EFFECT OF SUBMERGENCE ON THE REPRODUCTIVE STAGE AND YIELD OF DIFFERENT AMAN RICE VARIETIES

MD. HOSNE MOBARAK

DEPARTMENT OF AGRICULTURAL BOTANY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA -1207

JULY, 2020

EFFECT OF SUBMERGENCE ON THE REPRODUCTIVE STAGE AND YIELD OF DIFFERENT AMAN RICE VARIETIES

BY

MD. HOSNE MOBARAK

REGISTRATION NO. : 13-05663

A Thesis
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
IN
AGRICULTURAL BOTANY

SEMESTER: JANUARY-JUNE, 2018

Approved By:

Prof. Dr. Kamal Uddin Ahamed
Supervisor

Associate Professor Dr. Kamrunnahar
Co-Supervisor

Associate Professor. Dr. Kamrunnahar
and
Chairman

DEPARTMENT OF AGRICULTURAL BOTANY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled, "**EFFECT OF SUBMERGENCE ON THE REPRODUCTIVE STAGE AND YIELD OF DIFFERENT AMAN RICE VARIETIES**" 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** in **AGRICULTURAL BOTANY**, embodies the results of a piece of bona fide research work carried out by **MD. HOSNE MOBARAK, REGISTRATION NO.: 13-05663** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2020

Dhaka, Bangladesh

Prof. Dr. Kamal Uddin Ahamed

Supervisor
Department of Agricultural Botany
Sher-e-Bangla Agricultural University
Dhaka-1207

DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises and thanks are due to the supreme ruler of the universe, the almighty Allah for His grace bestowed upon the author for accomplishment of this research study.

The author expresses the deepest sense of respect and heartiest gratitude to his respectable supervisor **Dr. Kamal Uddin Ahamed**, Professor, Department of Agricultural Botany, Sher-e-Bangla Agricultural University for his efficient and scholastic guidance, constructive criticism, valuable suggestions and immense help to carry out the research work toward successful completion and preparation of the thesis by necessary corrections and modification through reviewing the text.

He wishes to express his sincere appreciation and heartfelt gratitude to his co-supervisor **Dr. Kamrunnahar**, Associate Professor, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, for her valuable suggestions, constant cooperation, inspiration and sincere advice to improve the quality of the thesis.

Cordial thanks to Chairman, Department of Agricultural Botany and all respected teachers of the Department of Agricultural Botany, Sher-e-Bangla Agricultural University for their help and co-operation during the study and research.

He is grateful to all those people who contributed to this research work although it is not possible to mention all by their names.

Last but not the least, the author expresses his immense indebtedness and the deepest senses of gratitude to his beloved parents and elder sister who sacrificed all their happiness during the whole study period. The author is grateful to all the respondents in the study area for their cooperation and help in accomplishing the objectives of this research work. Finally, he wishes to extend his heartfelt thanks and gratitude to all of his relatives for their inspiration, blessings and encouragement those opened the gate of his higher study.

The author

ABSTRACT

The experiment was conducted at the Agricultural Botany field of central research farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from June 2018 to December 2018 to find out the effect of submergence on the reproductive stage and yield of different *Aman* rice varieties. Four Submergence conditions at reproductive stage viz. S_0 – Control (No submergence), S_1 – Submergence for 4 days, S_2 - Submergence for 7 days, S_3 - Submergence for 10 days and five varieties viz. V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12 were used as treatment of the experiment. The pot experiment was laid out in Split Plot Design having two factors and replicated four times. Significant effect was found in case of different submerged conditions, varieties and their interaction. In Interaction effect it was found that the highest plant height, number of leaves and number of tillers per plant, SPAD value, no. of leaf before and after emergence of panicle were recorded from the S_0V_3 (Control treatment with variety BRRIdhan 52). The highest leaf, stem and root (18.6 g, 22.20 g and 5.02 g, respectively) dry weight were recorded from the treatment S_0V_3 at harvest. The highest no. of effective tillers and filled grains (13.85 and 150.39) and the lowest number of ineffective tillers and unfilled grains (2.05 and 20.51) were recorded from the S_0V_3. The highest grain yield, straw, biological yield (4.81, 6.17 and 10.98 t ha^{-1}) and harvest index (43.84 %) were recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest (1.70, 4.23 and 5.99 t ha^{-1}) were recorded from S_3V_2 (Submergence for 10 days in BR 5). Therefore, it is concluded that BRRIdhan 52 was superior in *Aman* season in consideration of growth and yield attributes among the mentioned five varieties with submerged condition. BRRIdhan 52 ultimately leads to the higher dry matter production. Panicles $hill^{-1}$, effective tiller, filled grain and 1000-grain weight are the determinants for the higher grain yield of the BRRIdhan 52.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I
INTRODUCTION

