biological yield (14.47 t ha^{-1}) was obtained from continuous submerged condition which was statistically similar (13.86 t ha^{-1}) to saturated condition.

2b.2.13 Harvest index

Dhar (2006) studied on the growth and yield of boro rice as influence by water level and seedling number hill^{-1} plant height of boro rice. He represented that harvest index was not statistically influenced by the water levels. However, he showed that the highest (45.03%) harvest index was found from irrigation applied at submerged condition and the lowest harvest index (44.65 %) was at saturated condition.

Raju (1980) who worked on the effect of irrigation regimes on agronomic characters of rice and reported that treatment having continuous flooding did not improve the harvest index.

2b.2.14 Dry matter of shoot hill^{-1}

Mostajeran and Rahimi-Eichi (2009) studied on effects of drought deficiency on growth and yield of rice cultivars. They showed that the shoot dry matter hill^{-1} was the highest at submerged than non-submerged treatment and decrease shoot dry matter under lower soil moisture might be due to reduction of leaf area and photosynthesis rate.

2b.2.15 Dry matter of root hill^{-1}

Bois and Couchat (1983) worked on comparison of the effects of water deficiency on the root systems of two cultivars of upland rice and concluded that dry matter of root hill^{-1} was significantly differ with water deficiency.

2b.2.16 Dry matter hill^{-1}

Dhar (2006) studied on the growth and yield of boro rice as influence by water level and seedling number hill^{-1} plant height of boro rice. He represented that total dry weight of plant was significantly influenced by water levels at harvest but statistically unaffected at 30 and 60 days after transplanting. Jayasankar and Ramakrishnayya (1993) also showed that the specific leaf weight increased when the plants were in submergence condition.

2c: Interaction effect of variety and water deficiency

Sarvestani *et al.* (2008) worked on study of water deficiency effects in different growth stages on yield and yield components of different rice (*Oryza sativa L.)* cultivars and concluded that water deficiency at vegetative stage significantly reduced plant height of all cultivars. Water deficiency at flowering stage had a greater grain yield reduction than water deficiency at other times and the reduction of grain yield largely resulted from the reduction in fertile panicle and filled grain percentage. Water deficit during vegetative, flowering and grain filling stages reduced mean grain yield by 21, 50 and 21% on average in comparison to control respectively and the yield advantage of two semi-dwarf varieties, Fajr and Nemat, were not maintained under drought deficiency. Total biomass, harvest index, plant height, filled grain, unfilled grain and 1000 grain weight were reduced under water deficiency in all cultivars. Water deficiency at vegetative stage effectively reduced total biomass due to decrease of photosynthesis rate and dry matter accumulation.

Sokoto and Muhammad (2014) conducted a pot experiment at the Botanical Garden of the Department of Biological Science, Usmanu Danfodiyo University, Sokoto Nigeria, during the 2013 dry season. The treatment consisted of water deficiency at three growth stages (Tillering, flowering, Grain filling) and undeficiency (control) and three rice varieties (FARO 44, NERICA 2 and FARO 15) laid out in a Completely Randomised Design (CRD) replicated three times and the result indicated that water deficiency significantly ($P < 0.05$) resulted to decreased in plant height, number of leaves per plant, total biomass, harvest index and grain yield. The results indicated significant ($P < 0.05$) differences among genotypes in which FARO 44 differed significantly from in plant height, number of leaves per plant, total biomass, harvest index and grain yield. FARO 44 differed significantly from NERICA 2 and FARO 15 at all the parameters under study and also water is very vital as far as rice production is concern should be applied at every stage of rice production.

Amiri *et al.* (2009) studied the effect of irrigation method on growth and yield of rice varieties and factorial experiment was conducted in 2008, on pot conditions. In maturity time, yield measurement, plant height, panicle length, unfilled grain weight, Weight of 1000 grains, amount of irrigation, number of grains per panicle, total biomass and number of tillers in pot were done and results showed that there were significant difference in probability level, all measured properties between rice varieties and all measured properties, except amount of Weight of 1000 grains, in irrigation management.

Zubaer *et al.* (2007) studied on the effects of water deficiency on growth and yield attributes of aman rice genotypes. They showed that soil moisture level and genotypes interacted significantly on number of tillers hill^{-1}. At all growing stages (booting, flowering and maturity), the highest number tillers hill^{-1} were obtained from 100% FC and the lowest number of tillers hill^{-1} was obtained from 40% FC. Number of tillers hill^{-1} varies due to different genotypes. Binadhan 4 produced the highest number of tillers hill^{-1}, Basmoti and RD 2585 produced the medium and the lowest number of tillers hill^{-1}, respectively. At booting, flowering and maturity stages, the highest number of tillers was observed the treatment combination of Binadhan 4X 100% FC showed significantly the lowest number of tillers hill^{-1}. The results showed that the number of tiller hill^{-1}was decreased with decreased soil moisture level. Reduced tiller production under lower soil moisture levels might be the fact that under water deficiency.

CHAPTER 3

MATERIALS AND METHODS

The field experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University farm, Dhaka-1207 during the period from October 2016 to May 2017.

3.1 Site description

3.1.1 Geographical location

The experimental area was situated at 23°77′N latitude and 90°33′E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

3.1.2 Agro-ecological region

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.3 Climate

The area has sub-tropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and less rainfall associated with moderately low temperature during the Rabi season (October-March).

3.1.4 Soil

The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish-brown mottles. Soil pH ranged from 5.6 and had organic matter 0.78% (Appendix II). The experimental area was flat having available irrigation and drainage system and above flood level.

3.2 Details of the experiment

3.2.1 Planting material

BRRI dhan74 and Heera-2 were the two variety of boro rice used in this experiment. BRRI dhan74 variety was developed by the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. The pedigree line (BR7671-37-2-2-3-7) of the variety was derived from a cross between IR68144 and BRRI dhan29. The variety was released in 2014 for cultivation in boro season. The grains are medium-slender with light-golden husks and the milled rice is medium-fine and white. Its front husks are rough. BRRI dhan74 is moderately resistant to blast disease.

3.2.2 Seed collection and sprouting

Seeds of BRRI dhan74 were collected from BRRI, Joydebpur, Gazipur and seeds of Heera-2 were collected from Supreme Seed Company at Gulistan market in Dhaka. Healthy seeds were selected. Seeds were immersed in water in a bucket for 24 hrs. Seeds were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hrs.

3.2.3 Raising of seedlings

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

3.2.4 Preparation of experimental land

The experimental field was first opened on 20 December, 2016 with the help of a power tiller, later the land was irrigated and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering to have a good puddled field and all kinds of weeds and residues of previous crop were removed from the field. The field layout was made on 29 December, 2016 according to design immediately after final land preparation.

3.2.5 Fertilizer management

The experimental land was fertilized with 300, 150, 200 and 120 kg ha^{-1} Urea, triple superphosphate (TSP), muriate of potash (MoP), gypsum respectively. The entire amounts of triple superphosphate (TSP), muriate of potash (MoP) and gypsum were applied at final land preparation. The first one-third urea was top dressed at 9 days after transplanting (DAT). The rest of urea was top dressed in two equal splits- one at 34 days after transplanting (DAT), second at 60 days after transplanting (DAT).

3.2.6 Experimental treatments

Two factors of treatments included in the experiment were as follows:

Factor A: Variety (2)

a. BRRI dhan74 (V_1) and b. Heera-2 (V_2)

Factor B: Water deficiency (7)

1. No deficiency (S_0)
2. Deficiency at 15-35 DAT (S_1)
3. Deficiency at 55-75 DAT (S_2)
4. Deficiency at 85-105 DAT (S_3)
5. Deficiency at 15-35 DAT and 55-75 DAT (S_4)
6. Deficiency at 15-35 DAT and 85-105 DAT (S_5)
7. Deficiency at 55-75 DAT and 85-105 DAT (S_6)

3.2.7 Experimental design

The experiment was laid in a split-plot design with three replications having variety in the main plots and water deficiency in the sub-plots. There were 14 treatment combinations and the total numbers of unit plots were 42. The size of unit plot is 3 m x 2 m. The distances between both plot to plot and replication to replication were 1m.

The layout of the experiment has been shown in Appendix III.

3.2.8 Transplanting of seedlings

From nursery, 37 days old seedlings for BRRI dhan74 and 32 days old seedlings for Heera-2 were uprooted carefully on 30^{th} December, 2016. The seedbeds were made wet by the application of water in the previous day before uprooting the seedlings to minimize mechanical injury of roots. Seedlings were then transplanted with 20 cm × 20 cm spacing on the well-puddled plots. In each plot, there were 10 rows, each row contains 14 hills of rice seedlings. There were in total 140 hills in each plot.

3.2.9 Intercultural operations

3.2.9.1 Weeding

The crop was infested with some weeds. Three hand weeding were done for each treatments, first weeding was done at 10 DAT followed by second weeding at 40 DAT. And the third weeding was done at 80 DAT.

3.2.9.2 Gap Filling

After one week of transplanting, some gap filling was done where it was necessary using the seedling from the same source.

3.2.9.3 Application of irrigation water

Irrigation water was added to each plot according to the schedule of the treatments and all the plots were irrigated as per treatments through irrigation channels. Treatment S_0 was maintained by standing water every day, treatment S_1 was maintained by standing water except 10-35 DAT, treatment S_2 was maintained by standing water except 50-75 DAT, treatment S_3 was maintained by standing water except 80-105 DAT, treatment S_4 was maintained by standing water except 10-35 DAT and 50-75 DAT, treatment S_5 was maintained by standing water except 10-35 DAT and 80-105 DAT and treatment S_6 was maintained by standing water except 50-75 DAT and 80-105 DAT.

3.2.9.4 Plant protection measures

Plants were infested with rice stem borer (*Scirphophaga incertolus*) at 3 to 4 hill in a plot, so that infested plants were uprooted by hand and there was no need of insecticide application. Crop was protected from birds during the grain filling period by net.

3.2.9.5 General observation of the experimental field

The experimental field was observed everyday to detect visual difference among the treatments and any kind of infestation by weeds, insects and diseases so that considerable losses by pest can be minimized. The field looked nice with normal green color plants and the plants in no water deficiency condition appeared more vigorous and luxuriant growth than the other water deficiency conditions. Weed infestation in no water deficiency condition was less than other water deficiency condition. Some infested plants with stem borer were observed during tillering stage but any bacterial and fungal disease was not observed. The flowering was not uniform where BRRI dhan74 took less time to flowering than Heera-2.

3.2.9.6 Harvesting and post-harvest operation

The rice plant was harvested depending upon the maturity of plant and harvesting was done manually from each plot. Maturity of crop was determined when 90% of the grains become matured. Five pre-selected hills per plot from which different data were collected and middle six line of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done using foot. The grains were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly. Finally grain and straw yields plot^{-1} were determined and converted to ton ha^{-1}.

3.3 Recording of data

Experimental data on the following parameters were recorded from 17 DAT with 25 days interval and continued until harvest.

A. Crop Growth Characters

i. Plant height (cm) at 25 days interval and at harvest
ii. Number of tillers hill^{-1} at 25 days interval and at harvest
iii. Leaf area index at 25 days interval and at harvest
iv. Dry matter hill^{-1} at 25 days interval and at harvest
v. Days to 50% flowering and maturity
vi. SPAD value at 83 DAT
vii. Dry matter of weed at 38 DAT

B. Yield and other crop characters

i. Number of effective tillers hill^{-1}
ii. Number of ineffective tillers hill^{-1}
iii. Length of panicle (cm)
iv. Number of rachis branches panicle^{-1}
v. Number of filled grains panicle^{-1}
vi. Number of unfilled grains panicle^{-1}
vii. Number of total grains panicle^{-1}
viii. Sterility percentage
ix. Weight of 1000-grain
x. Grain yield
xi. Straw yield
xii. Biological yield
xiii. Harvest index

3.4 Detailed procedures of recording data

The necessary data on agronomic characters were collected from five selected hills from each plot. A brief outline of the data recording procedure followed during the study is given below:

A. Crop growth characters

1. Plant height (cm)

Plant height was measured at 25 days interval and continued up to harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf height before heading, and to the tip of panicle after heading.

2. Number of tillers hill^{-1}

Number of tillers hill^{-1} were counted at 25 days interval and continued up to harvest from five randomly pre-selected hills and was expressed as number hill^{-1}. Only those tillers having three or more leaves were used for counting.

3. Leaf Area Index (LAI)

Leaf area index were estimated measuring the length and average breadth of leaf (25 days interval and continued up to harvest) and multiplying by a factor of 0.75 followed by (Yoshida, 1981).

4. Dry matter

The sub-samples of 2 hills plot^{-1} uprooted from 2nd line and oven dried until a constant level from which the weight of root and shoot dry matter were recorded at 25 days interval up to harvest.

5. Days to 50% flowering and maturity

Time of flowering (days) was considered when about 50% of the panicle within a plot emerged.

6. SPAD value at 83 DAT

The SPAD-502 chlorophyll meter (Minolta Camera Co., Japan) is a simple, portable, diagnostic and nondestructive light weight device used to estimate leaf chlorophyll content (Minolta, 1989). The computed values by this device represents the whole content of chlorophyll (a, b) in plant, (Feibo *et al.*, 1998; Ichie *et al.*, 2002; Ramesh *et al.*, 2002). Five plants per plot were selected randomly and SPAD values at 83 DAT were recorded from the fully matured leaves counted from the top of the plants, the youngest fully expanded leaf.

7. Dry matter of weed at 38 DAT

The sub-samples of weed plot^{-1} uprooted from 800 cm^2 and oven dried until a constant level from which the weight of root and shoot dry matter were recorded at 38 DAT.

B. Yield and other crop characters

1. Effective tillers hill^{-1}

The panicles which had at least one grain was considered as effective tillers and the number of effective tillers of 5 hills was recorded and expressed as number of effective tillers hill^{-1}.

2. Ineffective tillers hill^{-1}

The tillers having no panicle was regarded as ineffective tillers and the number of ineffective tillers of 5 hills was recorded and expressed as number of ineffective tillers hill^{-1}.

3. Panicle length

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

4. Rachis branches of panicle

Primary branches of 10 panicles were recorded and averaged.

5. Filled grains panicle^{-1}

Grain was considered to be filled if any kernel was present and the number of total filled grain present on 10 panicles were recorded and finally averaged.

6. Unfilled grains panicle^{-1}

Unfilled grain means the absence of any kernel inside and the number of total unfilled grain present on 10 panicles were recorded and finally averaged.

7. Total grains panicle^{-1}

The number of filled grains panicle^{-1} with the number of unfilled grains panicle^{-1} gave the total number of grains panicle^{-1}.

8. Sterility percentage

At the harvest time, 10 panicles were harvested at maturity from five randomly chosen plants in each plot and the no. of filled, unfilled and total grain was counted. Spikelets fertility percentage was then computed as

$$\text{Sterility percentage} = \frac{\text{No.of unfilled grains in the panicle}}{\text{Total no.of grains in the panicle}} \times 100$$

9. Weight of 1000-grain

One thousand cleaned dried seeds were counted randomly from each plot and weighed by using a digital electric balance at the stage the grain retained 14% moisture and the mean weight were expressed in gram.

10. Grain yield

Grain yield was determined from the mid 6 lines of each plot and expressed as t ha^{-1} and adjusted with 12% moisture basis.

11. Straw yield

Straw yield was determined from the mid 6 lines of each plot after separating of grains. The sub-samples were sun dried to a constant weight and finally converted to t ha^{-1}.

12. Biological yield

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

$$\text{Biological yield (t ha}^{-1}\text{)} = \text{Grain yield (t ha}^{-1}\text{)} + \text{Straw yield (t ha}^{-1}\text{)}$$

13. Harvest index

It denotes the ratio of economic yield (grain yield) to biological yield and was calculated with following formula (Donald, 1963; Gardner *et al.*, 1985).

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

3.5 Statistical analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique using CROPSTAT package and the mean differences were adjudged by LSD technique at 5% level of significance (Gomez and Gomez, 1984).

CHAPTER 4
RESULTS AND DISCUSSION

4.1 Growth parameters

4.1.1 Plant height (cm)

4.1.1.1 Effect of variety

BRRI dhan74 and Heera-2 had no significant difference in terms of plant height during the whole growth period (Appendix IV). Here BRRI dhan74 showed the maximum plant height than Heera-2, except harvesting period. This might be due to V_2 took 128 DAT and V_1 took 117 DAT for harvesting. So V_2 got 11 days more from V_1 to harvest. The maximum plant height for V_1 was 80.67 cm and for V_2 was 86.43 cm (Table 1). BRRI (2014) reported that average plant height (92 cm) was obtained from BRRI dhan74. Alam *et al.* (2009) investigated the growth pattern of three high yielding rice varieties under different phosphorus levels and found differences among the varieties in respect of plant height and he showed that “Aloron” and “Heera-2” statistically similar plant height up to 100 days after transplanting. Hoque *et al.* (2013) reported similar effects of variety on the plant height of rice. Debnath (2010) studied the influence of planting material and variety on yield of boro rice and showed significant variation of plant height was among different varieties.

Table 1. Effect of variety on plant height at different growth stages of boro rice

Treatments	Plant height (cm) at				
	16 DAT	41 DAT	66 DAT	91 DAT	harvest
V_1	17.59	35.40	59.46	77.02	80.67
V_2	17.05	34.71	55.82	76.79	86.43
$LSD_{(0.05)}$	NS	NS	NS	NS	NS
CV (%)	13.44	4.35	10.21	4.67	6.49

V_1 = BRRI dhan74 and V_2 = Heera-2

4.1.1.2 Effect of water deficiency

Plant height was significantly influenced by water deficiency at 16 DAT, 41 DAT, 66 DAT, 91 DAT and harvest (Appendix IV). But at 16 DAT, there was no significant difference among S_0, S_1, S_2, S_4 and S_5 in terms of plant height in which S_1 showed the highest (19.05 cm) plant height and S_6 showed the lowest (15.41 cm) plant height and the highest value was 23.62% greater than the lowest value. Also there was no significant difference among S_0, S_2, S_3, S_4 and S_5. Again there was no significant difference among S_3, S_4, S_5 and S_6 in terms of plant height at 16 DAT.

On the other hand at 41 DAT, 66 DAT, 91 DAT and harvest, there was no significant difference among S_0, S_1, S_2, S_3 and S_6 in terms of plant height. Also there was no significant difference between S_1 and S_4, again there was no significant difference between S_4 and S_5 in terms of plant height at 41 DAT. The highest plant height (cm) were 37.31 (S_0), 61.24 (S_3) and 80.14 (S_3) at 41 DAT, 66 DAT and 91 DAT respectively and lowest plant height (cm) were 31.46 (S_5), 52.64 (S_4) and 73.42 (S_4) at 41 DAT, 66 DAT and 91 DAT respectively (Table 2).

At harvest stage S_3 showed the highest (87.75 cm) plant height and S_4 showed the lowest (79.23 cm) plant height and the highest value was 10.75% greater than the lowest value. So water deficiency at vegetative stage and reproductive stage mostly reduced the plant height but water deficiency at ripening stage had no effect on plant height. Therefore, vegetative stage and reproductive stage are the most critical stage for plant growth.

Sarvestani *et al.* (2008) also showed that water deficiency at vegetative stage significantly reduced plant height of all cultivars. Cruj *et al.* (1975) who concluded that plant height was greater under submerged condition than other treatments and decreased plant height in saturated condition might be due to enormous weeds which suppressed plant growth and development and such trend was higher at early stage due to the highest infestation of weed as suggested by Reddy and Raju (1987).