Rice (*Oryza sativa*) is a cereal food crop, of the grass family Gramineae extensively cultivated in warm climates especially in East Asia. The Crop has wider adaptability and grows from sea level to an elevation of about 2600 meters (Dey *et al.* 1996). As a staple food, about 90 percent of the population of Bangladesh live on rice. Rice is rich in carbohydrates. The protein content is 8.5 percent, The Thiamin and Riboflavin contents are 0.27 and 0.12 micrograms respectively. In Bangladesh total cultivable land is 85,86,864 hectares and near about 77 percent of total cropped area is occupied by rice cultivation (BBS, 2019).

Agriculture is the single largest producing sector of the economy of Bangladesh since it comprises about 13.82% of the gross domestic product (GDP) and employs more than 45 percent of total labor force (BBS, 2019). Bangladesh is one of the most important rice growing countries of the world. Bangladesh ranks fourth in terms of rice production. During the year 2018–2019 rice covered an area of 11.67 million hectares with a production of 37.36 million m. tons. *Aman* is the second largest rice crop in the country in respect to the volume of production while *boro* rice ranks top in production. *Aman* rice covers more than half of the rice area accounting 5.62 million hectares with a production of 14.54 million tons. Average yield of *Aman* rice during the year 2018–19 has been estimated 2.50 t ha^{-1} (BBS, 2019).

Bangladesh is one of the most climate-affected countries in the world. According to two recent reports, the global Climate Risk Index 2017 (Kreft *et al.*, 2016) and the Climate Change Vulnerability Index 2017 (Maplecroft, 2016), Bangladesh was ranked in the top-10 countries most vulnerable to climate change in the world. Note that more than 200 extreme climatic events such as floods, cyclones, and storms hit Bangladesh during the last two decades, which cost on average 1% of the national gross domestic product (GDP) (Kreft *et al.*, 2016). The most common climatic events in Bangladesh are floods, especially monsoon and flash floods (Dewan, 2015; Rahman and Zhang, 2016). Hydrological characteristics such as low-lying topography surrounded by a large network of rivers, high annual evapotranspiration (ca. 1,600 mm), and being situated at the head of the Bay of Bengal make the country highly vulnerable to floods (Ahmed *et al.*, 2000; Dewan *et al.*, 2003; Majumder, 2013).

Under rainfed lowland condition, among number of abiotic stress, submergence is major one and it affects rice production a lot. Submergence is a major limiting factors that reduces rice production. This abiotic stress can completely destroy crop production in extreme conditions, and consequently this stress is considered as key determinant of global food security. Moreover, climate change is also projected to undermine global food security (Sarkar *et al.*, 2006).

Water logging is defined as a condition of land in which the soil profile is saturated with water either temporarily or permanently. It creates the damages to plants as consequences of slow rates of gas exchange, severe shading by turbid water, mechanical damages due to strong flow rates and solute carrying capacity of flooded water (Michael and Phool, 2001). Water logging is one of the most hazardous natural occurrences, which can also be called as flood, submergence, soil saturation, anoxia, and hypoxia, which are generally used to describe water logging conditions depending upon the moisture or water level on the field. (Mohanty *et al*., 1985).