Table 2. Effect of water deficiency on plant height at different growth stages of boro rice

Treatments	Plant height (cm) at				
	16 DAT	41 DAT	66 DAT	91 DAT	harvest
S_0	18.32 ab	37.31 a	60.12 ab	77.21 ab	84.67 ab
S_1	19.05 a	35.07 ab	57.32 abc	77.84 ab	85.10 ab
S_2	18.00 ab	36.84 a	59.12 ab	77.72 ab	84.08 abc
S_3	16.47 bc	36.61 a	61.24 a	80.14 a	87.75 a
S_4	17.09 abc	32.33 bc	52.64 c	73.42 b	79.23 c
S_5	16.92 abc	31.46 c	55.40 bc	74.71 b	80.72 bc
S_6	15.41 c	35.76 a	57.65 abc	77.32 ab	83.32 abc
$LSD_{(0.05)}$	2.57	3.3	5.59	4.8	4.89
CV (%)	12.45	7.89	8.14	5.24	4.91

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.1.1.3 Interaction effect of variety and water deficiency

Plant height was significantly influenced by the interaction of variety and water deficiency at 16 DAT, 41 DAT, 66 DAT, 91 DAT and harvest (Appendix IV). At 16 DAT, the highest plant height was observed in V_1S_1 (19.90 cm) which was statistically similar with all the treatments except V_1S_6, V_2S_3 and V_2S_6, the second highest plant height was observed in V_1S_0 (19.15 cm) which was statistically similar with all the treatments except V_1S_1, V_1S_6 and V_2S_6, the lowest plant height was observed in V_2S_6 (15.36 cm) which was statistically similar with all the treatments except V_1S_0 and V_1S_1.

At 41 DAT, the highest plant height was observed in V_1S_0 (38.55 cm) which was statistically similar with all the treatments except V_1S_4, V_1S_5, V_2S_4 and V_2S_5, also there was no significant difference among the treatments except V_1S_0, V_1S_3, V_1S_4, V_1S_5 and V_2S_5, again there was no significant difference among the treatments except V_1S_0, V_1S_3, V_1S_4, V_2S_2 and V_2S_5, once again there was no significant difference among the treatments except V_1S_0, V_1S_3, V_1S_6, V_2S_0, V_2S_2 and V_2S_5 and the lowest plant height was observed in V_2S_5 (31.01 cm) which was statistically similar with V_1S_1, V_1S_4, V_1S_5, V_2S_1, V_2S_3, V_2S_4 and V_2S_6.

At 66 DAT, the highest plant height was observed in V_1S_3 (66.47 cm) which was statistically similar with V_1S_0, V_1S_1, V_1S_2 and V_2S_2, the second highest plant height was observed in V_1S_0 (62.45 cm) which was statistically similar with all the treatments except V_1S_3, V_1S_4, V_2S_1 and V_2S_4, again there was no significant difference among the treatments except V_1S_0, V_1S_3 and V_2S_4 and the lowest plant height was observed in V_2S_4 (51.36 cm) which was statistically similar with all the treatments except V_1S_0, V_1S_1, V_1S_2 and V_1S_3.

At 91 DAT, the highest plant height was observed in V_2S_2 (80.53 cm) which was statistically similar with all the treatments except V_2S_4 and the lowest plant height was observed in V_2S_4 (70.53 cm) which was statistically similar with all the treatments except V_1S_1, V_1S_3, V_1S_6, V_2S_0, V_2S_2 and V_2S_3.

At harvest, the highest plant height was observed in V_2S_2 (88.31 cm) which was statistically similar with the treatments except V_1S_2, V_1S_4, V_1S_5 and V_1S_6; the third highest plant height was observed in V_2S_1 (87.92 cm) which was statistically similar with all the treatments except V_1S_2, V_1S_4, V_1S_5, V_2S_2 and V_2S_3, again there was no significant differences among V_1S_0, V_1S_1, V_1S_2, V_1S_6, V_2S_4, V_2S_5 and V_2S_6; once again there was no significant difference among V_1S_0, V_1S_1, V_1S_2, V_1S_5, V_1S_6, V_2S_4, and V_2S_5 and the lowest plant height was observed in V_1S_4 (75.33 cm) which was statistically similar with V_1S_0, V_1S_2, V_1S_4, V_1S_5 and V_1S_6. The highest plant height was greater than the lowest plant height by 29.56%, 24.31%, 29.42%, 14.18% and 17.23% at 16 DAT, 41 DAT, 66 DAT, 91 DAT and at harvest respectively (Table 3).

Table 3. Interaction effect of variety and water deficiency on plant height at different growth stages of boro rice

Treatments	Plant height (cm) at				
	16 DAT	41 DAT	66 DAT	91 DAT	harvest
V_1S_0	19.15 ab	38.55 a	62.45 ab	76.81 ab	81.43 a-e
V_1S_1	19.90 a	35.56 a-e	60.21 abc	78.71 a	82.27 a-d
V_1S_2	17.47 abc	35.80 a-d	59.63 abc	74.90 ab	79.85 cde
V_1S_3	17.38 abc	38.40 a	66.47 a	80.15 a	87.20 ab
V_1S_4	16.70 abc	31.32 de	53.92 cd	74.30 ab	75.33 e
V_1S_5	17.09 abc	31.91 cde	55.78 bcd	74.67 ab	77.55 de
V_1S_6	15.46 c	36.25 abc	57.79 bcd	77.58 a	81.07 b-e
V_2S_0	17.48 abc	36.06 abc	57.78 bcd	77.60 a	87.91 ab
V_2S_1	18.19 abc	34.57 a-e	54.43 cd	76.96 ab	87.92 ab
V_2S_2	18.53 abc	37.88 ab	58.61 a-d	80.53 a	88.31 a
V_2S_3	15.55 bc	34.81 a-e	56.02 bcd	80.13 a	88.30 a
V_2S_4	17.49 abc	33.35 b-e	51.36 d	70.53 b	83.13 a-d
V_2S_5	16.75 abc	31.01 e	55.01 bcd	74.75 ab	83.88 a-d
V_2S_6	15.36 c	35.27 a-e	57.51 bcd	77.06 ab	85.57 abc
$LSD_{(0.05)}$	3.63	4.66	7.91	6.79	6.91
CV (%)	12.45	7.89	8.14	5.24	4.91

V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.1.2 Number of tillers hill^{-1}

4.1.2.1 Effect of variety

BRRI dhan74 and Heera-2 had no significant difference in terms of number of tillers hill^{-1} during the whole growth period except harvesting period (Appendix V). Here V_1 showed the maximum number of tillers hill^{-1} than V_2 from 66 DAT to harvesting period. This might be due to genetic character of V_1 which is able to produce more tiller than V_2. The maximum number of tillers hill^{-1} for V_1 was 14.49 and for V_2, the maximum number of tillers hill^{-1} was 9.54. So V_1 gave 51.89% more tillers hill^{-1} over V_2 (Table 4). Haque and Biswash (2014) worked on characterization of commercially cultivated hybrid rice in Bangladesh. Varieties were Sonarbangla-1, Jagoron, Heera, Aloron, Richer, BRRI hybrid1 and two checks are BRRI dhan28 and BRRI dhan29. They found that among all the genotypes, Heera showed the highest no. of effective tillers (17.7). Variable effect of variety on number of total tillers hill^{-1} was also reported by BINA (1998) and Nuruzzaman *et al.* (2000) who noticed that number of total tillers hill^{-1} differed among varieties.

Table 4. Effect of variety on no. of tillers hill^{-1} at different growth stages of boro rice

Treatments	Number of tillers hill^{-1} at				
	16 DAT	41 DAT	66 DAT	91 DAT	harvest
V_1	0.62	5.23	9.68	14.49 a	11.53
V_2	0.65	5.61	9.35	9.54 b	8.31
$LSD_{(0.05)}$	NS	NS	NS	4.45	NS
CV (%)	65.9	16.13	59	27.89	59

V_1 = BRRI dhan74 and V_2 = Heera-2

4.1.2.2 Effect of water deficiency

Number of tillers hill^{-1} was significantly influenced by water deficiency at 41 DAT, 66 DAT, 91 DAT and harvest. But at 16 DAT, there was no significant difference (Appendix V). At 41 DAT, the highest number of tillers hill^{-1} was observed in S_2 (6.50) which was statistically similar with S_0, S_3 and S_6 and the lowest number of tillers hill^{-1} was observed in S_5 (4.50) which was statistically similar with all the treatments except S_2 and S_3.

At 66 DAT, the highest number of tillers hill^{-1} was observed in S_0 (10.90), which was statistically similar with S_2, S_3, S_5 and S_6, the second highest number of tillers hill^{-1} was observed in S_3 (10.73) which was statistically similar with S_0, S_1, S_2, S_5 and S_6 and the lowest number of tillers hill^{-1} was observed in S_4 (7.70) which was statistically similar with S_1, S_5 and S_6.

At 91 DAT, the highest number of tillers hill^{-1} was observed in S_6 (13.47) which was statistically similar with all the treatments except S_4 and S_5 and the lowest number of tillers hill^{-1} was observed in S_4 (10.73) which was statistically similar with all the treatments except S_3 and S_6.

At harvest, the highest number of tillers hill^{-1} was observed in S_3 (11.77) which was statistically similar with all the treatments except S_1 and S_4 and the lowest number of tillers hill^{-1} was observed in S_4 (8.93) which was statistically similar with all the treatments except S_3. The highest number of tillers hill^{-1} was greater than the lowest number of tillers hill^{-1} by 44.44%, 41.56%, 25.54% and 31.8% at 41 DAT, 66 DAT, 91 DAT and at harvest respectively (Table 5).

Dhar (2006) studied on the growth and yield of boro rice as influence by water level and seedling number hill^{-1} plant height of boro rice. He showed that the production of total tiller hill^{-1} was significantly influenced by different water levels. Zain *et al.* (2014) studied on the impact of cyclic water deficiency on growth, physiological responses and yield of rice grown in tropical environment and showed that the water deficiency have remarkable influence on growth and yield components of rice. He showed that number of tillers hill^{-1} was significantly influenced by continuously flooding (CF) and continuously saturated conditions.

Table 5. Effect of water deficiency on no. of tillers hill^{-1} at different growth stages of boro rice

Treatments	Number of tillers hill^{-1} at				
	16 DAT	41 DAT	66 DAT	91 DAT	harvest
S_0	0.77	6.13 ab	10.90 a	12.13 ab	10.0 ab
S_1	0.53	4.67 b	8.30 bc	11.23 ab	8.97 b
S_2	0.93	6.50 a	10.30 ab	12.50 ab	10.13 ab
S_3	0.40	5.57 a	10.73 ab	13.23 a	11.77 a
S_4	0.57	4.72 b	7.70 c	10.73 b	8.93 b
S_5	0.63	4.50 b	8.90 abc	10.80 b	9.60 ab
S_6	0.60	5.87 ab	9.77 abc	13.47 a	10.03 ab
$LSD_{(0.05)}$	NS	1.70	2.5	2.29	2.89
CV (%)	78.9	26.38	22.05	15.98	19.36

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.1.2.3 Interaction effect of variety and water deficiency

Number of tillers hill^{-1} was significantly influenced by the interaction of variety and water deficiency at 41 DAT, 66 DAT, 91 DAT and harvest (Appendix V). AT 16 DAT, there was no significant difference. At 41 DAT, the highest number of tillers hill^{-1} was observed in V_2S_0 (6.73) which was statistically similar with all the treatments except V_1S_4 and V_1S_5, also there was no significant difference among the treatments except V_1S_2, V_1S_4, V_2S_0 and V_2S_2 and the lowest number of tillers hill^{-1} was observed in V_1S_4 (3.90) which was statistically similar with all the treatments except V_1S_2, V_1S_6, V_2S_0 and V_2S_2.

At 66 DAT, the highest number of tillers hill^{-1} was observed in V_1S_3 (12.73) which was statistically similar with all the treatments except V_1S_4, V_1S_5, V_2S_1, V_2S_3 and V_2S_4, again there was no significant difference among the treatments except V_1S_3, V_2S_0 and V_2S_1 and the lowest number of tillers hill^{-1} was observed in V_2S_1 (7.07) which was statistically similar with all the treatments except V_1S_2, V_1S_3 and V_2S_0.

At 91 DAT, the highest number of tillers hill^{-1} was observed in V_1S_3 (15.133) which was statistically similar with V_1S_2 and V_1S_6, there was no significant difference among the treatments except V_1S_3, V_2S_1, V_2S_2, V_2S_3, V_2S_4 and V_2S_6, again there was no significant difference among the treatments except V_1S_2, V_1S_3, V_1S_6, V_2S_1 and V_2S_6, once again there was no significant difference among the treatments except V_1S_1, V_1S_2, V_1S_3, V_1S_6 and V_2S_1 and the lowest number of tillers hill^{-1} was observed in V_2S_1 (6.467) which was statistically similar with V_1S_4, V_2S_0, V_2S_1, V_2S_2, V_2S_3, V_2S_4, V_2S_5 and V_2S_6.

At harvest, the highest number of tillers hill^{-1} was observed in V_1S_3 (16.80) which was statistically similar with V_1S_1, V_1S_2 and V_1S_6, there was no significant difference among the V_1S_0, V_1S_1, V_1S_2, V_1S_4 and V_1S_5, again there was no significant difference among the V_1S_0, V_1S_4, V_1S_5, V_2S_0 and V_2S_6, once again there was no significant difference among the V_1S_4, V_1S_5, V_2S_0, V_2S_2, V_2S_3 and V_2S_6, furthermore there was no significant difference among the V_1S_5, V_2S_0 V_2S_2, V_2S_3, V_2S_5 and V_2S_6 and the lowest number of tillers hill^{-1} was observed in V_2S_1 (8.13) which was statistically similar with V_2S_0, V_2S_1, V_2S_2, V_2S_3, V_2S_4, V_2S_5 and V_2S_6. The highest number of tillers hill^{-1} was greater than the lowest number of tillers hill^{-1} by 72.56%, 80.13%, 106.64% and 134% at 41 DAT, 66 DAT, 91 DAT and at harvest respectively. Here V_1S_3 produce the highest number of tillers hill^{-1} from 66 DAT to harvest time and V_2S_1 produce the lowest number of tillers hill^{-1} from 66 DAT to harvest time (Table 6). So V_1S_3 was the best treatments in terms of number of tillers hill^{-1}. Zubaer *et al.* (2007) studied on the effects of water deficiency on growth and yield attributes of aman rice genotypes. They showed that soil moisture level and genotypes interacted significantly on number of tillers hill^{-1}.

Table 6. Effect of variety and water deficiency on no. of tillers hill^{-1} at different growth stages

Treatments	Number of tillers hill^{-1} at				
	16 DAT	41 DAT	66 DAT	91 DAT	harvest
V_1S_0	0.73	5.53 abc	9.27 abc	13.27 bc	10.40 bcd
V_1S_1	0.33	4.40 abc	9.53 abc	14.33 ab	11.47 bc
V_1S_2	0.80	6.40 a	10.67 ab	15.33 ab	12.0 ab
V_1S_3	0.27	6.13 abc	12.73 a	16.80 a	15.13 a
V_1S_4	0.53	3.90 c	7.13 bc	12.80 bcd	9.40 b-e
V_1S_5	0.73	3.93 bc	8.53 bc	12.27 b-e	10.40 bcd
V_1S_6	0.93	6.33 ab	9.87 abc	16.60 a	11.93 ab
V_2S_0	0.80	6.73 a	12.53 a	11.00 c-f	9.60 b-e
V_2S_1	0.73	4.93 abc	7.07 c	8.13 f	6.467 e
V_2S_2	1.07	6.60 a	9.93 abc	9.67 def	8.267 cde
V_2S_3	0.53	5.00 abc	8.73 bc	9.67 def	8.4 cde
V_2S_4	0.60	5.53 abc	8.27 bc	8.67 f	8.467 cde
V_2S_5	0.53	5.07 abc	9.27 abc	9.33 ef	8.80 bcde
V_2S_6	0.27	5.40 abc	9.67 abc	10.33 c-f	8.13 de
$LSD_{(0.05)}$	NS	2.41	3.54	3.24	3.24
CV (%)	78.9	26.38	22.05	15.98	19.36

V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.1.3 Leaf area index

4.1.3.1 Effect of variety

BRRI dhan74 and Heera-2 had no significant difference in terms of leaf area index during the whole growth period except harvesting period (Appendix VI). Here V_1 showed the maximum leaf area index than V_2 from 66 DAT to harvesting period. This might be due to genetic character of V_1 over V_2. The maximum leaf area index for V_1 was 4.80 and for V_2, highest leaf area index was 4.07 at 91 DAT. So V_1 gave 17.94% more leaf area index over V_2 (Table 7). Mahato and Adhikari (2017) studied on the effect of planting geometry on growth of rice varieties and stated that the LAI significantly ($p<0.01$) influenced by the both plant spacing as well as varieties.

Table 7. Effect of variety on leaf area index at different growth stages of boro rice

Treatments	Leaf Area Index at				
	16 DAT	41 DAT	66 DAT	91 DAT	harvest
V_1	0.56	0.97	3.82	4.80	1.13 a
V_2	0.74	1.11	3.74	4.07	0.99 b
$LSD_{(0.05)}$	NS	NS	NS	NS	0.12
CV (%)	14.5	10.2	25.46	50.7	51.9

V_1 = BRRI dhan74 and V_2 = Heera-2

4.1.3.2 Effect of water deficiency

Leaf area index was significantly influenced by water deficiency at 16 DAT 41 DAT, 66 DAT and 91 DAT. But at harvest, there was no significant difference among the treatments in case of leaf area index (Appendix VI). At 16 DAT, there was a significant difference between S_2 and S_3. The highest leaf area index was observed in S_2 (0.80) which was statistically similar with all the treatments except S_3 and the lowest leaf area index was observed in S_3 (0.47) which was statistically similar with all the treatments except S_2.

At 41 DAT, the highest leaf area index was observed in S_2 (1.24), which was statistically similar with S_0, S_3, S_4 and S_6, the second highest leaf area index was observed in S_0 (1.20) which was statistically similar with S_1, S_3, S_4 and S_6 and the lowest leaf area index was observed in S_5 (0.78) which was statistically similar with S_1, S_3 and S_4. At 66 DAT, the highest leaf area index was observed in S_0 (4.51), which was statistically similar with S_1, S_2, S_3 and S_6. The lowest leaf area index was observed in S_4 (2.57) which was statistically similar with S_1, S_5 and S_6.

At 91 DAT, the highest leaf area index was observed in S_3 (5.74) which was statistically similar with S_0, S_2 and S_6 and the lowest leaf area index was observed in S_4 (3.67) which was statistically similar with all the treatments except S_3. The highest leaf area index was greater than the lowest leaf area index by 70.21%, 59%, 75.49%, 56.4% and 44.7% at 16 DAT, 41 DAT, 66 DAT, 91 DAT and at harvest respectively (Table 8).

Amano *et al.* (1993) who showed that leaf area index (LAI) was the highest in heading stage (61 DAT) and then decreased. At 60 DAT, significantly higher (7.57) and lower (5.72) LAI was found under submerged and saturated condition respectively. Tanaka (1976) and Faruque (1996) also showed the similar kind of result.

Table 8. Effect of water deficiency on leaf at area index different growth stages of boro rice

Treatments	Leaf Area Index at				
	16 DAT	41 DAT	66 DAT	91 DAT	harvest
S_0	0.67 ab	1.20 ab	4.51 a	4.55 ab	1.10
S_1	0.75 ab	0.90 bc	3.67 ab	3.86 b	1.05
S_2	0.80 a	1.24 a	4.46 a	4.51 ab	1.22
S_3	0.47 b	1.07 abc	4.50 a	5.74 a	1.23
S_4	0.65 ab	0.95 abc	2.57 b	3.67 b	0.85
S_5	0.67 ab	0.78 c	3.03 b	4.03 b	0.86
S_6	0.54 ab	1.13 ab	3.71 ab	4.70 ab	1.11
$LSD_{(0.05)}$	0.30	0.32	1.42	1.27	NS
CV (%)	39	25.8	29.69	23.9	30.9

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.1.3.3 Interaction effect of variety and water deficiency

Leaf area index was significantly influenced by the interaction of variety and water deficiency (Appendix VI). At 16 DAT, the highest leaf area index was observed in V_2S_2 (0.92) which was statistically similar with all the treatments except V_1S_3 and the lowest leaf area index was observed in V_1S_3 (0.39) which was statistically similar with all the treatments except V_2S_1 and V_2S_2.

At 41 DAT, the highest leaf area index was observed in V_2S_0 (1.30) which was statistically similar with all the treatments except V_1S_1, V_1S_4 and V_1S_5, also there was no significant difference among the treatments except V_1S_4, V_1S_5, V_2S_0 and V_2S_2 and the lowest leaf area index was observed in V_1S_5 (0.68) which was statistically similar with all the treatments except V_1S_2, V_1S_3, V_1S_6, V_2S_0, V_2S_2 and V_2S_4.