Though rice is a crop that requires flooded and irrigated condition for cultivation, most of the rice varieties are susceptible to flooding if the water stagnates keeping the plants submerged under water for more than seven days causing leaf or stem elongation, leaf rotting, loss of dry mass and also lodging after the flood water recedes. Submergence caused by flash flood is a key factor limiting the yield of lowland rice (Goswami *et al.,* 2015). Flash floods are highly unpredictable and can occur at any growth stage of the rice crop, resulting in yield loss of 10% to 100%, depending on water depth, duration of submergence, temperature, turbidity of water, light intensity, and age of the crop, etc (Setter *et al*., 1997).

Rice is grown in Bangladesh under diverse ecosystem like irrigated, rainfed and deep-water conditions in three distinct cropping seasons namely Aus, Aman and Boro. Transplanting aman rice varieties are generally cultivated in rainfed ecosystem which covers about 48.97% of total rice area and contributes to 38.14% of total rice production in the country (BRRI 2012). Modern varieties of T. aman cover about 68% of rice area in the aman season (BBS 2012). In Bangladesh rainfed low land rice covers an area 4.5 million hectares (Islam *et al.*, 1997) and is grown by transplanting Aman rice from June – September. As a result, following its transplanting as well as at early growing stage the crop is often submerged by flash flood. Such flood may continue for a week or more inflicting heavy damage to standing crop (Zeigler and Puckridge, 1995).

There are three growth phases in rice plant i.e. vegetative, reproductive and ripening phase. The initiation of panicle primordia starts about 30 days before heading. The total duration of panicle development varies with variety, weather ranges from 27-46 days. In Bangladesh, several districts like Nilphamari, Gaibandha, Lalmonirhat and some other districts undergo submergence due to flashflood in the panicle initiation stage. Submergence in panicle initiation stage can inflict heavy damage in rice growing regions.

Different research institutions of Bangladesh have invented some submergence tolerant varieties such as BRRI dhan51, BRRI dhan52, BINA dhan11, BINA dhan12. FR13A is a newly introduced variety that requires trials against other susceptible varieties. Some fragmentary works have been done by previous researchers on submergence, but no work has been done on panicle initiation stage. That’s why it is important to assess the level of submergence tolerance of some promising aman varieties in Bangladesh.

Objectives:

Sequel to the above mentioned submergence problem, present study was undertaken in order to achieve the following objectives:

i) To find out the independent effect of submergence and variety on the morphological and reproductive attributes and yield of aman rice.
ii) To find out the interaction effect of submergence and variety on the morphological and reproductive attributes and yield of aman rice.
iii) To find out the highest submergence period for different varieties in which rice plant can survive and to identify the suitable submergence tolerant varieties for flood prone area.

CHAPTER II
REVIEW OF LITERATURE

Karim e*t al.* (2019) evaluated morphological and phenological traits associated with submergence tolerance in rice. The experiment consisted of two factors - Rice cultivars (Binadhan-11, Binadhan-12, BRRI dhan51 and BRRI dhan52 as tolerant and BRRI dhan49 as susceptible) and submergence stress for 14 days at vegetative stage and control. Among the five cultivars, BRRI dhan51 contributed the highest yield under stress treatment. Submergence tolerant rice cultivars (Binadhan-11, Binadhan-12, BRRI Dhan51 and BRRI Dhan52) had maintained higher tiller number, 1000-grain weight and the higher number of grains per panicle during submergence, as compared to susceptible rice cultivar BRRI Dhan49.

Hassan *et al.* (2019) conducted a pot experiment was conducted at the net house of Department of Crop Botany, Bangladesh Agricultural University, during Aman season from July to December, 2017 to evaluate the changes in root porosity and water soluble carbohydrates (WSCs) associated with submergence tolerance in rice. The experiment consisted of two factors- (i) Rice cultivars (Binadhan-11, Binadhan-12, BRRI dhan51 and BRRI dhan52 as tolerant and BRRI dhan49 as susceptible) and(ii) Submergence stress: Submergence for 14 days at vegetative stage and control. Submergence stress was imposed by dipping of pots into a water tank with about 90 cm depth of water while the control plants are maintained in the pot house of the field laboratory. Tolerant cultivars showed greater root porosity development in both control and stress condition but the susceptible cultivar showed significantly lower root development in stress condition. Higher root porosity might help tolerant cultivars to survive in submergence stress more efficiently. Tolerant rice cultivars had high initial soluble carbohydrate than the susceptible one. Under submerged condition, the tolerant cultivars showed slow depletion of water soluble carbohydrate compared to susceptible cultivar.