At 66 DAT, the highest leaf area index was observed in V_1S_3 (5.44) which was statistically similar with all the treatments except V_1S_4, V_1S_5, V_2S_1, V_2S_4 and V_2S_5, again the second highest leaf area index was observed in V_2S_0 (5.10) which was statistically similar with all the treatments except V_1S_3, V_1S_4, V_1S_5, V_2S_4 and V_2S_5. Also there was no significant difference among the treatments except V_1S_3, V_1S_4 and V_2S_0 and the lowest leaf area index was observed in V_1S_4 (2.18) which was statistically similar with V_1S_0, V_1S_1, V_1S_5, V_1S_6, V_2S_1, V_2S_3, V_2S_4, V_2S_5 and V_2S_6.

At 91 DAT, the highest leaf area index was observed in V_1S_3 (7.20) which was not statistically similar with all other treatments, so V_1S_3 was the best treatments for leaf area index. There was no significant difference among the treatments except V_1S_3 and V_2S_1. The lowest leaf area index was observed in V_2S_1 (2.88) which was statistically similar with V_1S_0, V_1S_4, V_1S_5, V_2S_2, V_2S_3, V_2S_4, V_2S_5 and V_2S_6.

At harvest, the highest leaf area index was observed in V_1S_3 (1.51) which was statistically similar with V_1S_0, V_1S_1, V_1S_2, V_1S_6, V_2S_0 and V_2S_2, the second highest leaf area index was observed in V_2S_2 (1.36) which was statistically similar with all the treatments except V_1S_3 and V_2S_4. The lowest leaf area index was observed in V_2S_4 (0.78) which was statistically similar with all the treatments except V_1S_3, V_1S_6 and V_2S_2. The highest leaf area index was greater than the lowest leaf area index by

135.9%, 91.18%, 149.5%, 150% and 93.6% at 16 DAT, 41 DAT, 66 DAT, 91 DAT and at harvest respectively. Here V_1S_3 produced the highest leaf area index from 66 DAT to harvest time (Table 9). So V_1S_3 was the best treatments in terms of leaf area index.

Table 9. Interaction effect of variety and water deficiency on leaf area index at different growth stages of boro rice

Treatments	Leaf Area Index at				
	16 DAT	41 DAT	66 DAT	91 DAT	harvest
V_1S_0	0.57 ab	1.09 abc	3.91 a-d	4.17 bc	0.97 abc
V_1S_1	0.60 ab	0.78 bc	3.96 a-d	4.84 b	1.21 abc
V_1S_2	0.67 ab	1.20 ab	4.33 abc	5.03 b	1.08 abc
V_1S_3	0.39 b	1.18 ab	5.44 a	7.20 a	1.51 a
V_1S_4	0.55 ab	0.70 c	2.18 d	3.71 bc	0.92 bc
V_1S_5	0.59 ab	0.68 c	3.05cd	3.75 bc	0.85 bc
V_1S_6	0.57 ab	1.17 ab	3.85 a-d	4.95 b	1.34 ab
V_2S_0	0.77 ab	1.30 a	5.10 ab	4.93 b	1.23 abc
V_2S_1	0.90 a	1.04 abc	3.38 bcd	2.88 c	0.88 bc
V_2S_2	0.92 a	1.28 a	4.58 abc	3.98 bc	1.36 ab
V_2S_3	0.55 ab	0.97 abc	3.55 a-d	4.27 bc	0.94 bc
V_2S_4	0.74 ab	1.19 ab	2.96 cd	3.64 bc	0.78 c
V_2S_5	0.75 ab	0.88 abc	3.01 cd	4.32 bc	0.86 bc
V_2S_6	0.51 ab	1.09 abc	3.57 a-d	4.46 bc	0.88 bc
$LSD_{(0.05)}$	0.43	0.45	2.01	1.80	0.55
CV (%)	39	25.8	29.69	23.9	30.9

V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.1.4 Dry matter hill^{-1}

4.1.4.1 Effect of variety

BRRI dhan74 and Heera-2 had no significant difference in terms of dry matter hill^{-1} during the growth period except 72 DAT (Appendix VII). Here V_1 showed the maximum dry matter hill^{-1} than V_2 from 47 DAT to 97 DAT. This might be due to genetic character of V_1 which is able to produce more dry matter than V_2. The maximum dry matter hill^{-1} for V_1 was 34.09g and for V_2, the maximum dry matter hill^{-1} was 33.54 g at 97 DAT. At 72 DAT, V_1 produced the maximum dry matter (19.01g) which had significant difference with V_2 (16.03). So V_1 gave 18.59% more dry matter hill^{-1} over V_2 at 72 DAT (Table 10).

Alam *et al.* (2009) investigated the growth pattern of three high yielding rice varieties under different phosphorus levels and found that the significant effect of variety on total dry matter production in plant was observed at 75 DAT and 100 DAT but at 25 DAT and 50 DAT, dry matter plant^{-1} was influenced non-significantly across the varieties. At 75 DAT and at 100 DAT the highest dry weight (17.28 g) and (42.2 g) plant^{-1} was found with Heera-2 variety followed by Aloron (16.06 g) and (39.91 g) respectively. Reddy *et al.* (1994) showed that dry matter production and grain yield were positively and significantly associated with each other and also with Net Assimilation Rate (NAR) and Harvest Index (HI).

Table 10. Effect of variety on dry matter hill^{-1} at different growth stages of boro rice

Treatments	Dry matter (g hill^{-1})			
	22 DAT	47 DAT	72 DAT	97 DAT
V_1	1.06	4.94	19.01 a	34.09
V_2	1.26	4.91	16.03 b	33.54
$LSD_{(0.05)}$	NS	NS	2.04	NS
CV (%)	5.18	6.16	8.77	8.82

V_1 = BRRI dhan74 and V_2 = Heera-2

4.1.4.2 Effect of water deficiency

Dry matter hill^{-1} was significantly influenced by water deficiency at 22 DAT, 47 DAT, 72 DAT and 97 DAT (Appendix VII). At 22 DAT, there was a significant difference between S_0 and S_5. The highest dry matter hill^{-1} was observed in S_0 (1.53 g) which was statistically similar with all the treatments except S_5. The lowest dry matter hill^{-1} was observed in S_5 (0.85 g) which was statistically similar with all the treatments except S_0.

At 47 DAT, the highest dry matter hill^{-1} was observed in S_2 (6.46 g) which was statistically similar with S_3. The lowest dry matter hill^{-1} was observed in S_5 (2.87 g) which was statistically differ with all other treatments. But there was no significant difference between S_1 and S_4.

At 72 DAT, the highest dry matter hill^{-1} was observed in S_0 (22.71 g), which was statistically differ with all other treatments. The second highest dry matter hill^{-1} was observed in S_1 (20.00 g) which was also statistically differ with all other treatments. But there was no significant difference among S_2, S_3 and S_6. The lowest dry matter hill^{-1} was observed in S_4 (12.17 g) which was statistically differ with all other treatments.

At 97 DAT, the highest dry matter hill^{-1} was observed in S_2 (35.86 g) which was statistically similar with all the treatments except S_5 and S_6 and the lowest dry matter hill^{-1} was observed in S_5 (32.69 g) which was statistically similar with all the treatments except S_2. The highest dry matter hill^{-1} was greater than the lowest dry matter hill^{-1} by 80%, 125%, 86.6% and 9.7% at 22 DAT, 47 DAT, 72 DAT and 97 DAT respectively (Table 11).

Dhar (2006) studied on the growth and yield of boro rice as influence by water level and seedling number hill^{-1} of boro rice. He reported that total dry weight of plant was significantly influenced by water levels at harvest but statistically unaffected at 30 and 60 days after transplanting. Jayasankar and Ramakrishnayya (1993) also showed that the specific leaf weight increased when the plants were in submergence condition.

Table 11. Effect of water deficiency on dry matter hill^{-1} at different growth stages of boro rice

Treatments	Dry matter (g hill^{-1})			
	22 DAT	47 DAT	72 DAT	97 DAT
S_0	1.53 a	4.17 d	22.71 a	33.77 ab
S_1	0.96 ab	4.78 c	20.00 b	34.04 ab
S_2	1.28 ab	6.46 a	16.84 d	35.86 a
S_3	1.27 ab	6.35 a	18.01 cd	33.09 ab
S_4	1.12 ab	4.53 c	12.17 f	34.46 ab
S_5	0.85 b	2.87 e	15.10 e	32.69 b
S_6	1.12 ab	5.33 b	17.83 d	32.80 b
$LSD_{(0.05)}$	0.61	0.28	1.43	2.94
CV (%)	4.43	4.83	6.82	7.29

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.1.4.3 Interaction effect of variety and water deficiency

Dry matter hill^{-1} was significantly influenced by the interaction of variety and water deficiency (Appendix VII). AT 22 DAT, there was a significant difference between V_1S_5 and V_2S_0. The highest dry matter hill^{-1} was observed in V_2S_0 (1.78 g) which was statistically similar with all the treatments except V_1S_5. The lowest dry matter hill^{-1} was observed in V_1S_5 (0.72 g) which was statistically similar with all the treatments except V_1S_5.

At 47 DAT, the highest dry matter hill^{-1} was observed in V_1S_2 (6.80 g) which was statistically similar with V_2S_3. But there was no significant difference between V_1S_6 and V_2S_3. Again there was no significant difference among V_1S_3, V_1S_6 and V_2S_2. Once again there was no significant difference between V_2S_0 and V_2S_6. Further again there was no significant difference between V_1S_1 and V_2S_6. Also there was no significant difference among V_1S_0, V_2S_4 and V_2S_5. The lowest dry matter hill^{-1} was observed in V_1S_5 (2.13 g) which was statistically differ with all the treatments.

At 72 DAT, the highest dry matter hill^{-1} was observed in V_2S_0 (24.07 g) which was statistically similar with V_1S_6. But there was no significant difference among V_1S_0, V_1S_2, V_1S_3, V_1S_6 and V_2S_1. Again there was no significant difference among V_1S_0, V_1S_1, V_1S_2, V_1S_3 and V_2S_1. Further again there was no significant difference among V_1S_5, V_2S_3 and V_2S_5. Also there was no significant difference among V_1S_4, V_2S_2, V_2S_5 and V_2S_6. The lowest dry matter hill^{-1} was observed in V_2S_4 (10.90 g) which was statistically differ with all the treatments.

At 97 DAT, the highest dry matter hill^{-1} was observed in V_2S_4 (39.00 g) which was statistically similar with V_1S_0, V_1S_2, V_1S_3, V_1S_6, V_2S_1 and V_2S_5. There was no significant difference among V_1S_0, V_1S_2, V_1S_3, V_1S_6, V_2S_1, V_2S_2 and V_2S_5. Again there was no significant difference among V_1S_1, V_1S_3, V_1S_6, V_2S_1, V_2S_2 and V_2S_5. Once again there was no significant difference among V_1S_1, V_2S_2 and V_2S_3. The lowest dry matter hill^{-1} was observed in V_2S_6 (29.43 g) which was statistically similar with V_1S_1, V_1S_4, V_1S_5, V_2S_0 and V_2S_3. The highest dry matter hill^{-1} was greater than the lowest dry matter hill^{-1} by 147%, 219.2%, 120.8% and 32.5% at 22 DAT, 47 DAT, 72 DAT and 91 DAT respectively (Table 12).

Table 12. Interaction effect of variety and water deficiency on dry matter hill^{-1} at different growth stages of boro rice

Treatments	Dry matter (g hill^{-1})			
	22 DAT	47 DAT	72 DAT	97 DAT
V_1S_0	1.28 ab	3.86 g	21.35 bc	37.99 ab
V_1S_1	0.97 ab	3.96 f	19.37 c	32.15 cde
V_1S_2	1.05 ab	6.80 a	20.63 bc	37.24 ab
V_1S_3	1.01 ab	6.09 c	20.44 bc	35.27 abc
V_1S_4	1.19 ab	5.39 d	13.44 e	29.92 e
V_1S_5	0.72 b	2.13 h	15.77 d	29.90 e
V_1S_6	1.19 ab	6.35 bc	22.10 ab	36.18 abc
V_2S_0	1.78 a	4.47 e	24.07 a	29.54 e
V_2S_1	0.94 ab	5.6 d	20.64 bc	35.94 abc
V_2S_2	1.50 ab	6.12 c	13.05 e	34.49 bcd
V_2S_3	1.53 ab	6.61 ab	15.59 d	30.90 de
V_2S_4	1.05 ab	3.67 g	10.90 f	39.00 a
V_2S_5	0.97 ab	3.62 g	14.43 de	35.47 abc
V_2S_6	1.04 ab	4.31 ef	13.55 e	29.43 e
$LSD_{(0.05)}$	0.87	0.40	2.02	4.15
CV (%)	4.43	4.83	6.82	7.29

V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.1.5 Days to 50% flowering and maturity

4.1.5.1 Effect of variety

The significant difference was observed for days to maturity (Appendix VIII). Heera-2 needed longer time for maturity (155.05 days) and BRRI dhan74 needed shorter time for maturity (148.95 days). So, modern variety BRRI dhan74 matured 06 days earlier than Heera-2. Significant difference was not observed for days to 50% flowering but here also Heera-2 needed 2 days less to 50% flowering than BRRI dhan74 (Figure 1).

Ganesan (2001) said that days to flowering, plant height, number of tillers plant^{-1}, and productive tillers plant^{-1} had both positive and negative indirect effects on yield.

Samsuzzaman (2007) worked on the varietal characterization and yield evaluation of six rice hybrids grown in Bangladesh and studied the number of days taken for 50% flowering and it had significant difference with varieties. It took 96.0 days in case of Heera to 116.3 days in case of BRRI dhan29. He also showed that the grand mean for days to maturity of all the genotypes was 131.95 days. In which Heera took 130 days to mature.

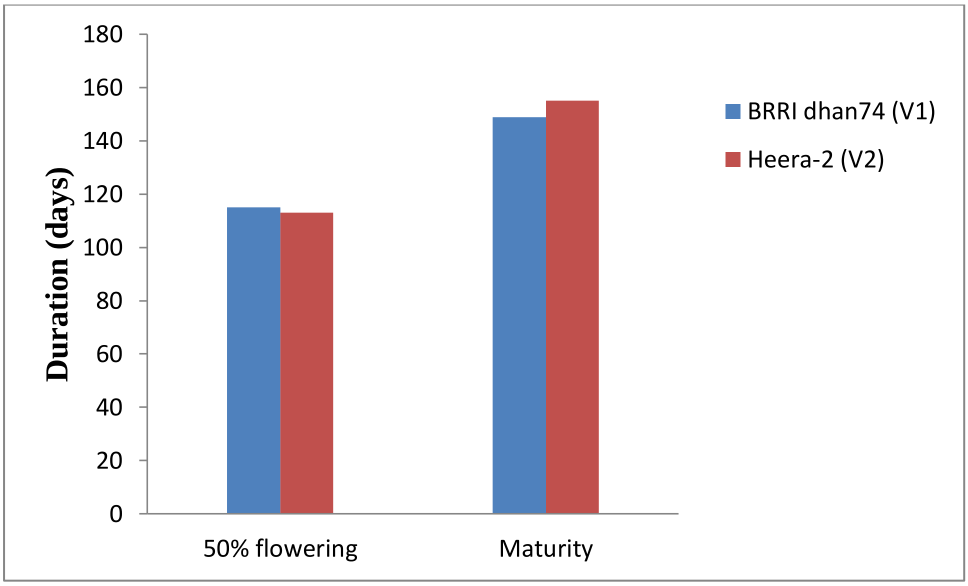

Figure 1. Effect of variety on 50% flowering and maturity of boro rice ($LSD_{(0.05)}$= 3.45 for maturity)

4.1.5.2 Effect of water deficiency

The significant difference was not observed for days to 50% flowering and also maturity in BRRI dhan74 and Heera-2 (Appendix VIII). So water deficiency had no effect on 50% flowering and also maturity. Here S_6 needed the longest time for 50% flowering (115.17 days) and also maturity (152.67 days) and S_1 needed the shortest time for 50% flowering (113.50 days) and also maturity (151.33 days). So, S_6 needed 1 day more to 50% flowering and maturity than S_1 (Figure 2).

Sikuku *et al.* (2010) showed that the varieties had significant difference ($P \leq 0.05$) in days to flowering. The watering regimes affected the number of days taken by the plants to reach 50% flowering. He used the plants watered daily (control) took the least days to attain 50% flowering while plants watered after every six days which were the most deficiencyed plants took the longest duration to attain 50% flowering.

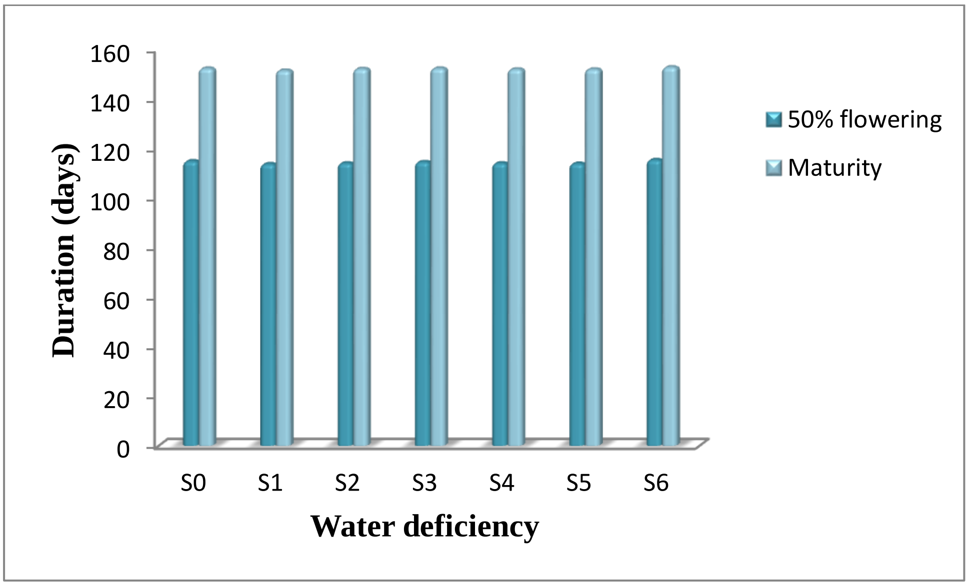

Figure 2. Effect of water deficiency on 50% flowering and maturity of boro rice

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.1.5.3 Interaction effect of variety and water deficiency

The significant difference was observed for days to 50% flowering and also maturity in BRRI dhan74 and Heera-2 (Appendix VIII). So 50% flowering and also maturity influenced by the interaction effect of variety and water deficiency. Here V_1S_3 needed the longest time for 50% flowering (115.67 days). But V_2S_6 needed the longest time for maturity (156.33 days) which was statistically similar with V_2S_0, V_2S_1, V_2S_2, V_2S_3, V_2S_4 and V_2S_5 for both 50% flowering and also maturity. So Heera-2 needed the longest time than BRRI dhan74 which was not influenced by any water deficiency.

At 50% flowering, V_1S_3 was statistically similar with all the treatments except V_2S_1, V_2S_2 and V_2S_5. The V_2S_1, V_2S_2 and V_2S_5 needed the shortest time for 50% flowering (112.33 days) which was statistically similar with all the treatments except V_1S_0, V_1S_2, V_1S_3, V_1S_5, V_1S_6 and V_2S_3. But at maturity, V_1S_4 and V_1S_5 needed the shortest time for maturity (148.33 days) which was statistically similar with V_1S_0, V_1S_1, V_1S_2, V_1S_3 and V_1S_6 (Figure 3).

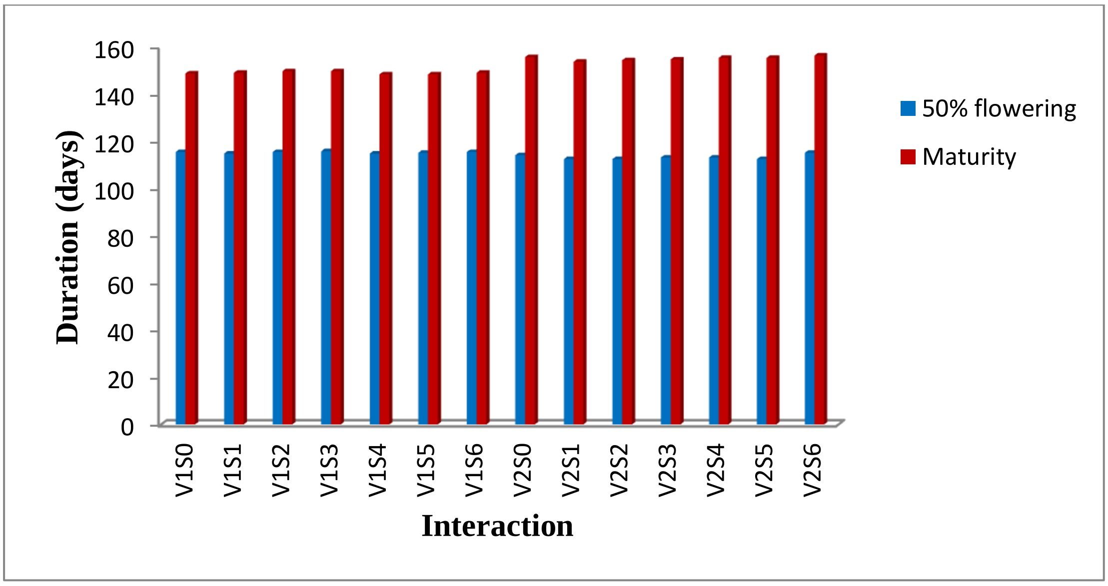

Figure 3. Interaction effect of variety and water deficiency on 50% flowering and maturity of boro rice ($LSD_{(0.05)}$= 2.77 for 50% flowering and 2.95 for maturity)

V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.1.6 SPAD value

4.1.6.1 Effect of variety

The significant difference was not observed for SPAD value in case of Heera-2 and BRRI dhan74 (Appendix VIII). But BRRI dhan74 showed more SPAD value (39.13) than Heera-2 (38.53) (Table 13). Figueiredo *et al.* (2015) worked on elevated carbon dioxide and temperature effects on rice yield, leaf greenness, and phenological stages duration and stated that the SPAD-readings at reproductive stage explained by more than 60 % variation the straw dry matter.

Table 13. Effect of variety on SPAD value of boro rice

Treatments	SPAD value at 83 DAT
V_1	39.13
V_2	38.53
$LSD_{(0.05)}$	NS
CV (%)	6.61

V_1 = BRRI dhan74 and V_2 = Heera-2

4.1.6.2 Effect of water deficiency

The significant difference was not observed for SPAD value in Heera-2 and BRRI dhan74 due to water deficiency (Appendix VIII). But S_3 showed the highest SPAD value (40.57), where S_5 showed the lowest SPAD value (36.40) (Figure 4). Stephan *et al.* (2010) worked on effect of abiotic deficiencyes on the non-destructive estimation of rice leaf nitrogen concentration and concluded that SPAD and LCC are potentially useful tools for improved N management in moderately unfavorable rice environments.

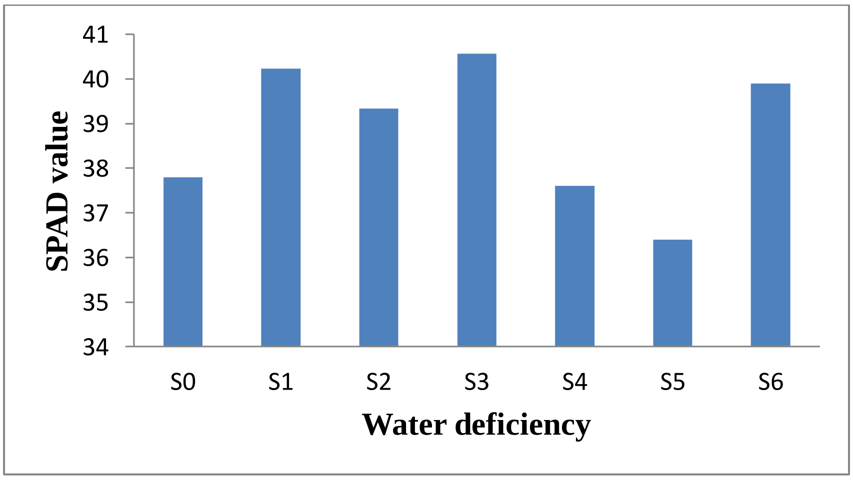

Figure 4. Effect of water deficiency on SPAD value of boro rice
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.1.6.3 Interaction effect of variety and water deficiency

The significant difference was observed for SPAD value in case of Heera-2 and BRRI dhan74 by the interaction effect of variety and water deficiency (Appendix VIII). The V_1S_3 showed the highest SPAD value (43.05) which was statistically similar with all the treatments except V_2S_5. The V_2S_5 showed the lowest SPAD value (35.34) which was statistically similar with all the treatments except V_1S_3. So, V_1S_3 showed 21.82% more SPAD value than V_2S_5 (Figure 5). For SPAD value at 83 DAT LSD was 7.59.

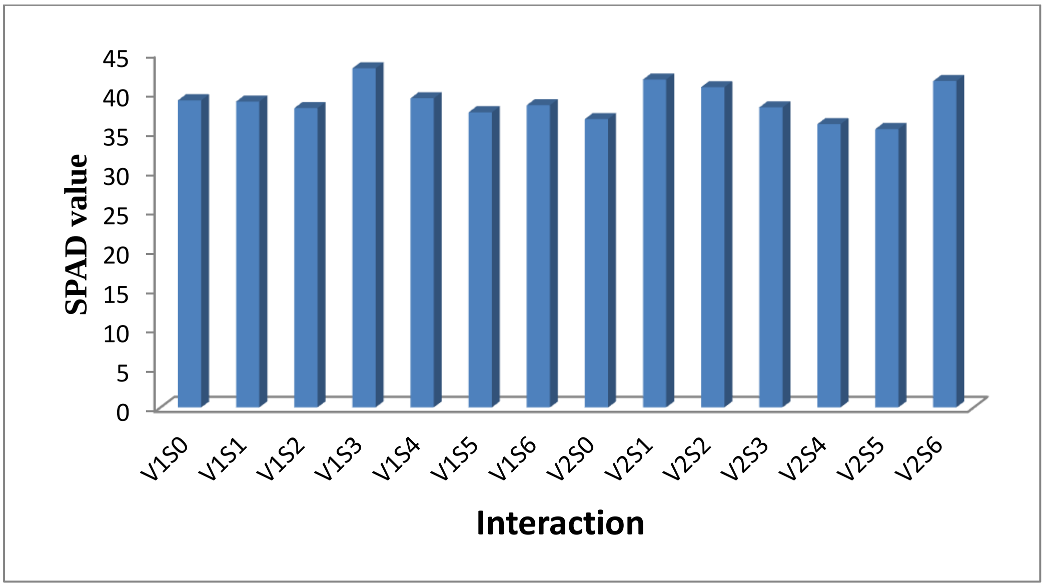

Figure 5. Interaction effect of variety and water deficiency on SPAD value of boro rice ($LSD_{(0.05)}$= 7.59)

V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.1.7 Dry matter of weed

4.1.7.1 Effect of variety

The significant difference was not observed for dry matter of weed at 38 DAT in Heera-2 and BRRI dhan74 (Appendix VIII). But BRRI dhan74 showed more dry matter of weed (10.13 g) than Heera-2 (10.08 g) (Table 14).

Table 14. Effect of variety on dry matter of weed of boro rice

Treatments	Dry Matter of Weed at 38 DAT (g/800 cm^2)
V_1	10.13
V_2	10.08
$LSD_{(0.05)}$	NS
CV (%)	29.28

V_1 = BRRI dhan74 and V_2 = Heera-2

4.1.7.2 Effect of water deficiency

The significant difference was observed for dry matter of weed at 38 DAT in case of Heera-2 and BRRI dhan74 by different water deficiency (Appendix VIII). Here S_3 showed the highest dry matter of weed (10.79 g) which was statistically similar with all the treatments except S_0 and S_5. S_0 showed the lowest dry matter of weed (9.26 g) which was statistically similar with all the treatments except S_2 and S_3 (Figure 6). So in water deficiency condition weeds produced more dry matter than standing water. That's why in water deficiency condition weed can reduce rice yield.

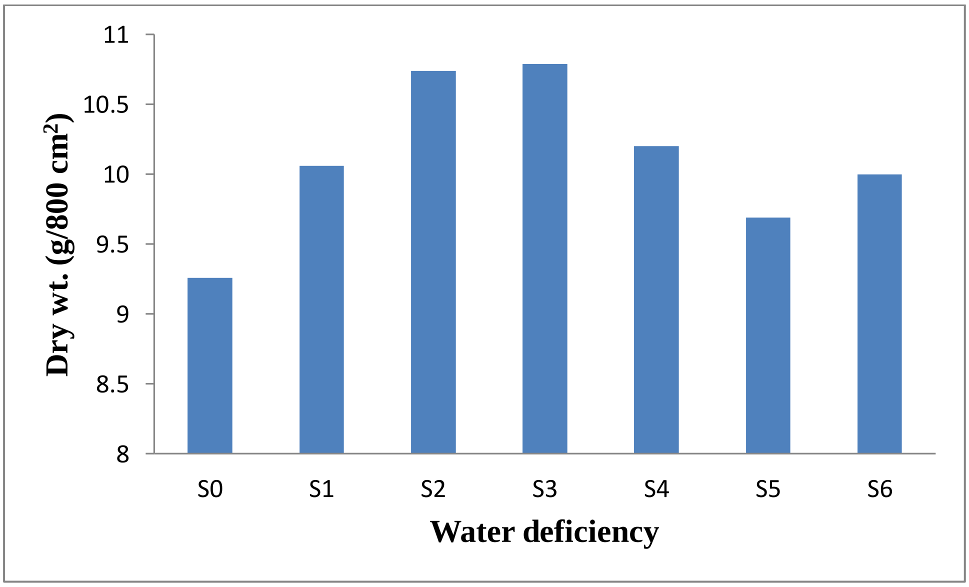

Figure 6. Effect of water deficiency on dry matter of weed of boro rice($LSD_{(0.05)}$= 1.06)

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.1.7.3 Interaction effect of variety and water deficiency

The significant difference was observed for dry matter of weed at 38 DAT in case of Heera-2 and BRRI dhan74 by the interaction effect of variety and water deficiency (Appendix VIII). The V_1S_3 showed the highest dry matter of weed (11.19 g) which was statistically similar with all the treatments except V_1S_0, V_1S_6, V_2S_0, V_2S_1 and V_2S_3. The V_1S_0 showed the lowest dry matter of weed (9.20 g) which was statistically similar with all the treatments except V_1S_3 and V_2S_2. So, V_1S_0 showed 17.78% less dry matter of weed than V_1S_3 (Figure 7).

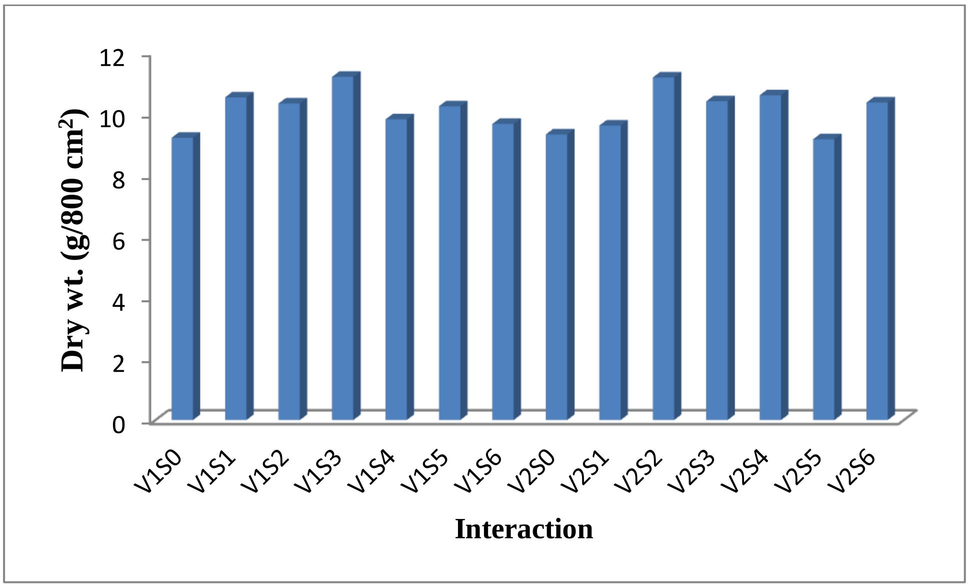

Figure 7. Interaction effect of variety and water deficiency on dry matter of weed of boro rice ($LSD_{(0.05)}$= 1.495)

V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2 Yield and other crop characters

Amiri *et al.* (2009) studied the effect of irrigation method on growth and yield of rice varieties and factorial experiment was conducted in 2008, on pot conditions. In maturity time, yield measurement, plant height, panicle length, unfilled grain weight, Weight of 1000 grains, amount of irrigation, number of grains per panicle, total biomass and number of tillers in pot were done and results showed that there were significant difference in probability level, all measured properties between rice varieties and all measured properties, except amount of Weight of 1000 grains, in irrigation management.

4.2.1 Number of effective and ineffective tillers hill^{-1}

4.2.1.1 Effect of variety

The significant difference was not observed for both effective and ineffective tillers hill^{-1} by the effect of variety at harvest (Appendix IX). Here BRRI dhan74 showed the higher number of effective (9.7) and ineffective tillers (1.83) hill^{-1} and Heera-2 showed the lower number of effective (7.71) and ineffective tillers (0.59) hill^{-1}. So, Zn-rich variety BRRI dhan74 gave 25.81% and 210.17% more effective and ineffective tillers hill^{-1} respectively than Heera-2 at harvest time (Figure 8).

Samsuzzaman (2007) worked on the varietal characterization and yield evaluation of six rice hybrids grown in Bangladesh and showed that among all the genotypes, Heera showed the highest no. of effective tillers (17.7). Debnath (2010) studied the influence of planting material and variety on yield of boro rice and showed that the number of ineffective tillers m^{-2} was not significantly influenced by variety. But Ullah (2013) showed that non-effective tillers hill^{-1} exerted significant difference among the varieties. The highest number of non- effective tillers hill^{-1} (1.78) was obtained in BRRI dhan29 followed by Heera (1.18) and Sl8H (1.17) and the lowest number of non-effective tillers hill^{-1} was produced by BRRI dhan58 (1.11) which is statistically similar with Heera (1.18) and Sl 8H (1.17).

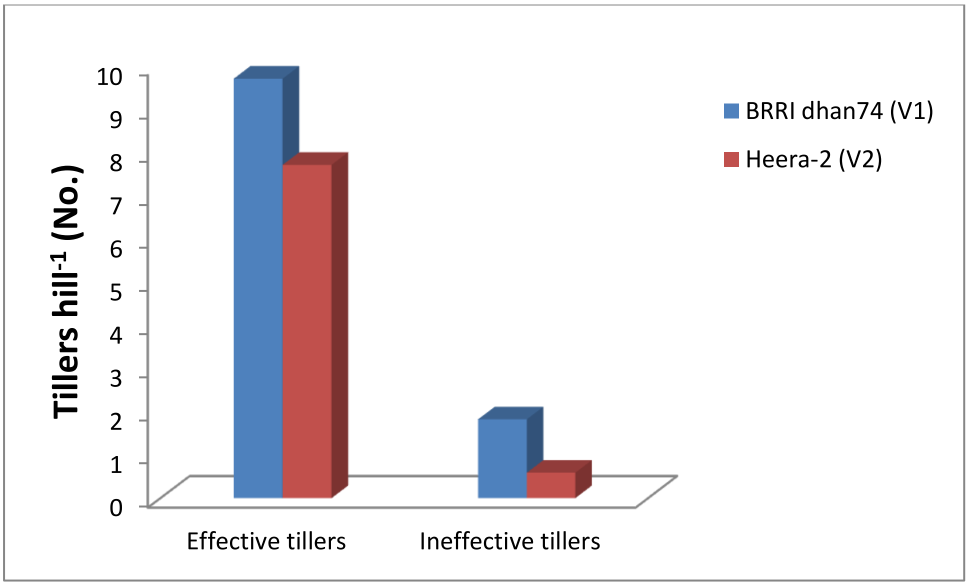

Figure 8. Effect of variety on effective and ineffective tillers hill^{-1} of boro rice ($LSD_{(0.05)}$= 5.82 and 1.97 for effective and ineffective tillers hill^{-1}, respectively)

4.2.1.2 Effect of water deficiency

The significant difference was observed for effective tillers hill^{-1} by the effect of water deficiency at harvest (Appendix IX). For effective tillers, S_3 showed the highest number of effective tillers (10.27) which was statistically similar with all the treatments except S_1 and S_4. And S_1 showed the lowest number of effective tillers (7.7) which was statistically similar with all the treatments except S_3. So, S_3 gave 33.37% more effective tillers than S_1.

The significant difference was not observed for ineffective tillers (Figure 9).

Krishnamurty *et al.* (1980) who observed that submergence of rice field increased number of productive tillers compared to under saturation condition but the difference was not significant. Chowdhury (1988) also showed that the highest number of effective tillers m^{-2} with continuous flooding that was significantly different from that obtained with continuous saturation. Su-Mei *et al.* (2016) worked on effect of water deficiency on growth and yield of rice and said water control may increase rice tiller amount but the tiller reduces fast in the late stage of tillering as drought period becomes longer, the ineffective tiller will increase and effective tiller will decrease.

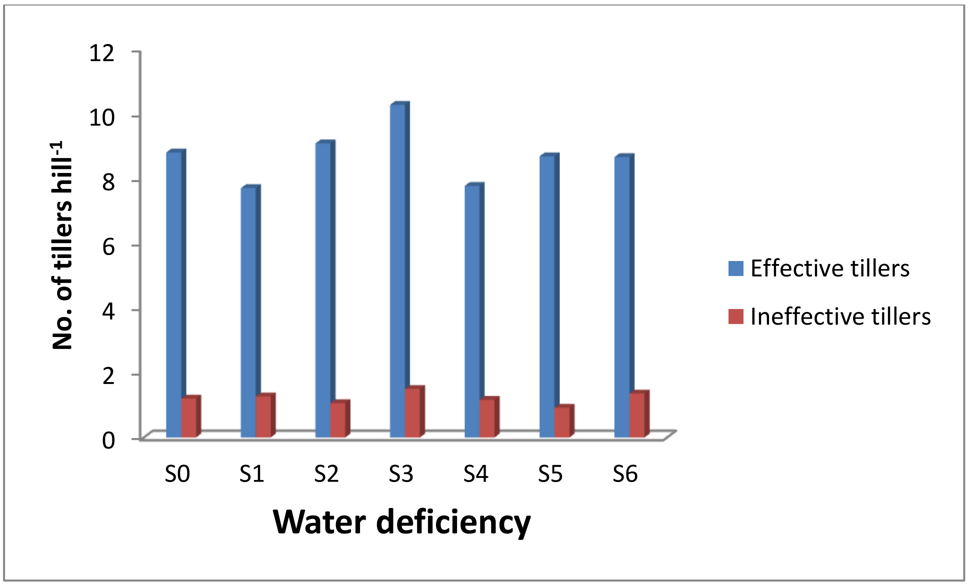

Figure 9. Effect of water deficiency on effective and ineffective tillers hill^{-1} of boro rice ($LSD_{(0.05)}$= 1.96 and 0.75 for effective and ineffective tillers hill^{-1} respectively)

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.1.3 Interaction effect of variety and water deficiency

The significant difference was observed for both effective and ineffective tillers hill^{-1} by the interaction effect of variety and water deficiency at harvest (Appendix IX). For effective tillers, V_1S_3 showed the highest number of effective tillers (12.54) which was statistically similar with V_1S_2 and V_1S_6. But there was no significant difference among all the treatments except V_2S_1 and V_2S_6. V_2S_1 showed the lowest number of effective tillers (5.78) which was statistically similar with V_1S_4, V_2S_2, V_2S_3, V_2S_4, V_2S_5 and V_2S_6. So, V_1S_3 gave 116.96% more effective tillers than V_2S_1.