Murshida *et al.*, (2017) examined the effect of variety and water management system on the growth and yield performance of *boro* rice. The experiment consisted of three varieties (cv. BRRI dhan28, BRRI dhan29 and Binadhan-14) and four water management systems (viz. Traditional flooding, non-flooded rice straw mulching, non-flooded water hyacinth mulching and non-flooded no mulching). The experiment was laid out in a split plot design with three replications. Different growth characters, yield and yield contributing characters of *boro* rice were found to the significantly influenced by variety, water management system and their interactions. At 100 DAT, the highest plant height, maximum number of tillers hill^{-1}, dry matter of shoot hill^{-1} and dry matter of root hill^{-1} were obtained from BRRI dhan29 and the lowest values were found in Binadhan-14. At 100 DAT, the highest plant height, maximum number of tillers hill-1, dry matter of shoot hill^{-1} and dry matter of root hill^{-1} were obtained in nonflooded rice straw mulching treatment and the lowest ones were obtained from non-flooded no mulching treatment.

Variety had significant effect on all the crop characters under study except 1000-grain weight. The highest grain yield was obtained from BRRI dhan29 and the lowest value was recorded from Binadhan-14. Water management system was also significantly influenced all crop characters. The highest grain yield was recorded from non-flooded rice straw mulching treatment and the lowest grain yield was found from non-flooded no mulching treatment. The interaction of variety and water management system showed that BRRI dhan29 with non-flooded rice straw mulching resulted in the highest grain yield whereas the lowest yield was observed from the interaction of Binadhan-14 with non-flooded no mulching treatment. The result of the experiment suggests that BRRI dhan29 can be grown economically with non-flooded rice straw mulching treatment.

Salma *et al.* (2017) was conducted experiment to find out the effect of variety and planting density on weed dynamics and yield performance of transplant *Aman* rice. The experiment consisted of four varieties viz. Binadhan-7, BR25, BRRI dhan56 and BRRI dhan62 and four planting density viz. 25 cm × 15 cm, 25 cm × 10 cm, 20 cm × 15 cm and 20 cm × 10 cm. The experiment was laid out in a randomized complete block design with three replications. Variety exerted significant effect on weed density and dry weight at different days after transplanting (DAT). The lowest weed density and dry weight were observed in BR25 and the highest ones were observed in Binadhan-7. Weed population was not significantly affected by planting density while weed dry weight was significantly affected and closer spacing produce the lowest weed dry weight. Yield and yield contributing characters of transplant *Aman* rice were significantly influenced by variety and planting density. BR25 showed produce the highest plant height (157.9 cm), panicle length (24.94 cm), grains panicle (103.10), sterile spikelets panicle−1 (29.36), grain yield (4.30 t ha−1) and straw yield (8.99 t ha^{-1}) while BRRI dhan62 the highest number of total tillers $hill^{-1}$ (14.75), effective tillers $hill^{-1}$ (11.62), and non-effective tillers $hill^{-1}$ (3.10). The highest 1000-grain weight (25.21g) was found in the variety Binadhan-7and the highest harvest index (53.50%) was obtained from BRRI dhan56. In case of planting density, the highest value of plant height (124.27 cm), total tillers $hill^{-1}$ (13.53), effective tillers $hill^{-1}$ (11.20), non-effective tillers $hill^{-1}$ (2.32), panicle length (22.59 cm), grain yield (4.17 t ha−1) and straw yield (5.75 t ha^{-1}) were obtained from 25 cm × 15 cm spacing. On the other hand, the highest number of grains $panicle^{-1}$ (84.23) and harvest index (45.18 %) were obtained from 25 cm × 10 cm spacing, heaviest 1000-grain weight (23.83 g) from 20 cm × 15 cm spacing. Experimental results indicated that BR25 grown under 25 cm × 15 cm planting density appeared to be the best in order to get maximum grain yield as well as reducing weed infestation.