For ineffective tillers, V_1S_3 showed the highest number of ineffective tillers (2.6) which was statistically similar with V_1S_1, V_1S_2 and V_1S_6. The V_2S_2 showed the lowest number of ineffective tillers (0.35) which was statistically similar with V_2S_0, V_2S_1, V_2S_3, V_2S_4, V_2S_5 and V_2S_6. So, V_2S_2 gave 86.5% less ineffective tillers than V_1S_3 and V_1S_6 (Figure 10). Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that number of ineffective tillers $hill^{-1}$ was not significantly influenced by variety.

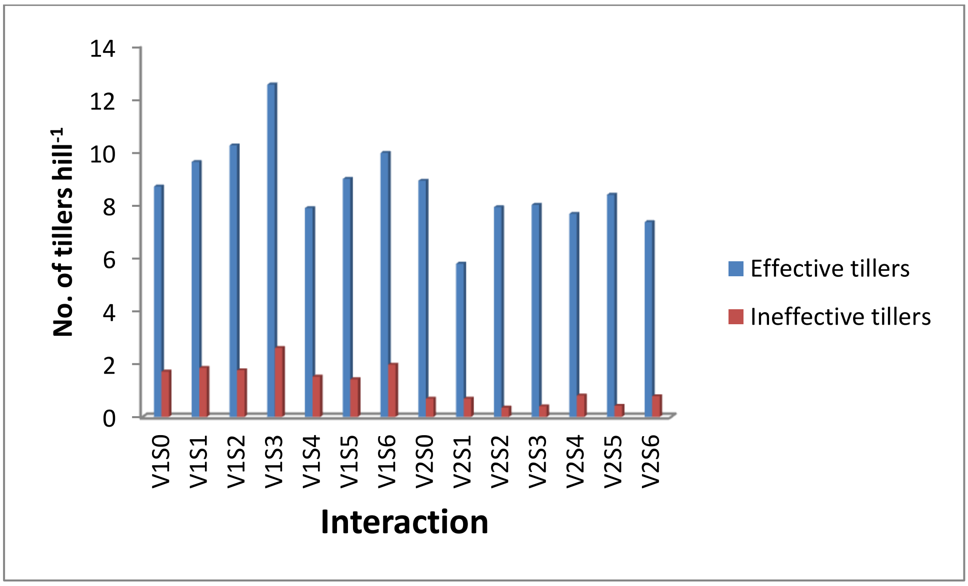

Figure 10. Interaction effect of variety and water deficiency on effective and ineffective tillers $hill^{-1}$ of boro rice ($LSD_{(0.05)}$= 2.77 and 1.06 for effective and ineffective tillers $hill^{-1}$ respectively)

V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.2 Panicle length

4.2.2.1 Effect of variety

The significant difference was observed for panicle length in case of BRRI dhan74 and Heera-2 (Appendix IX). Here BRRI dhan74 showed less panicle length (20.71 cm) than Heera-2 (23.03 cm). So, V_2 showed 11.2% long panicle length than V_1 (Table 15). Obaidullah (2007) stated that variety significantly influenced panicle length and the maximum panicle length was 27.36 cm. Devaraju *et al.* (1998), BINA (1993) and Chowdhury *et al.* (1993) also said panicle length was significantly influenced by different rice varieties. Babiker (1986) also observed that panicle length differed due to the varietals variation.

Table 15. Effect of variety on panicle length at harvest of boro rice

Treatments	Panicle length (cm)
V_1	20.71 b
V_2	23.03 a
$LSD_{(0.05)}$	0.99
CV (%)	3.39

V_1 = BRRI dhan74 and V_2 = Heera-2

4.2.2.2 Effect of water deficiency

Panicle length was significantly influenced by water deficiency at harvest (Appendix IX). In which S_3 showed the highest (22.347 cm) panicle length which was statistically similar with all the treatments except S_4 and S_5. But there was no significant difference among all the treatments except S_3 and S_5. The S_5 showed the lowest (21.04 cm) panicle length. So, S_3 showed 6.21% long panicle length than S_5 (Table 16). Bhuiyan (1999) showed that rice plant did not suffer from water deficiency if soil was saturated and there was no standing water but this result was disagreed with Khare *et al.* (1970) who reported that the panicle length was highest at 5 cm flooding than that's of continuous saturation.

Table 16. Effect of water deficiency on panicle length of boro rice at harvest

Treatments	Panicle length (cm)
S_0	22.182 ab
S_1	22.068 ab
S_2	22.133 ab
S_3	22.347 a
S_4	21.275 b
S_5	21.04 c
S_6	22.013 ab
$LSD_{(0.05)}$	0.969
CV (%)	3.72

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.2.3 Interaction effect of variety and water deficiency

Panicle length was significantly influenced by the interaction effect of variety and water deficiency at harvest (Appendix IX). In which V_2S_2 showed the highest (23.67 cm) panicle length which was statistically similar with V_2S_0, V_2S_1, V_2S_3, V_2S_4 and V_2S_6. But V_2S_3 showed the second highest (23.46 cm) panicle length which also statistically similar with V_2S_0, V_2S_1, V_2S_4, V_2S_5 and V_2S_6. There was no significant difference among V_1S_0, V_2S_0, V_2S_4 and V_2S_5. Again there was no significant difference among V_1S_0, V_1S_1, V_1S_3 and V_2S_5. Once again there was no significant difference among V_1S_0, V_1S_1, V_1S_2, V_1S_3 and V_1S_6. V_1S_5 showed the lowest (19.87 cm) panicle length which was statistically similar with V_1S_1, V_1S_2, V_1S_3, V_1S_4 and V_1S_6. So, V_2S_2 showed 19.12% long panicle length than V_1S_5 (Figure 11).

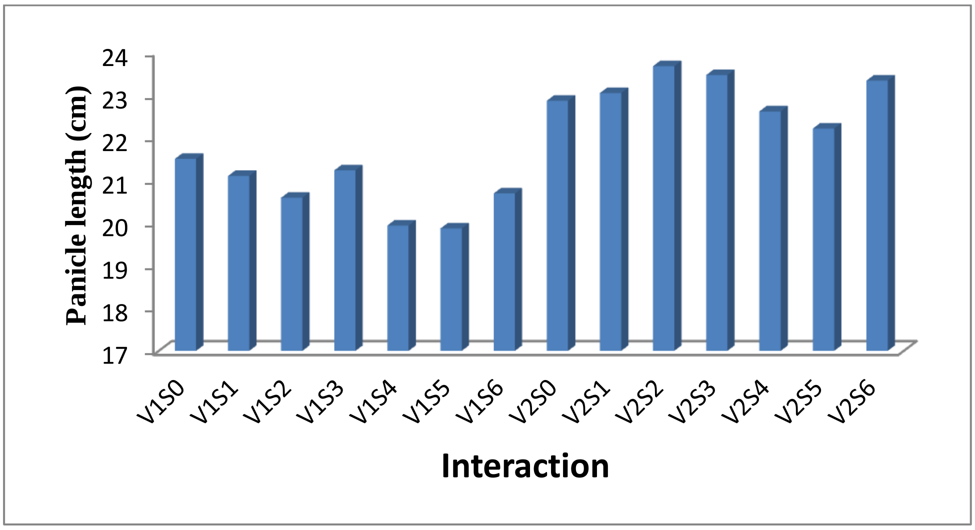

Figure 11. Interaction effect of variety and water deficiency on panicle length of boro rice ($LSD_{(0.05)}$= 1.37)

V_1 = BRRI dhan74 and V_2 = Heera-2

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.3 Number of rachis branches panicle^{-1}

4.2.3.1 Effect of variety

The significant difference was not observed for rachis branches panicle^{-1} in case of BRRI dhan74 and Heera-2 (Appendix IX). Here BRRI dhan74 showed less rachis branches panicle^{-1} (8.88) than Heera-2 (9.08). The V_2 showed 2.2% more rachis branches panicle^{-1} than V_1 (Table 17). So, Heera-2 was able to produce more number of grains. Mo *et al.* (2012) worked on changes in the panicle-related traits of different rice varieties under high temperature condition and showed that number of rachis branches panicle^{-1} was significantly differ with rice variety.

Table 17. Effect of variety on rachis branches panicle^{-1} of boro rice at harvest

Treatments	Rachis branches panicle^{-1}(No.)
V_1	8.88
V_2	9.08
$LSD_{(0.05)}$	NS
CV (%)	5.33

V_1 = BRRI dhan74 and V_2 = Heera-2

4.2.3.2 Effect of water deficiency

Rachis branches panicle^{-1} was significantly influenced by water deficiency (Appendix IX). In which S_0 showed the highest (9.62) rachis branches panicle^{-1} which was statistically similar with S_1 and S_3. But there was no significant difference among S_1, S_3 and S_6. The S_5 showed the lowest (8.35) rachis branches panicle^{-1} which was statistically similar with S_2, S_4 and S_6. So, S_0 showed 15.21% more rachis branches panicle^{-1} than S_5 (Table 18). Wu *et al.* (2011) worked on effect of water deficiency on physiological traits and yield in rice backcross lines after anthesis and concluded that rachis branches panicle^{-1} was significantly differ with water deficiency.

Table 18. Effect of water deficiency on rachis branches panicle^{-1} of boro rice at harvest

Treatments	Rachis branches panicle^{-1}(No.)
S_0	9.62 a
S_1	9.53 ab
S_2	8.65 c
S_3	9.48 ab
S_4	8.48 c
S_5	8.35 c
S_6	8.73 bc
$LSD_{(0.05)}$	0.804
CV (%)	7.52

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.3.3 Interaction effect of variety and water deficiency

Rachis branches panicle^{-1} was significantly influenced by the interaction effect of variety and water deficiency (Appendix IX). In which V_1S_0 showed the highest (9.87) rachis branches panicle^{-1} which was statistically similar with V_1S_1, V_1S_3, V_2S_0, V_2S_1, V_2S_2, V_2S_3 and V_2S_6. But V_1S_3 showed the second highest (9.83) rachis branches panicle^{-1} which also statistically similar with V_1S_1, V_2S_0, V_2S_1, V_2S_2, V_2S_3, V_2S_5 and V_2S_6. There was no significant difference among V_1S_1, V_1S_2, V_1S_4, V_1S_6, V_2S_0, V_2S_2, V_2S_3, V_2S_4, V_2S_5 and V_2S_6. The V_1S_5 showed the lowest (8.00) rachis branches panicle^{-1} which was statistically similar with all the treatments except V_1S_0, V_1S_1, V_1S_3, V_2S_0 and V_2S_1. So, V_1S_0 showed 23.38% more rachis branches panicle^{-1} than V_1S_5 (Figure 12).

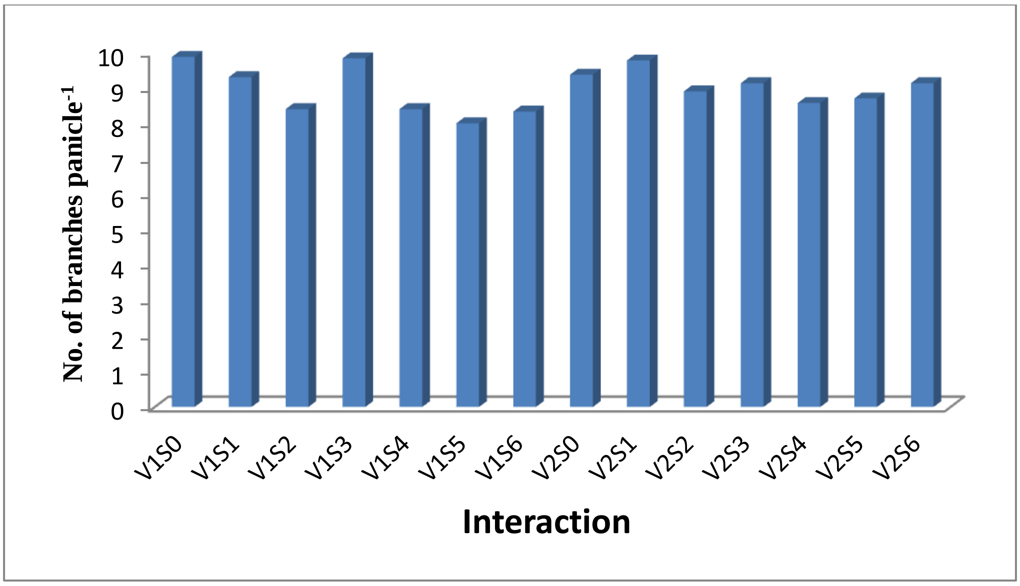

Figure 12. Interaction effect of variety and water deficiency on primary branches panicle^{-1} of boro rice (LSD$_{(0.05)}$= 1.137)

V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.4 Number of filled and unfilled grains panicle^{-1}

4.2.4.1 Effect of variety

The significant difference was observed for filled grains by the effect of variety but there was no significant difference between BRRI dhan74 and Heera-2 in case of unfilled grains (Appendix X). For filled grains V_2 showed highest number of filled grains (129.44) and also unfilled grains (18.07) and V_1 showed the lowest number of filled grains (79.87) and unfilled grains (11.30). So, Zn-rich variety BRRI dhan74 gave 38.3% less filled grains than Heera-2 (Figure 13). That's why Heera-2 was able to produce more grain yield than BRRI dhan74.

Obaidullah (2007) stated that variety significantly influenced filled grains panicle^{-1} and the highest filled grains panicle^{-1} was 156.84. Debnath (2010) studied the influence of planting material and variety on yield of boro rice and showed that the filled grains panicle^{-1} differed significantly for variation of the variety.

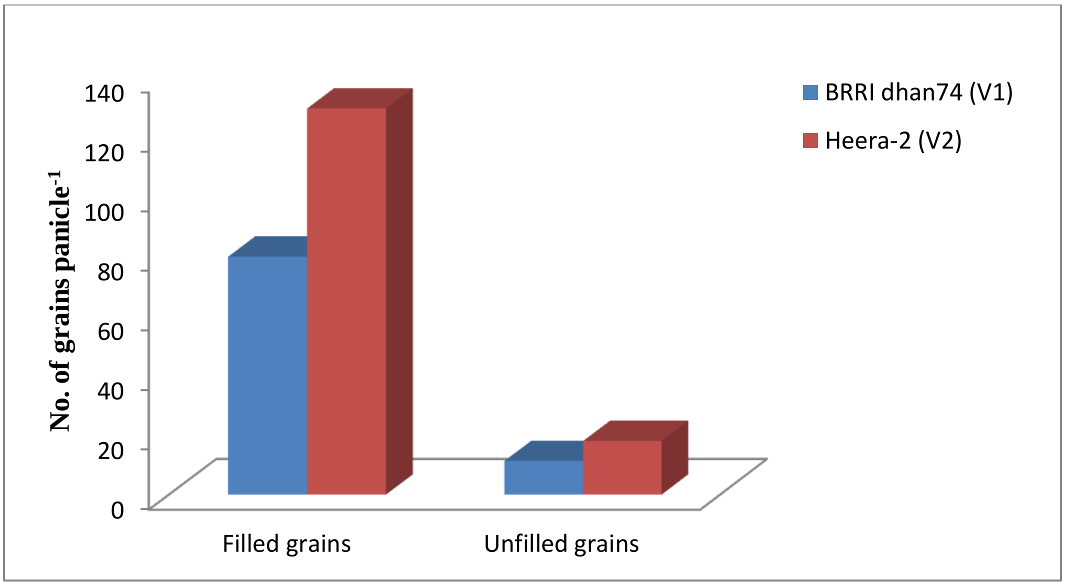

Figure 13. Effect of variety on filled and unfilled grains panicle^{-1} of boro rice ($LSD_{(0.05)}$= 13.809)

4.2.4.2 Effect of water deficiency

The significant difference was observed for filled and unfilled grains panicle^{-1} by the effect of water deficiency at harvest (Appendix X). For filled grains, S_3 showed the highest number of filled grains (113.25) which was statistically similar with all the treatments except S_5. And S_5 showed the lowest number of filled grains (98.65) which was statistically similar with all the treatments except S_3. So, S_3 gave 14.80% more filled grains than S_5.

For unfilled grains, S_0 showed the highest number of unfilled grains (19.12) which was statistically similar with S_2, S_3 and S_6. The S_4 showed the lowest number of unfilled grains (11.75) which was statistically similar with all the treatments except S_0 and S_3. So, S_0 gave 62.72% more unfilled grains than S_4 (Figure 14).

Dhar (2006) studied on the growth and yield of boro rice as influence by water level and seedling number hill^{-1} plant height of boro rice. He showed that the filled grains did not differ significantly for water levels.

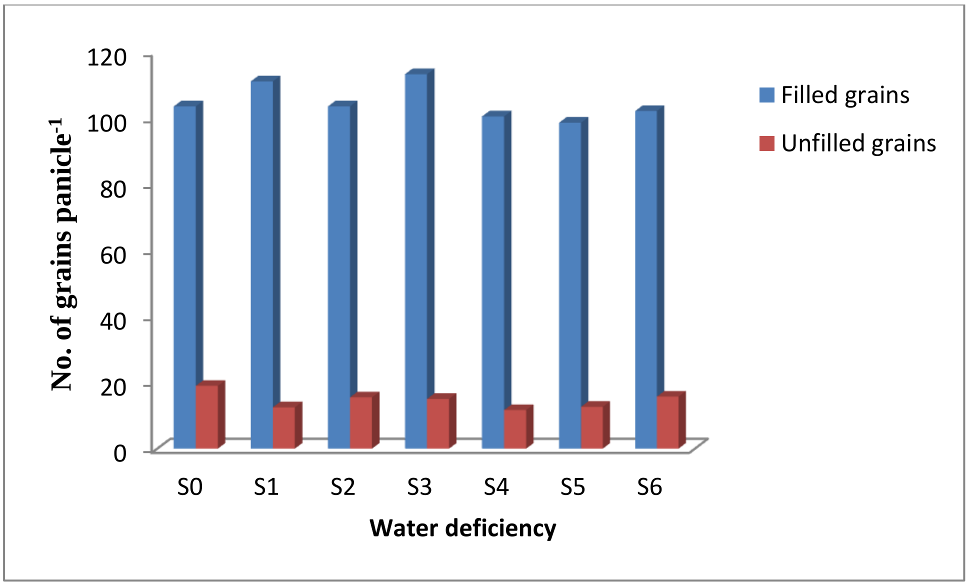

Figure 14. Effect of water deficiency on filled and unfilled grains panicle^{-1} of boro rice ($LSD_{(0.05)}$= 13.386 and 5.876 for filled grains and unfilled grains panicle^{-1}, respectively)

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.4.3 Interaction effect of variety and water deficiency

The significant difference was observed for filled and unfilled grains panicle^{-1} by the interaction effect of variety and water deficiency at harvest (Appendix X). For filled grains, V_2S_3 showed the highest number of filled grains (138.93) which was statistically similar with V_2S_0, V_2S_1, V_2S_2, V_2S_4, V_2S_5 and V_2S_6. But there was no significant difference among V_1S_0, V_1S_1, V_1S_2, V_1S_3 and V_1S_5. The V_1S_4 showed the lowest number of filled grains (71.33) which was statistically similar with V_1S_0, V_1S_2, V_1S_3 and V_1S_5. So, V_2S_3 gave 94.77% more filled grains than V_1S_4.

For unfilled grains, V_2S_0 showed the highest number of unfilled grains (23.77) which was statistically similar with V_2S_2, V_2S_3, V_2S_4, V_2S_5 and V_2S_6. But there was no significant difference among all the treatments except V_1S_1, V_1S_4, V_1S_5, V_1S_6 and V_2S_0. Again there was no significant difference among all the treatments except V_1S_4, V_1S_5, V_2S_0 and V_2S_6. Once again there was no significant difference among all the treatments except V_1S_4, V_2S_0, V_2S_2, V_2S_3 and V_2S_6. The V_1S_4 showed the lowest number of unfilled grains (7.40) which was statistically similar with V_1S_0, V_1S_1, V_1S_2, V_1S_3, V_1S_5, V_1S_6 and V_2S_1. So, V_1S_4 gave 68.87% less unfilled grains than V_2S_0 (Figure 15).

Zubaer *et al.* (2007) showed that, the interaction effect of soil moisture levels and rice genotypes on the number of unfilled grains per panicle was significant. In all the rice genotypes, number of unfilled grains was increased with reduced soil moisture levels but the degree of increment was different in different genotypes. Increased unfilled grains per panicle under lower soil moisture level might be due to inactive pollen grain for dryness, incomplete development of pollen tube; insufficient assimilates production and its distribution to grains. Hossain (2001), Yambao and Ingram (1988), Begum (1990) and Islam *et al* (1994) also showed the similar kind of result.

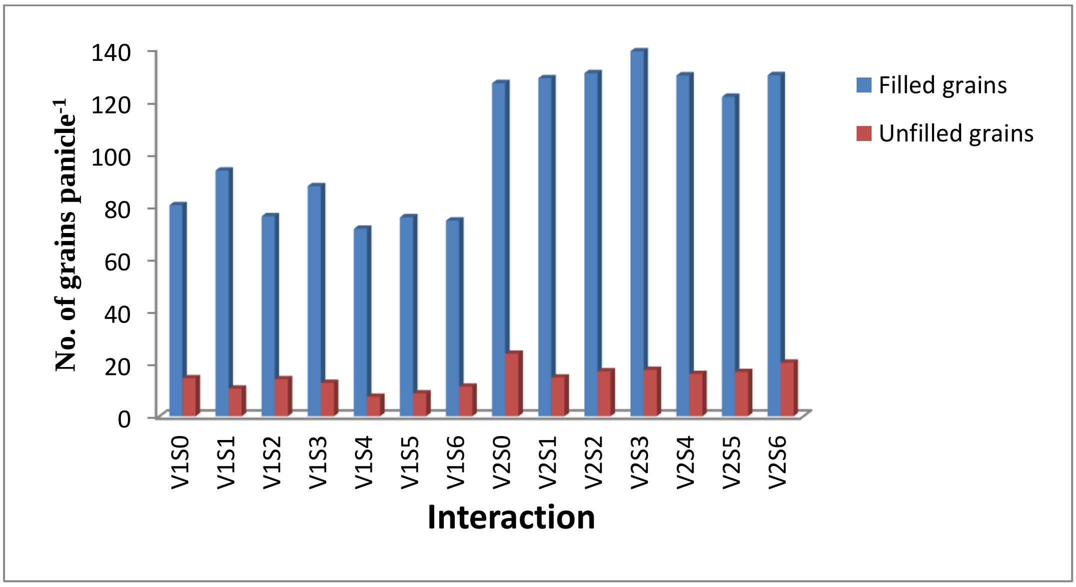

Figure 15. Interaction effect of variety and water deficiency on filled and unfilled grains panicle^{-1} of boro rice ($LSD_{(0.05)}$= 18.931 and 8.31 for filled grains and unfilled grains panicle^{-1}, respectively)

V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.5 Total Number of grains and sterility percentage panicle^{-1}

4.2.5.1 Effect of variety

The significant difference was observed for total number of grains panicle^{-1} by the effect of variety but there was no significant difference between BRRI dhan74 and Heera-2 in case of sterility percentage (Appendix X). For total number of grains V_2 showed the maximum number of total grains panicle^{-1} (147.51) and V_1 showed the minimum value (91.16). So, Zn-rich variety BRRI dhan74 gave 38.2% less total number of grains than Heera-2 (Table 19). That's why Heera-2 was able to produce more grain yield than BRRI dhan74. But both varieties showed near about same sterility percentage. Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that the number of grains panicle^{-1} was significantly influenced by variety. Obaidullah (2007) also stated that variety significantly influenced number of total grains panicle^{-1} which was 196.75 panicle^{-1}.

Table 19. Effect of variety on total number of grains and sterility percentage panicle^{-1} of boro rice

Treatments	Number of grains and sterility percentage panicle^{-1}	
	Total number of grains	Sterility percentage
V_1	91.16 b	12.36
V_2	147.51 a	12.17
$LSD_{(0.05)}$	24.93	NS
CV (%)	15.73	47.90

V_1 = BRRI dhan74 and V_2 = Heera-2

4.2.5.2 Effect of water deficiency

The significant difference was observed for total number of grains and sterility percentage panicle^{-1} by the effect of water deficiency (Appendix X). For total number of grains, S_3 showed the highest number of total number of grains (128.38) which was statistically similar with all the treatments except S_4 and S_5. And S_5 showed the lowest number of total number of grains (111.40) which was statistically similar with all the treatments except S_3. So, S_3 gave 15.24% more total number of grains than S_5.

For sterility percentage, S_0 showed the highest sterility percentage (15.47) which was statistically similar with S_2, S_3, S_5 and S_6. S_1 showed the lowest sterility percentage (10.16) which was statistically similar with all the treatments except S_0. So, S_1 gave 34.32% less sterility than S_0 (Table 20). Joseph and Havnagi (1987) who showed that number of grains panicle^{-1} under standing water was superior than that's of under saturated condition and they also found 8.21% more grains panicle^{-1} over saturated to submerged condition.

Table 20. Effect of water deficiency on total number of grains and sterility percentage panicle^{-1} of boro rice

Treatments	Number of grains and sterility percentage panicle^{-1}	
	Total number of grains	Sterility percentage
S_0	122.67 ab	15.47 a
S_1	123.70 ab	10.16 b
S_2	118.95 ab	13.47 ab
S_3	128.38 a	11.76 ab
S_4	112.27 b	10.24 b
S_5	111.40 b	11.10 ab
S_6	117.98 ab	13.64 ab
$LSD_{(0.05)}$	13.899	4.516
CV (%)	9.77	30.91

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.5.3 Interaction effect of variety and water deficiency

The significant difference was observed for total number of grains but there was no significant difference between BRRI dhan74 and Heera-2 in case of sterility percentage panicle^{-1} by the interaction effect of variety and water deficiency at harvest (Appendix X). For total number of grains, V_2S_3 showed the highest number of total grains (156.53) which was statistically similar with V_2S_0, V_2S_1, V_2S_2, V_2S_4, V_2S_5 and V_2S_6. But there was no significant difference among V_1S_0, V_1S_1, V_1S_2, V_1S_3 and V_1S_5. The V_1S_4 showed the lowest number of total grains (78.73) which was statistically similar with V_1S_0, V_1S_2, V_1S_5 and V_1S_6. So, V_2S_3 gave 98.82% more filled grains than V_1S_4. But in case of sterility percentage, there was no significant difference among the treatments (Table 21).

Table 21. Interaction effect of variety and water deficiency on total no. of grains and sterility percentage panicle^{-1} of boro rice

Treatments	Number of grains and sterility percentage panicle^{-1}	
	Total number of grains	Sterility percentage
V_1S_0	94.80 bc	15.24
V_1S_1	104.03 b	10.09
V_1S_2	90.20 bc	15.31
V_1S_3	100.23 b	12.66
V_1S_4	78.73 c	9.351
V_1S_5	84.37 bc	10.38
V_1S_6	85.77 bc	13.46
V_2S_0	150.53 a	15.69
V_2S_1	143.37 a	10.23
V_2S_2	147.70 a	11.64
V_2S_3	156.53 a	10.85
V_2S_4	145.80 a	11.13
V_2S_5	138.43 a	11.83
V_2S_6	150.20 a	13.81
$LSD_{(0.05)}$	19.66	NS
CV (%)	9.77	30.91

V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.6 1000-grain weight

4.2.6.1 Effect of variety

The significant difference was observed for 1000-grain weight in case of BRRI dhan74 and Heera-2 (Appendix XI). Here BRRI dhan74 showed more 1000-grain weight (29.33 g) than Heera-2 (26.06 g). V_1 showed 12.55% more grains weight than V_2 (Table 22). So, 38.37 (Heera-2) grains weight is equal to 34.09 (BRRI dhan74) grains weight.

Akter *et al.* (2015) studied on seed treatment for improving quality of hybrid seeds of rice. They found that moisture content of collected hybrid seed samples varied significantly from one to another, while the lowest (12.20%) and the highest (14.37%) records were made in Moyna and Meghna, respectively. In respect of 1000-seeds weight, the varieties of hybrid rice were also found to vary significantly from one to another, where the lowest 1000-seed weight (20.00 g) was found in variety Aloron and Heera-1, but the highest weight (26.00 g) was recorded in Heera-4.

Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that 1000 grains weight was significantly influenced by variety. He showed that BRRI dhan29 produced the highest 1000 grains weight (20.74 g) and Binadhan-14 produced the lowest 1000 grains weight.

Table 22. Effect of variety on 1000-grain weight of boro rice

Treatments	1000-grain weight (g)
V_1	29.33 a
V_2	26.06 b
$LSD_{(0.05)}$	0.93
CV (%)	2.53

V_1 = BRRI dhan74 and V_2 = Heera-2

4.2.6.2 Effect of water deficiency

Grains weight was significantly influenced by water deficiency (Appendix XI). In which S_6 showed the highest 1000-grain weight (28.223 g) which was statistically similar with all the treatments except S_1 and S_3. The S_3 showed the lowest 1000-grain weight (27.18 g) which was statistically similar with all the treatments except S_6. So, S_6 showed 3.84% more grains weight than S_5 (Table 23).

Table 23. Effect of water deficiency on 1000-grain weight of boro rice

Treatments	1000-grain weight (g)
S_0	27.677 ab
S_1	27.312 b
S_2	27.925 ab
S_3	27.18 b
S_4	27.727 ab
S_5	27.832 ab
S_6	28.223 a
$LSD_{(0.05)}$	0.825
CV (%)	2.5

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.6.3 Interaction effect of variety and water deficiency

Grains weight was significantly influenced by the interaction effect of variety and water deficiency (Appendix XI). In which V_1S_5 showed the highest 1000-grain weight (30.113 g) which was statistically similar with V_1S_0, V_1S_2, V_1S_4 and V_1S_6. But there was no significant difference among V_1S_0, V_1S_3 and V_1S_4. V_1S_1 and V_2S_1 also had no significant difference between them. Again there was no significant difference among V_2S_0, V_2S_1, V_2S_2, V_2S_3, V_2S_4 and V_2S_6. The V_2S_5 showed the lowest 1000-grain weight (25.55 g) which was statistically similar with V_2S_0, V_2S_2, V_2S_3, V_2S_4 and V_2S_6. So, V_1S_5 showed 17.86% more grains weight than V_2S_5 (Figure 16).

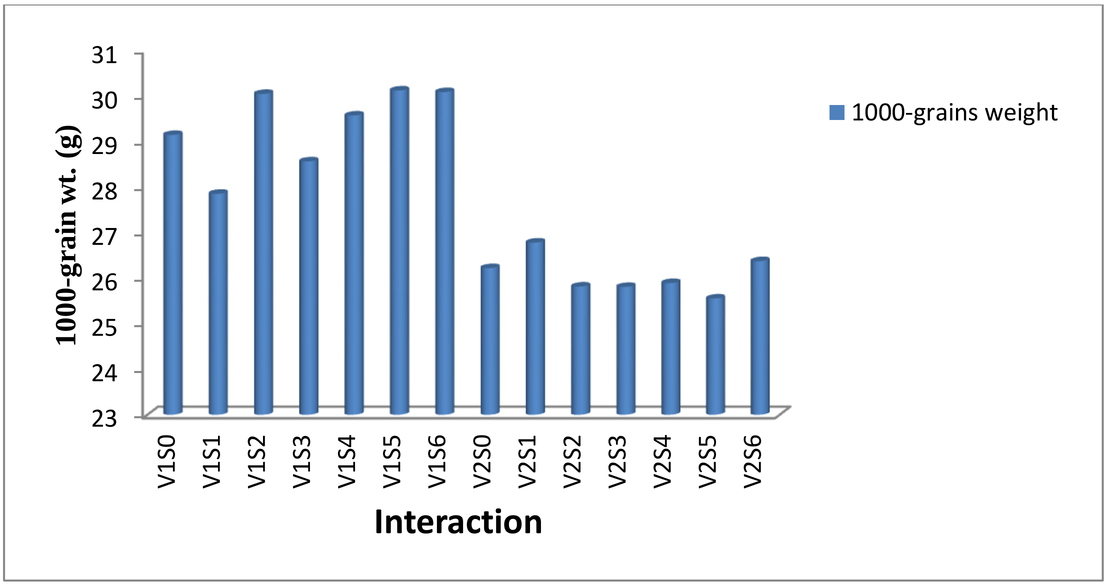

Figure 16. Interaction effect of variety and water deficiency on 1000-grain weight of boro rice ($LSD_{(0.05)}$= 1.166)

V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.7 Grain yield and straw yield

4.2.7.1 Effect of variety

The significant difference was not observed for grain yield and straw yield by the effect of variety in case of BRRI dhan74 and Heera-2 (Appendix XI). Here V_2 showed the maximum grain yield (6.62 t ha^{-1}) than V_1 (5.32 t ha^{-1}). But V_1 showed the maximum straw yield (5.98 t ha^{-1}) than V_2 (4.87 t ha^{-1}). So, Zn-rich variety BRRI dhan74 gave 1.00 : 1.124 ratio for grain yield to straw yield but Heera-2 gave 1.36 : 1.00 ratio for grain yield to straw yield (Figure 17).

Samsuzzaman (2007) worked on the varietal characterization and yield evaluation of six rice hybrids grown in Bangladesh and showed that among the hybrids, grain yield ha^{-1} significantly differ by varieties. He showed that highest yield was 7.45 t ha^{-1} (aloron) but yield of Heera was 6.2 t ha^{-1}. Main *et al.* (2007) stated that there was no significant variation of straw yield and harvest index observed between the two varieties.

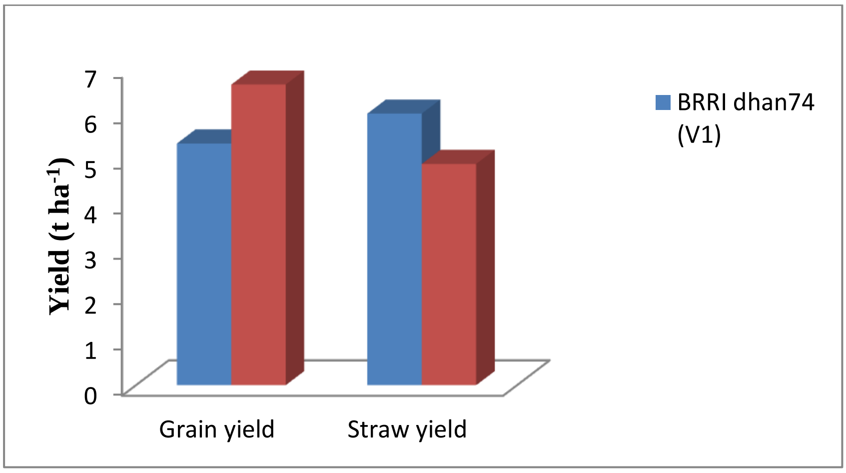

Figure 17. Effect of variety on grain yield and straw yield of boro rice

4.2.7.2 Effect of water deficiency

The significant difference was observed for grain yield and straw yield by the effect of water deficiency (Appendix XI). For grain yield, S_3 showed the highest grain yield (6.69 t ha^{-1}) which was statistically similar with S_0, S_2 and S_6. So deficiency at 85-105 DAT (ripening stage) was the best treatment in terms of yield because it gave more yield than no deficiency condition but statistically similar with yield of no deficiency condition. Also second highest grain yield (6.51 t ha^{-1}) was given by S_2 treatment which was statistically similar with S_0, S_1 and S_6. So deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage) was the best treatment than no deficiency condition in terms of yield because it gave significant yield to no deficiency condition and also it saved more water and power which reduced the highest cost of production. On the other hand S_4 showed the lowest grain yield (5.27 t ha^{-1}) which was statistically similar with S_1. So, vegetative stage was more sensitive to water for rice production because it reduced the highest yield.

For straw yield, S_3 showed the highest straw yield (6.79 t ha^{-1}) which was statistically similar with S_0. The second highest straw yield (6.222 t ha^{-1}) was given by S_0 treatment which was statistically similar with S_1, S_2 and S_6. The S_5 showed the lowest straw yield (4.43 t ha^{-1}) which was statistically similar with all the treatments except S_0 and S_3. So, S_5 gave 34.76% less sterility than S_3 (Figure 18).

IRRI (1995) showed that maintaining a saturated soil throughout the growing season could save upto 40% of water in clay loam soil, without yield reduction. Maity and Sarkar (1990), who observed no significant yield difference under saturated and submerged condition. But the result was disagreed with Gowda (1995) who stated statistically higher grain yield at submerged condition than that of saturated condition.

Choudhury (1988) opined that straw yield was significantly decreased whenever soil moisture dropped below saturation and Islam (1997) also observed significantly the highest straw yield in submerged condition than that of saturated condition.

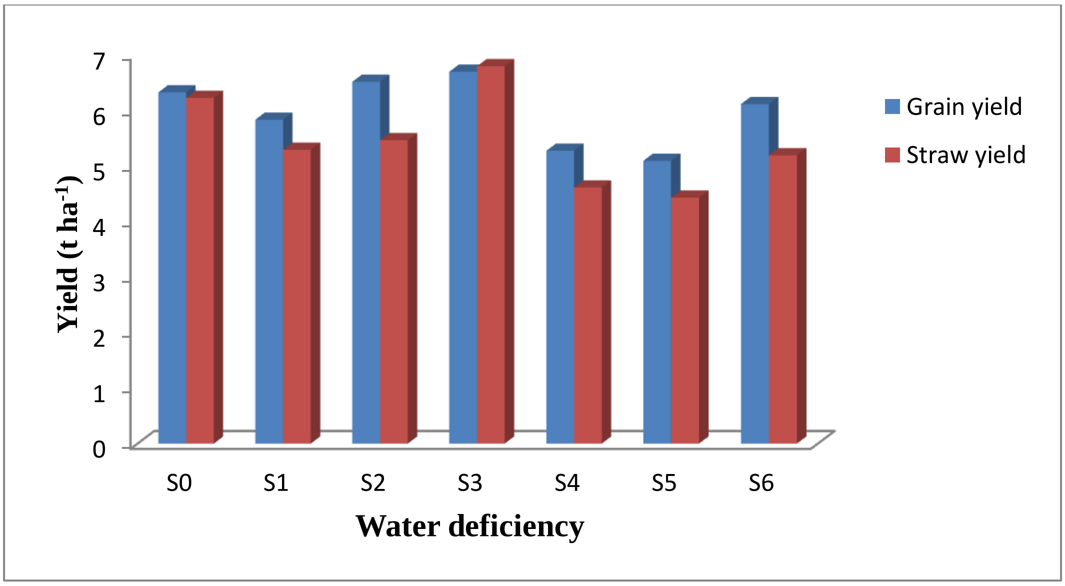

Figure 18. Effect of water deficiency on grain yield and straw yield of boro rice ($LSD_{(0.05)}$= 0.683 and 1.03 for grain yield and straw yield ha^{-1}, respectively)

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.7.3 Interaction effect of variety and water deficiency

The significant difference was observed for grain yield and straw yield between BRRI dhan74 and Heera-2 by the interaction effect of variety and water deficiency at harvest (Appendix XI). For grain yield, V_2S_2 showed the highest grain yield (7.52 t ha^{-1}) which was statistically similar with V_2S_0, V_2S_1, V_2S_3 and V_2S_6. So in case of Heera-2, farmer can give water deficiency at 15-35 DAT (vegetative stage) or 85-105 DAT (ripening stage) or 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage). But vegetative stage is more crucial for rice plant so deficiency at ripening stage or deficiency at both ripening stage and reproductive stage can give significantly more yield and reduce the cost of production.