Mahamud *et al.* (2017) investigated the response of some short duration *aman* rice varieties to date of transplanting. The experiment consisted of three transplanting dates viz. 26 July, 5 August and 15 August and seven short duration T. *aman* rice varieties viz. BRRI dhan33, BRRI dhan39, BRRI dhan49, BRRI dhan56, BRRI dhan57, BRRI hybrid dhan4 and Binadhan-7. The experiment was laid out in split plot design with three replications. Transplanting dates were allocated into the main plot and varieties into the sub plot. Results indicate that Binadhan-7 produced the highest grain yield (4.90 t ha^{-1}), straw yield (5.58 t ha^{-1}), biological yield (10.44 t ha^{-1}), and harvest index (47.10%). Lowest grain yield (3.27 t ha^{-1}), straw yield (3.96 t ha^{-1}) and biological yield (7.20 t ha–1) were produced by BRRI dhan57. BRRI dhan49 had taken the longest field duration (120 DAT) while BRRI dhan57 had taken the shortest field duration (88 DAT). Plant height (119.12 cm), number of total tillers m^{-2} (276.40), number of effective tillers m^{-2} (260.02), number of grains $panicle^{-1}$ (109.19), grain yield (4.75 t ha^{-1}), straw yield (5.22 t ha^{-1}), biological yield (9.97 t ha^{-1}) and harvest index (47.64%) were highest on 26 July transplanting; decreased on 5 August transplanting and drastically declined on 15 August transplanting. The present study concludes that the highest yield for short duration T. *aman* rice cultivation could be possible by Binadhan-7 transplanting on 26 July.

Rahman *et al.* (2016) conducted an experiment was to evaluate the effect of levels of urea super granules and depth of placement on the growth and yield of transplant aman rice. The experiment consisted of two varieties namely, BINA Dhan 4 and BRRI Dhan32, three levels of urea super granules and three depth of placement of urea super granules. The results revealed that the effect of variety was significant in respect of yield and most of the plant characters. The higher grain yield (6.06 t ha^{-1}) was obtained from BRRI Dhan 32 mainly contributed by its higher numbers of effective tillers1hill and grains panicle. The lowest grain yield (3.85 t ha^{-1}) was observed in BINA Dhan 4. Effect of levels of urea super granules significantly influenced all the yield attributes and growth characters, except plant height, total grains panicle, 1000-grain weight, straw yield and harvest index. The highest grain yield (5.22 t ha^{-1}) was obtained when the crop fertilized with 80 kg N ha^{-1} as USG. Effect of depth of placement of urea super granules significantly influenced all the yield attributes and growth character of transplant aman rice except 1000-grain weight and harvest index. The highest grain yield (5.36 t ha^{-1}) was obtained when the crop grown with 6 cm depth of placement of urea super granules. Depth of 8 cm placement of USG gave the lowest grain yield (4.58 t ha^{-1}). The interaction effect of variety, levels of urea super granules and depth of placement of USG had significant effects on most of the growth characters and yield attributes. The grain yield was not affected by the interaction of variety, levels of urea super granules and depth of placement of USG. However, numerically the highest grain yield (7.00 t ha^{-1}) was found in BRRIDhan32 coupled with 80 kg N ha^{-1} as USG at 6 cm depth of placement and the lowest grain yield (3.33 t ha^{-1}) was found in BINA Dhan 4 fertilized with 120 kg N ha^{-1} as USG at 8 cm depth of placement.