But in case of BRRI dhan74, it gave the highest grain yield (6.43 t ha^{-1}) at S_3 condition than any other treatments, so farmer can give water deficiency at 85-105 DAT (ripening stage). Again there was no significant difference among V_1S_3, V_2S_0, V_2S_1, V_2S_3 and V_2S_6. Once again there was no significant difference among V_1S_3, V_2S_1, V_2S_3, V_2S_4 and V_2S_6. Further again there was no significant difference among V_1S_2, V_1S_3, V_1S_6 and V_2S_4. And also there was no significant difference among V_1S_0, V_1S_1, V_1S_2, V_1S_6, V_2S_4 and V_2S_5. The V_1S_0, V_1S_1, V_1S_2, V_1S_5 and V_1S_6 also had no significant difference among them. The V_1S_4 showed the lowest grain yield (4.51 t ha^{-1}) which was statistically similar with V_1S_0, V_1S_1, V_1S_5 and V_2S_5. For straw yield, V_1S_3 showed the highest straw yield (7.56 t ha^{-1}) which was statistically similar with V_1S_0 and V_1S_1. The second highest straw yield (7.42 t ha^{-1}) was given by V_1S_0 which was statistically similar with V_1S_1. But there was no significant difference among V_1S_1, V_1S_2, V_1S_5, V_1S_6, V_2S_2 and V_2S_3. Again there was no significant difference among V_1S_2, V_1S_4, V_1S_5, V_1S_6, V_2S_0, V_2S_2, V_2S_3, V_2S_4 and V_2S_6. Once again there was no significant difference among V_1S_2, V_1S_4, V_1S_5, V_1S_6, V_2S_0, V_2S_1, V_2S_2, V_2S_4 and V_2S_6. V_2S_5 showed the lowest straw yield (4.10 t ha^{-1}) which was statistically similar with V_1S_4, V_1S_5, V_2S_0, V_2S_1, V_2S_2, V_2S_4 and V_2S_6. So, V_2S_5 gave 45.77% less straw yield than V_1S_3 (Figure 19).

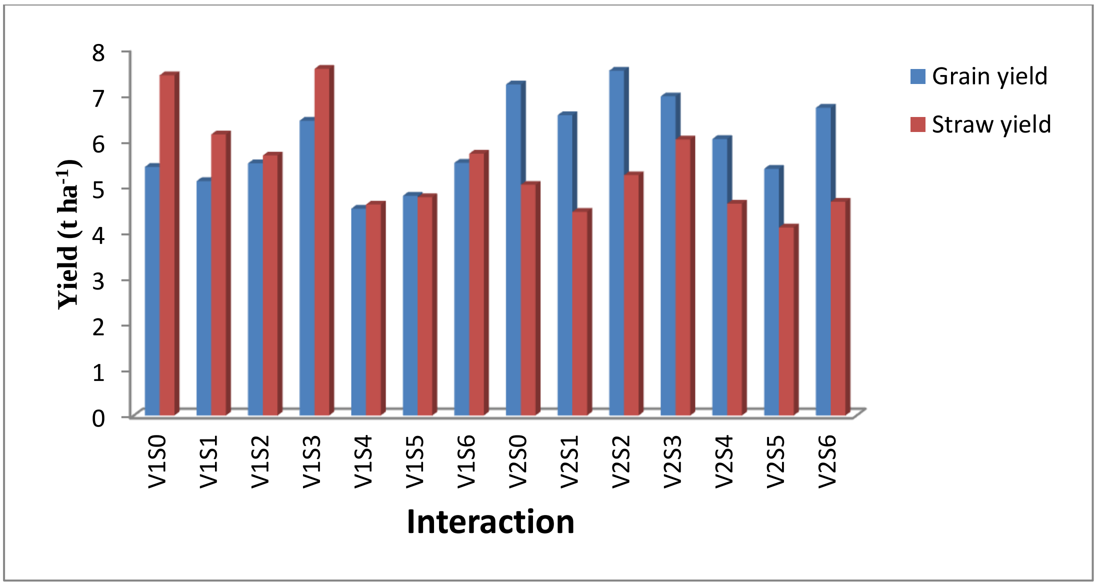

Figure 19. Interaction effect of variety and water deficiency on grain yield and straw yield of boro rice ($LSD_{(0.05)}$= 0.966 and 1.457 for grain yield and straw yield ha^{-1}, respectively)

V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.8 Biological yield (above ground) and harvest index

4.2.8.1 Effect of variety

The significant difference was not observed for biological yield (above ground) by the effect of variety in case of BRRI dhan74 and Heera-2 (Appendix XI). Here V_1 showed the maximum biological yield (10.91 t ha^{-1}) than V_2 (11.47 t ha^{-1}). But significant difference was observed for harvest index by the effect of variety in case of BRRI dhan74 and Heera-2. Here V_2 showed the maximum harvest index (57.70%) than V_1 (48.86%). But V_1 showed the maximum straw yield (5.98 t ha^{-1}) than V_2 (4.87 t ha^{-1}). So, Heera-2 is better variety than Zn-rich variety in terms of grain yield to biological yield (Table 24).

Samsuzzaman (2007) worked on the varietal characterization and yield evaluation of six rice hybrids grown in Bangladesh and showed that among the hybrids, biological yield plant^{-1} ranged from 28.0g in Heera to 46.45g in BRRI dhan29, with a mean value of 33.89g. Murshida *et al.* (2017) studied on the effect of variety and water management on the growth and yield of boro rice and found that biological yield and also harvest index was significantly influenced by variety.

Table 24. Effect of variety on biological yield and harvest index of boro rice

Treatments	**Biological yield (above ground) and harvest index**	
	Biological yield (t ha^{-1})	**Harvest index (%)**
V_1	10.91	48.86 b
V_2	11.47	57.70 a
$LSD_{(0.05)}$	NS	4.22
CV (%)	12.9	5.96

V_1 = BRRI dhan74 and V_2 = Heera-2

4.2.8.2 Effect of water deficiency

The significant difference was observed for biological yield by the effect of water deficiency (Appendix XI). For biological yield, S_3 showed the highest biological yield (12.62 t ha^{-1}) which was statistically similar with S_0 and S_2. Also the second highest biological yield (12.24 t ha^{-1}) was given by S_0 treatment which was statistically similar with S_2 and S_6. On the other hand S_5 showed the lowest biological yield (9.5 t ha^{-1}) which was statistically similar with S_4. So, vegetative stage was more sensitive to water for rice production because it reduced the highest yield. For harvest index, significant difference was not observed by the effect of water deficiency (Table 25).

Dhar (2006) studied on the growth and yield of boro rice as influence by water level and seedling number hill^{-1} plant height of boro rice. He represented that harvest index was not statistically influenced by the water levels. However, he showed that the highest (45.03%) harvest index was found from irrigation applied at submerged condition and the lowest harvest index (44.65) was at saturated condition. Raju (1980) who worked on the effect of irrigation regimes on agronomic characters of rice and reported that treatment having continuous flooding did not improve the harvest index.

Table 25. Effect of water deficiency on biological yield and harvest index of boro rice

Treatments	Biological yield (above ground) and harvest index	
	Biological yield (t ha^{-1})	Harvest index (%)
S_0	12.24 ab	51.48
S_1	10.87 cd	53.5
S_2	11.94 abc	54.28
S_3	12.62 a	52.93
S_4	9.86 d	53.28
S_5	9.5 d	53.54
S_6	11.31 bc	53.97
$LSD_{(0.05)}$	1.28	NS
CV (%)	9.62	6.99

S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

4.2.8.3 Interaction effect of variety and water deficiency

The significant difference was observed for biological yield and harvest index between BRRI dhan74 and Heera-2 by the interaction effect of variety and water deficiency at harvest (Appendix XI). For biological yield, V_2S_3 showed the highest biological yield (12.96 t ha^{-1}) which was statistically similar with V_1S_0, V_1S_3, V_1S_6, V_2S_0, V_2S_2 and V_2S_6. The second highest straw yield (12.73 t ha^{-1}) was given by V_2S_2 which was statistically similar with V_1S_0, V_1S_2, V_1S_3, V_1S_6, V_2S_0, V_2S_1 and V_2S_6. The V_1S_4 showed the lowest biological yield (9.09 t ha^{-1}) which was statistically similar with V_1S_1, V_2S_4 and V_2S_5. So, V_2S_3 gave 40% more biological yield than V_1S_4.

In case of Heera-2, it gave more grain yield and harvest index when water deficiency was given at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage). But there was no significant difference among the treatments in terms of harvest index in which V_2S_1 gave the highest harvest index (59.89%). On the other hand BRRI dhan74 gave the highest harvest index (52.23%) at S_3 condition than any other treatments (Table 26).

Table 26. Interaction effect of variety and water deficiency on biological yield and harvest index of boro rice

Treatments	Biological yield (above ground) and harvest index	
	Biological yield (t ha^{-1})	Harvest index (%)
V_1S_0	12.26 abc	44.15 f
V_1S_1	10.77 cde	47.11 ef
V_1S_2	11.14 bcd	49.38 def
V_1S_3	12.29 abc	52.23 bcde
V_1S_4	9.09 e	49.98 def
V_1S_5	9.53 d	50.35 cdef
V_1S_6	11.27 abcd	48.86 def
V_2S_0	12.23 abc	58.81 a
V_2S_1	10.97 bcd	59.89 a
V_2S_2	12.73 ab	59.18 a
V_2S_3	12.96 a	53.63 abcd
V_2S_4	10.63 cde	56.59 abc
V_2S_5	9.46 de	56.73 ab
V_2S_6	11.35 abc	59.07 a
$LSD_{(0.05)}$	1.81	6.28
CV (%)	9.62	6.99

V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

CHAPTER 5

SUMMARY AND CONCLUSION

The field experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University (SAU) farm, Dhaka, during the period from October 2016 to May 2017 to study the influence of variety and water deficiency on the growth and yield of boro rice under the Modhupur Tract (AEZ-28). The experiment consisted of 2 rice variety (BRRI dhan74 and Heera-2) and 7 levels of water deficiency {S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage)}. The experiment was laid out in a split-plot design with three replications having variety in the main plots and water deficiency in the sub-plots. There were 14 treatment combinations and the total numbers of unit plots were 42. The size of unit plot is 3 m x 2 m. Thirty days old seedlings were transplanted following line to line distance 20 cm and hill to hill distance 20 cm with 1 seedling hill^{-1}.

The data on crop growth parameters such as plant height, number of tillers hill^{-1}, leaf area index at different growth stages, dry matter hill^{-1}, SPAD reading and time of 50% flowering and maturity were recorded. Yield parameters such as number of effective and ineffective tillers hill^{-1}, panicle length, primary branches panicle^{-1}, sterility percentage, number of grains panicle^{-1}, filled and unfilled grains panicle^{-1}, 1000-grain weight, grain and straw yield, biological yield and harvest index were recorded after harvest. Data were analyzed using CROPSTAT package and the mean differences among the treatments were compared by least significant difference test (LSD) at 5% level of significance.

Significant variation was recorded for all data (crop growth parameters, yield and yield contributing parameters). At harvest, the highest plant height was observed in V_2S_2 (88.31 cm) which was statistically similar with the treatments except V_1S_2, V_1S_4, V_1S_5 and V_1S_6 and the lowest plant height was observed in V_1S_4 (75.33 cm) which was statistically similar with V_1S_0, V_1S_2, V_1S_4, V_1S_5 and V_1S_6. At harvest, the highest number of tillers hill^{-1} was observed in V_1S_3 (16.80) which was statistically similar with V_1S_1, V_1S_2 and V_1S_6, the lowest number of tillers hill^{-1} was observed in V_2S_1 (8.13) which was statistically similar with V_2S_0, V_2S_1, V_2S_2, V_2S_3, V_2S_4, V_2S_5 and V_2S_6. At 91 DAT, the highest leaf area index was observed in V_1S_3 (7.20) and the lowest leaf area index was observed in V_2S_1 (2.88) which was statistically similar with V_1S_0, V_1S_4, V_1S_5, V_2S_2, V_2S_3, V_2S_4, V_2S_5 and V_2S_6. At 97 DAT, the highest dry matter hill^{-1} was observed in V_2S_4 (39.00 g) which was statistically similar with V_1S_0, V_1S_2, V_1S_3, V_1S_6, V_2S_1 and V_2S_5 and the lowest dry matter hill^{-1} was observed in V_2S_6 (29.43 g) which was statistically similar with V_1S_1, V_1S_4, V_1S_5, V_2S_0 and V_2S_3. V_2S_6 needed the longest time for 50% flowering (82.00 DAT) and also maturity (123.33 DAT) and V_1S_1 and V_1S_4 needed the shortest time for 50% flowering (77.67 DAT) but at maturity, V_1S_4 and V_1S_5 needed the shortest time for maturity (111.33 DAT). The V_1S_3 showed the highest SPAD value (43.05) which was statistically similar with all the treatments except V_2S_5. The V_2S_5 showed the lowest SPAD value (35.34) which was statistically similar with all the treatments except V_1S_3. At 38 DAT, V_1S_3 showed the highest dry matter of weed (11.19 g) which was statistically similar with all the treatments except V_1S_0, V_1S_6, V_2S_0, V_2S_1 and V_2S_3. The V_1S_0 showed the lowest dry matter of weed (9.20 g) which was statistically similar with all the treatments except V_1S_3 and V_2S_2.

For effective tillers, V_1S_3 showed the highest number of effective tillers (12.54) which was statistically similar with V_1S_2 and V_1S_6. V_2S_1 showed the lowest number of effective tillers (5.78) which was statistically similar with V_1S_4, V_2S_2, V_2S_3, V_2S_4, V_2S_5 and V_2S_6. For ineffective tillers, V_1S_3 showed the highest number of ineffective tillers (2.6) which was statistically similar with V_1S_1, V_1S_2 and V_1S_6. The V_2S_2 showed the lowest number of ineffective tillers (0.35) which was statistically similar with V_2S_0, V_2S_1, V_2S_3, V_2S_4, V_2S_5 and V_2S_6.

The V_2S_2 showed the highest (23.67 cm) panicle length which was statistically similar with V_2S_0, V_2S_1, V_2S_3, V_2S_4 and V_2S_6. V_1S_5 showed the lowest (19.87 cm) panicle length which was statistically similar with V_1S_1, V_1S_2, V_1S_3, V_1S_4 and V_1S_6. The V_1S_0 showed the highest (9.87) rachis branches panicle^{-1} which was statistically similar with V_1S_1, V_1S_3, V_2S_0, V_2S_1, V_2S_2, V_2S_3 and V_2S_6. The V_1S_5 showed the lowest (8.00) rachis branches panicle^{-1} which was statistically similar with all the treatments except V_1S_0, V_1S_1, V_1S_3, V_2S_0 and V_2S_1.

For filled grains, V_2S_3 showed the highest number of filled grains (138.93) which was statistically similar with V_2S_0, V_2S_1, V_2S_2, V_2S_4, V_2S_5 and V_2S_6. The V_1S_4 showed the lowest number of filled grains (71.33) which was statistically similar with V_1S_0, V_1S_2, V_1S_3 and V_1S_5. For unfilled grains, V_2S_0 showed the highest number of unfilled grains (23.77) which was statistically similar with V_2S_2, V_2S_3, V_2S_4, V_2S_5 and V_2S_6. The V_1S_4 showed the lowest number of unfilled grains (7.40) which was statistically similar with V_1S_0, V_1S_1, V_1S_2, V_1S_3, V_1S_5, V_1S_6 and V_2S_1. For total number of grains, V_2S_3 showed the highest number of total grains (156.53) which was statistically similar with V_2S_0, V_2S_1, V_2S_2, V_2S_4, V_2S_5 and V_2S_6. The V_1S_4 showed the lowest number of total grains (78.73) which was statistically similar with V_1S_0, V_1S_2, V_1S_5 and V_1S_6.

The V_1S_5 showed the highest 1000-grain weight (30.113 g) which was statistically similar with V_1S_0, V_1S_2, V_1S_4 and V_1S_6. The V_2S_5 showed the lowest 1000-grain weight (25.55 g) which was statistically similar with V_2S_0, V_2S_2, V_2S_3, V_2S_4 and V_2S_6. For grain yield, V_2S_2 showed the highest grain yield (7.52 t ha^{-1}) which was statistically similar with V_2S_0, V_2S_1, V_2S_3 and V_2S_6. The V_1S_4 showed the lowest grain yield (4.51 t ha^{-1}) which was statistically similar with V_1S_0, V_1S_1, V_1S_5 and V_2S_5. For straw yield, V_1S_3 showed the highest straw yield (7.56 t ha^{-1}) which was statistically similar with V_1S_0 and V_1S_1. The V_2S_5 showed the lowest straw yield (4.10 t ha^{-1}) which was statistically similar with V_1S_4, V_1S_5, V_2S_0, V_2S_1, V_2S_2, V_2S_4 and V_2S_6.

For biological yield, V_2S_3 showed the highest biological yield (12.96 t ha^{-1}) which was statistically similar with V_1S_0, V_1S_3, V_1S_6, V_2S_0, V_2S_2 and V_2S_6. The V_1S_4 showed the lowest biological yield (9.09 t ha^{-1}) which was statistically similar with V_1S_1, V_2S_4 and V_2S_5. V_2S_1 gave the highest harvest index (59.89%). On the other hand BRRI dhan74 gave the highest harvest index (52.23%) at S_3 condition than any other treatments.

Based on the results of the present study, the following conclusions may be drawn-

- Both the varieties showed different results for different parameters.
- In case of Heera-2, water deficiency at 15-35 DAT (vegetative stage) or 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage) or 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) reduced rice yield. So, vegetative stage is more crucial for rice plant because it reduced significant yield. So no deficiency at vegetative stage or no deficiency at both vegetative stage and reproductive to ripening stage can be ensured for significantly more yield and reduce the cost of production.

- But in case of BRRI dhan74, it gave the highest grain yield reduction at S_1, S_4 and S_5 condition than any other combination. So farmer could aware about no water deficiency at 15-35 DAT (vegetative stage) or 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage) or 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) for BRRI dhan74.

- No deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage) should be ensured in rice because it caused significant yield reduction.

- It needs further research to find out the water stress impacts on rice production in different agro-ecological area with control condition because in this field experiment water stress conditions were interrupted by rain at times.

However, to reach a specific conclusion and recommendation the same experiment needs to be repeated and more research work should be done over different Agro-ecological zones.