Ray *et al.* (2015) was conducted a research work to find out the effect of variety, spacing of transplanting and nitrogen (N) rate on the growth, yield and protein content of transplant *aman* rice. The experiment consisted of three rice varieties: BR11, BRRI dhan49 and BRRI dhan56; two spacings of transplanting: 25 cm × 15 cm and 20 cm × 10 cm; and three N-levels: 0, 60 and 80 kg N ha^{-1}. Morpho-physiological characters, yield contributing characters and yield of transplant *aman* rice were significantly influenced by variety, spacing of transplanting and N rate. Experimental results indicated that BRRI dhan49 in combination with 25 cm × 15 cm spacing and 80 kg N ha^{-1} gives the highest leaf area index, total dry matter content, crop growth rate, number of effective tillers hill^{-1} and number of grains pancle^{-1}, and lowest number of sterile spikelets panicle^{-1} and sterility percentage of grain. These growth and yield parameters attributed the highest grain yield (5.51 t ha^{-1}) by this combination. In terms of grain protein content variety BR11 combination with spacing 20 cm × 10 cm with 80 kg N ha^{-1} appears the highest (9.05%). The value was statistically similar with the combination of BRRI dhan49, 25 cm × 15 cm spacing and 80 kg N ha^{-1} (8.91%). Therefore, it can be concluded that BRRI dhan49 combined with 25 cm × 15 cm spacing and fertilization with 80 kg N ha^{-1} appears as the promising practice for the maximization of grain yield and protein content of transplant *aman* rice.

Rana *et al.* (2014) conducted a field trail to find out the effect of planting methods on the yield and yield attributes of short duration Aman rice varieties, a field trial was at the farm of Bangladesh Rice Research Institute, Gazipur, during July to November 2012. The treatments comprised of three BRRI released high yielding varieties viz., BRRI dhan39, BRRI dhan49 and BRRI dhan57 and three planting methods viz., direct seeding of dry seed, direct seeding of sprouted seed and transplanting. It was a factorial experiment conducted in a Randomized Complete Block Design with three replications. Planting methods had a significant effect on the growth duration of rice. The rice crop established with direct seeding of the dry and sprouted seed matured 7 days earlier than transplanting. The variety BRRI dhan39 gave the highest yield (4.964 t ha^{-1}) when grown with direct seeding of sprouted seed compared to other varieties. The highest net return (23362.00 BDT ha^{-1}) and cost benefit ratio (1:1.49) were observed in direct seeding of the sprouted seed method. So, direct seeding of sprouted seed might be the best planting method be-cause about 19.94% production cost is reduced due to the omission of seedling raising and transplanting operations as well as the reduction in the length of the crop cultivation period.

Salam *et al.* (2012) observed that net returns obtained from hybrid rice was Tk. 59,056 ha^{-1} whereas it was Tk. 42,818 ha^{-1} for inbred HYVs rice. Average net return of inbred rice was 38% lower compared to that of hybrid rice. Benefit cost ratio of inbred and hybrid production was estimated to be 1.93 and 1.70, respectively. The average yield of inbred HYV was 6.03 t ha^{-1} and by product was 4.50 t ha^{-1}, while those of hybrid were 7.76 t ha^{-1} and 5.50 t ha^{-1}, respectively.

Debnath *et al.* (2012) showed the highest grain yield (7.67 t ha^{-1}) was produced by BRRI hybrid dhan2 variety.

Swain *et al.* (2010) also reported that the control cultivar IR64 with high translocation efficiency and 1000 grain weight and lowest spikelet sterility recorded a grain of 5.6 t ha^{-1} that was at par with hybrid PA6210.