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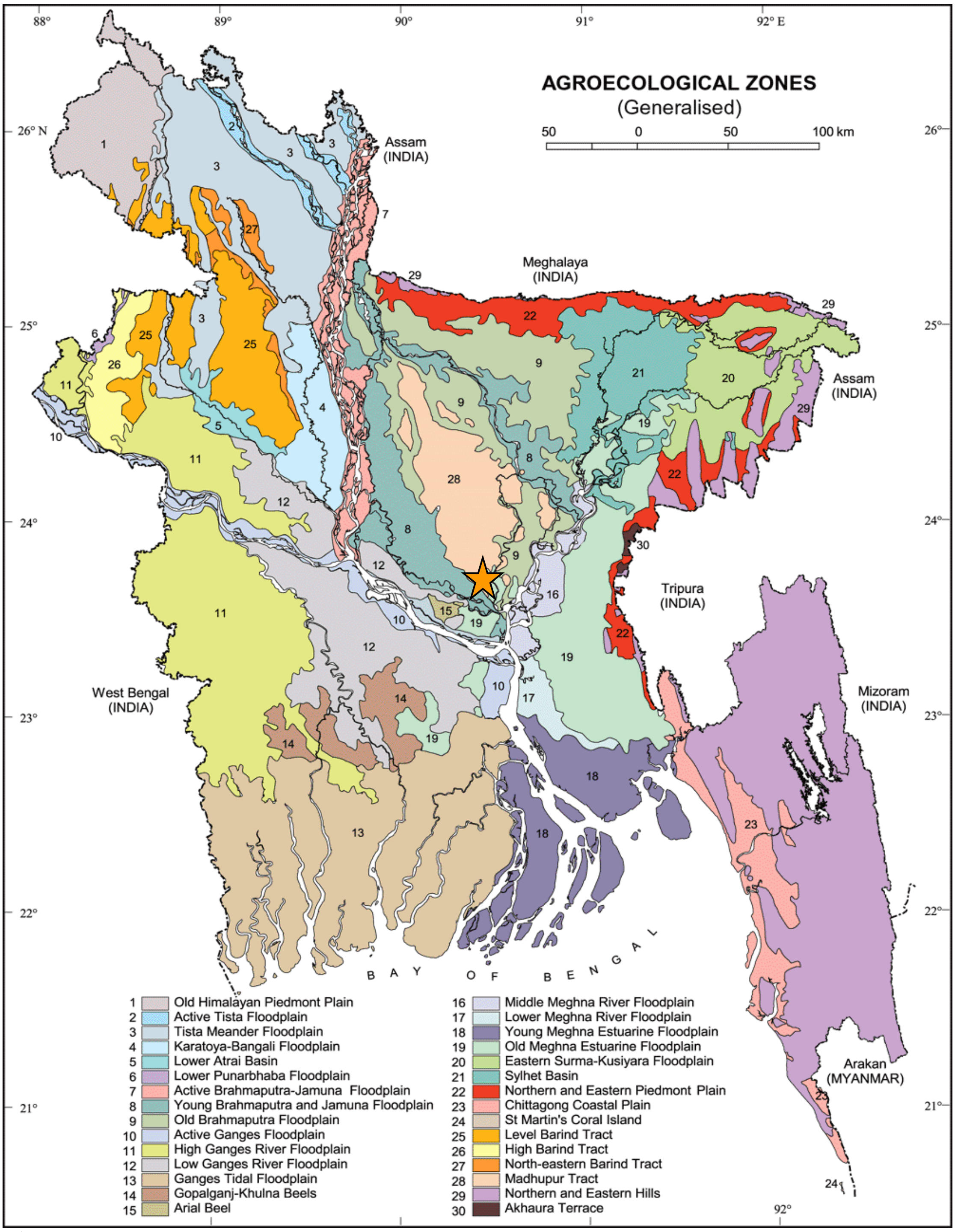
APPENDICES

Appendix I. Map showing the experimental sites under study



☆ = The experimental site under study

Appendix II. Physical characteristics of field soil analyzed in Soil Resources Development Institute (SRDI) laboratory, Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

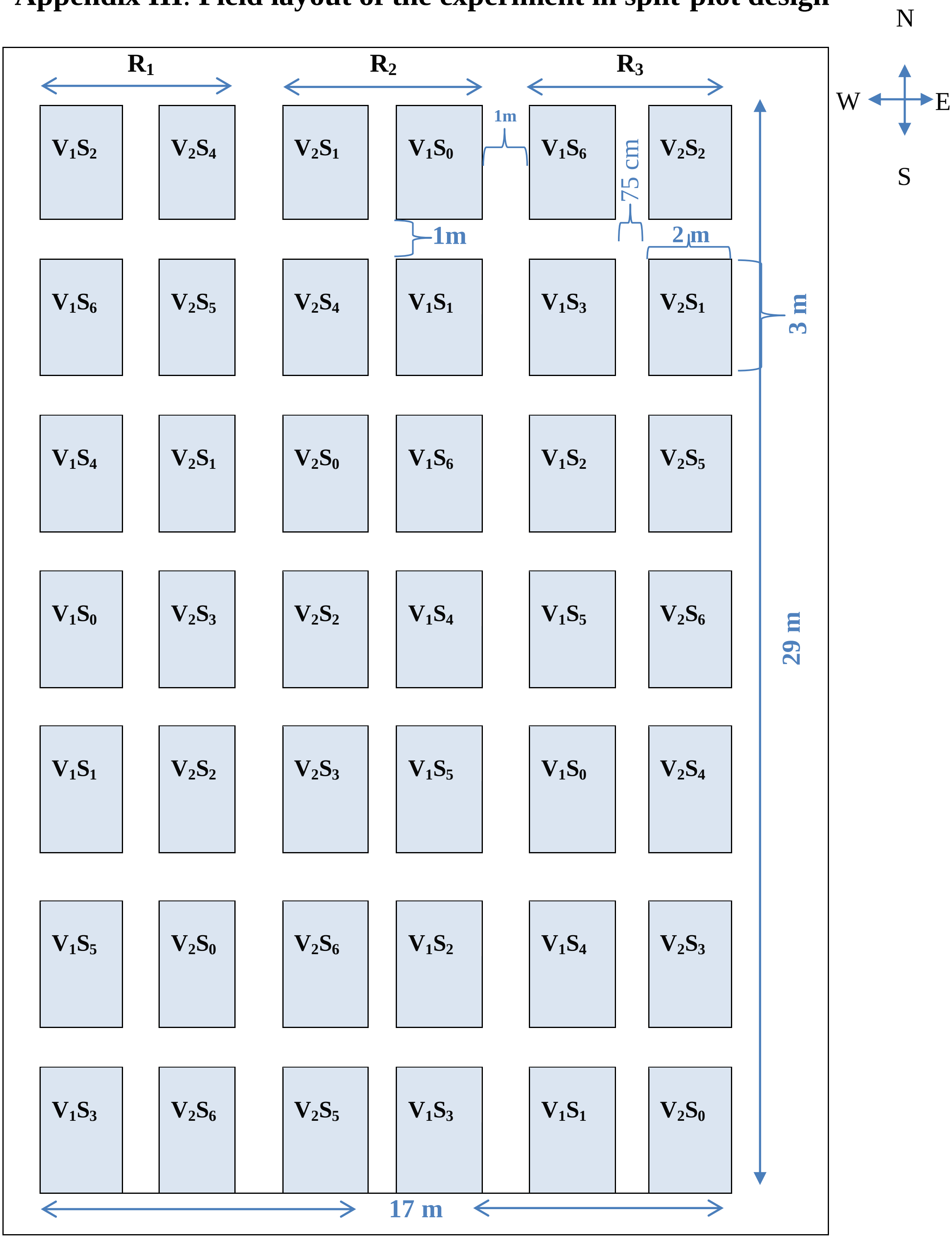
Morphological features	Characteristics
Location	Agronomy field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

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

Source: Soil Resources Development Institute (SRDI)

Appendix III. Field layout of the experiment in split-plot design



V_1 = BRRI dhan74 and V_2 = Heera-2
S_0 = No deficiency, S_1 = Deficiency at 15-35 DAT (vegetative stage), S_2 = Deficiency at 55-75 DAT (reproductive stage), S_3 = Deficiency at 85-105 DAT (ripening stage), S_4 = Deficiency at 15-35 DAT and 55-75 DAT (vegetative stage and reproductive stage), S_5 = Deficiency at 15-35 DAT and 85-105 DAT (vegetative stage and ripening stage) and S_6 = Deficiency at 55-75 DAT and 85-105 DAT (ripening stage and reproductive stage).

Appendix IV. Summary of analysis of variance for plant height of BRRI dhan74 and Heera-2

Sources of variation	Degrees of freedom	Mean square values of plant height at different DAT				
		16	41	66	91	at harvest
Replication	2	0.58	0.29	62.14	25.22	5.20
Variety (V)	1	3.11	5.03	139.70	0.52	348.37
Error-1	2	5.42	2.32	34.63	12.92	29.42
Water deficiency (S)	6	9.04 *	31.50 *	51.44 *	29.23 *	48.31 *
V X S	6	2.22 *	6.73 *	19.86 *	17.15 *	8.91 *
Error-2	24	4.66	7.64	22.02	16.22	16.82

* Significant at 5% level

Appendix V. Summary of analysis of variance for no. of tillers hill^{-1} of BRRI dhan74 and Heera-2

Sources of variation	Degrees of freedom	Mean square values of tillers hill^{-1} at different DAT				
		16	41	66	91	at harvest
Replication	2	0.29	1.05	10.82	3.42	39.59
Variety (V)	1	0.86	1.48	1.10	256.53 *	109.45
Error-1	2	0.17	0.76	31.68	11.23	34.25
Water deficiency (S)	6	0.18	3.80 *	9.23 *	7.57 *	5.46 *
V X S	6	0.19	1.72 *	8.60 *	5.12 *	7.45 *
Error-2	24	0.25	2.04	4.40	3.69	3.69

* Significant at 5% level

Appendix VI. Summary of analysis of variance for leaf area index of BRRI dhan74 and Heera-2

Sources of variation	Degrees of freedom	Mean square values of leaf area index at different DAT				
		16	41	66	91	at harvest
Replication	2	0.61	0.91	4.40	2.37	0.45
Variety (V)	1	0.31	0.19	.68	5.71	0.19 *
Error-1	2	0.89	0.11	9.26	5.08	0.30
Water deficiency (S)	6	0.77 *	0.16 *	3.52 *	2.86 *	0.14
V X S	6	0.20 *	0.78 *	1.50 *	2.72 *	0.17 *
Error-2	24	0.65	0.72	1.42	1.13	0.11

* Significant at 5% level

Appendix VII. Summary of analysis of variance for dry matter hill^{-1} of BRRI dhan74 and Heera-2

Sources of variation	Degrees of freedom	Mean square values of dry matter hill^{-1} at different DAT			
		22	**47**	**72**	**97**
Replication	2	0.39	0.31	0.30	25.00
Variety (V)	1	0.42	0.64	93.28 *	3.23
Error-1	2	0.36	0.92	2.36	8.89
Water deficiency (S)	6	0.30 *	9.50 *	68.43 *	7.49 *
V X S	6	0.13 *	3.28 *	27.27 *	67.32 *
Error-2	24	0.26	0.56	1.43	6.07

* Significant at 5% level

Appendix VIII. Summary of analysis of variance for 50% flowering, maturity, dry matter of weed and SPAD value of BRRI dhan74 and Heera-2

Sources of variation	Degrees of freedom	Mean square values at different DAT			
		50% flowering	**Maturity**	**SPAD value**	**Dry matter of weed**
Replication	2	3.50	6.50	46.54	1.05
Variety (V)	1	42.00	1070.10 *	3.82	0.25
Error-1	2	3.07	6.74	6.58	8.75
Water deficiency (S)	6	2.19 *	1.00 *	14.82	1.79 *
V X S	6	1.33 *	2.32 *	16.88 *	1.12 *
Error-2	24	2.70	3.06	20.26	0.79

* Significant at 5% level

Appendix IX. Summary of analysis of variance for effective tillers, ineffective tillers, panicle length and rachis branches panicle^{-1} of BRRI dhan74 and Heera-2

Sources of variation	Degrees of freedom	Mean square values at harvest			
		Effective tillers	**Ineffective tillers**	**Panicle length**	**Rachis branches panicle^{-1}**
Replication	2	26.6	1.34	0.55	0.11
Variety (V)	1	41.40	16.22	56.49 *	0.44
Error-1	2	19.18	2.2	0.55	0.23
Water deficiency (S)	6	4.48 *	0.23	1.50 *	1.78 *
V X S	6	5.09 *	0.33 *	0.47 *	0.52 *
Error-2	24	2.70	0.4	0.66	0.45

* Significant at 5% level

Appendix X. Summary of analysis of variance for filled and unfilled grains, total no. of grains panicle^{-1} and sterility percentage of BRRI dhan74 and Heera-2

Sources of variation	Degrees of freedom	Mean square values at harvest			
		Filled grains	Unfilled grains	Total no. of grains panicle^{-1}	Sterility percentage
Replication	2	13.98	26.22	63.37	9.92
Variety (V)	1	25801.90 *	482.13	33338.1 *	0.37
Error-1	2	108.14	78.75	352.34	34.52
Water deficiency (S)	6	177.80 *	38.70 *	226.92 *	23.74 *
V X S	6	92.37 *	10.46 *	119.17 *	5.52
Error-2	24	126.20	24.32	136.05	14.37

* Significant at 5% level

Appendix XI. Summary of analysis of variance for 1000-grains wt., grain and straw yield, biological yield and harvest index of BRRI dhan74 and Heera-2

Sources of variation	Degrees of freedom	Mean square values at harvest				
		1000-grains wt.	Grain yield	Straw yield	Biological yield	Harvest index
Replication	2	0.24	0.13	2.55	2.38	7.78
Variety (V)	1	112.47 *	6.36	7.42	3.36	819.73 *
Error-1	2	0.49	0.39	1.76	2.12	10.09
Water deficiency (S)	6	0.76 *	0.80 *	1.64 *	8.47 *	4.96
V X S	6	2.04 *	0.17 *	0.66 *	0.78 *	29.67 *
Error-2	24	0.48	0.12	0.41	1.16	13.88

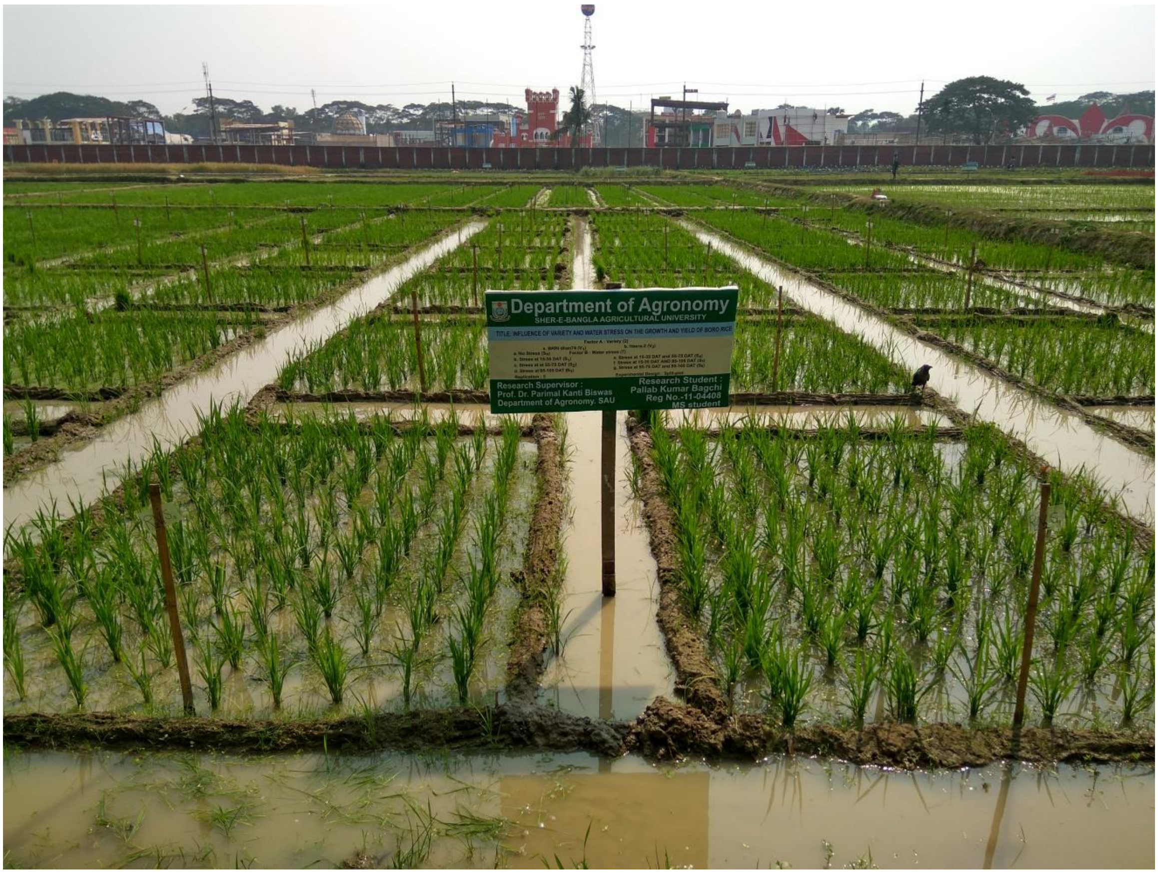
* Significant at 5% level

PICTURE

Picture 1. Rice seedlings at seedbed

Picture 2. Rice seedlings transplantation

Picture 3. Field condition at 12 DAT



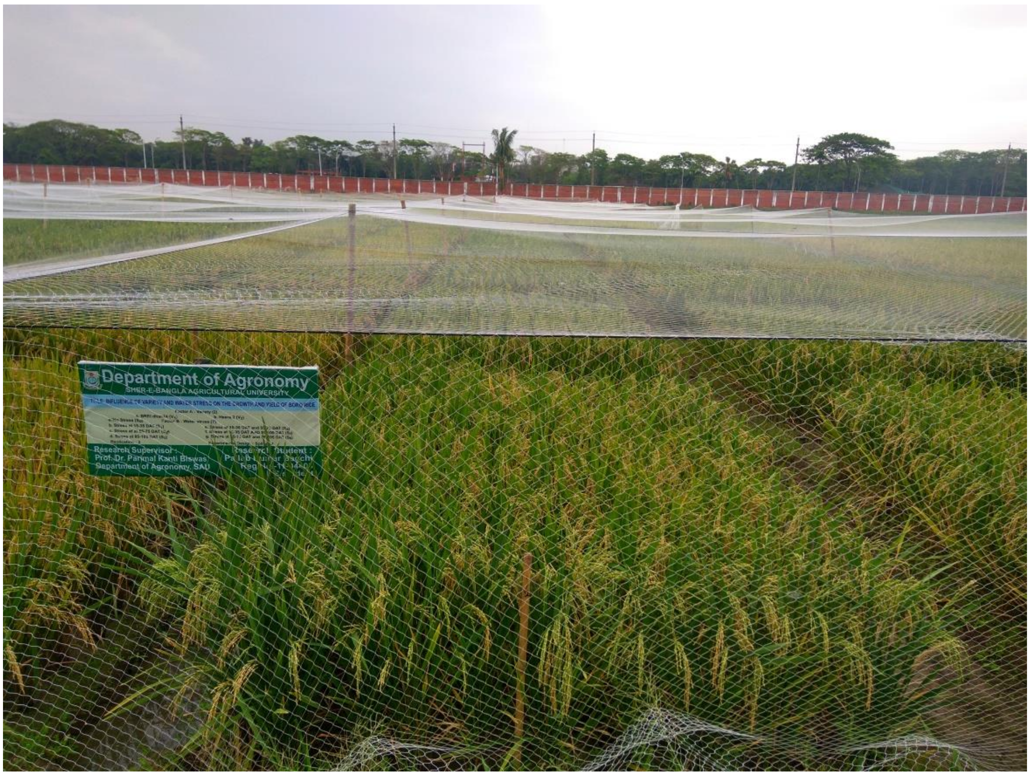
Picture 4. No deficiency condition at 38 DAT after deficiency at 15-35 DAT

Picture 5. Deficiency condition at 85 DAT

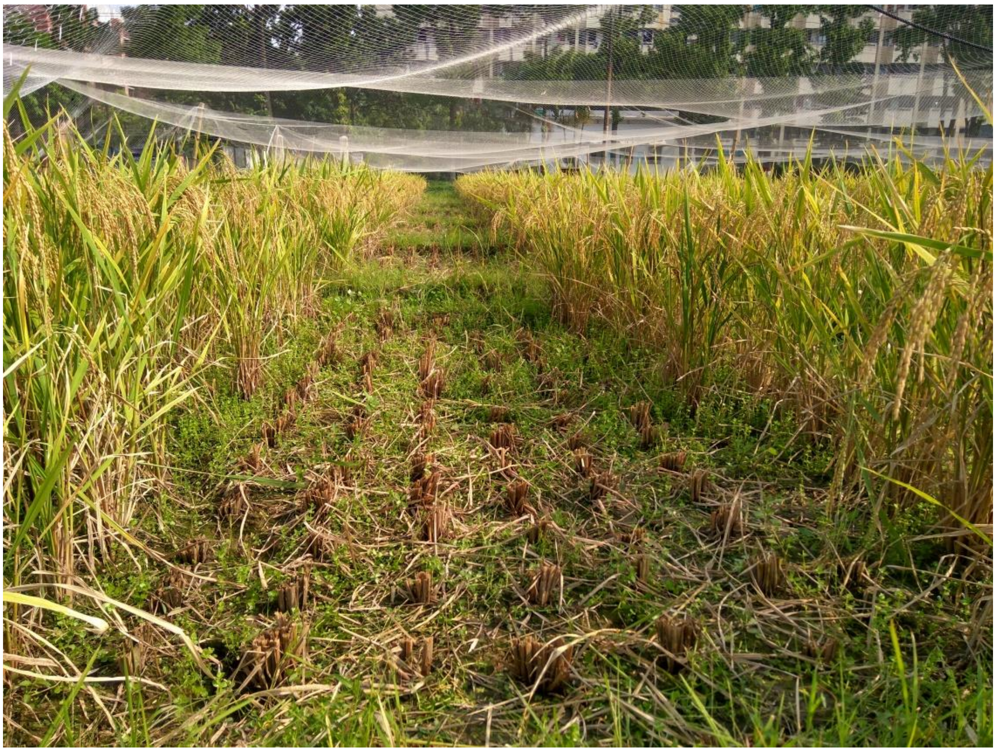
Picture 6. Flowering condition at 85 DAT for BRRI dhan74

Picture 7. Field view at 102 DAT

Picture 8. Difference between V_1 (left) and V_2 (right) in case of ripening at 102 DAT



Picture 9. Net was given to protect rice crop from birds



Picture 10. Harvesting was done from mid 6 lines

Picture 11. Rice grains of two varieties