Islam *et al*. (2009) conducted pot experiments to compare the growth and yield behaviour of hybrid and inbred rice varieties under controlled condition. In 2001, BRRI dhan3l had about 10-15% higher plant height, very similar tillers/plant, 15-25% higher leaf area at all days after transplanting (DAT) compared to Sonarbangla-1. Sonarbangla-1 had about 40% higher dry matter production at 25 DAT but had very similar dry matter production at 50 and 75 DAT, 4-11% higher rooting depth at all DATs, about 22% higher root dry weight at 25 DAT, but 5-10% lower root dry weight at 50 and 75 DAT compared to BRRI dhan31. The photosynthetic rate was higher (20 µ mol m-2 sec-1) in BRRI dhan3l at 35 DAT (maximum tillering stage) but at 65 DAT, Sonarbangla-l had higher photosynthetic rate of 19.5 µ mol m^{-2} sec^{-1}. BRRI dhan3l had higher panicles $plant^{-1}$ than $Sonarbangla^{-1}$, but $Sonarbangla^{-1}$ had higher number of grains $panicle^{-1}$, 1000-grain weight and grain yield than BRRI dhan31. In 2002, BRRI dhan31 had the highest plant height at 25 DAT, but at 75 DAT, BRRI hybrid dhanl had the highest plant height. $Sonarbangla^{-1}$ had the largest leaf area at 25 and 50 DAT followed by BRRI dhan31, but at 75 DAT, BRRI dhan31 had the largest leaf area. The highest shoot dry matter was observed in BRRI dhan31 followed by Sonarbangla-1 at all DATs. Sonarbangla-1 had the highest rooting depth and root dry weight at all DATs. BRRI dhan31 gave the highest number of panicles plant-1 followed by Sonarbangla-1, BRRI hybrid dhanl had the highest grains $panicle^{-1}$ followed by BRRI dhan31 and Sonarbangla-1 had the highest 1000-grain weight followed by BRRI dhan31. The highest amount of grains $plant^{-1}$ (34.6 g) was obtained from BRRI dhan31.

Xia *et al.* (2007) in experiment found that Shanyou63 variety gave the higher yield (12 t ha^{-1}) compared to Xieyou46 variety (10 t ha^{-1}). Bisne *et al.* (2006) conducted an experiment with eight promising varieties using four CMS lines and showed that plant height, tiller number hill^{-1} and grain yield differed significantly among the varieties and Pusa Basmati gave the highest plant height, tiller number hill^{-1} and grain yield in each line.

Nagarathna and Prakasha (2007) was studied to investigate the variation in nitrogen use efficiency (NUE) in two rice hybrids, PHB-71 and KRH-2, and inbred line IR-20 response to four different nitrogen (N) levels (0, 50%, 100% and 150% of the recommended N rate). Observations were recorded on the yield, nitrogen harvest index (NHI), nitrogen uptake and few yield parameters at harvest. PHB-71 showed significantly higher yields (7.80 t ha^{-1}). Increase in N levels to 150% recommended nitrogen increased the grain yield by 23.0%. NHI in PHB-71 and IR-20 were superior to KRH-2. PHB-71 was superior to other hybrid and inbred in terms of uptake of N by grain (89.52 kg N ha^{-1}), spikelet number (147) and grain number per panicle (111).

Amin *et al.* (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (*viz.* Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (*viz.* KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety. Wang *et al.* (2006) studied the effects of plant density and row spacing (equal row spacing and one seedling hill^{-1}, equal row spacing and 3 seedlings hill^{-1}, wide-narrow row spacing and one seedling hill^{-1}, and wide-narrow row spacing and 3 seedlings hill^{-1}) on the yield and yield components of hybrids and conventional cultivars of rice. Compared with conventional cultivars, the hybrids had larger panicles, heavier seeds, resulting in an average yield increase of 7.27%.

Rautaray (2006) was studied to the response of promising rice (*Oryza sativa*) hybrids (PA 6201, PHB 71, PAC 832 and Tapaswini) to late-sown double transplanting. The hybrid PA 6201, with tall seedlings, recorded the highest grain yield (6.36 t ha^{-1}) and net returns (Rs. 9973). Adoption of double transplanting using seedlings grown for 30 days in one nursery followed by 20 days in a second nursery was beneficial in terms of easy stand establishment, low weed pressure, high grain yield (6.31 tons ha^{-1}) and net returns (Rs. 9682) compared with the standard practice of single planting (6.03 t ha^{-1} and Rs. 7726). However, allowing seedlings for 40 or 50 days in the second nursery resulted in low grain yield (5.68 or 5.40 t ha^{-1}, respectively) and net returns (Rs. 7439 or 6330, respectively).

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

Ahmad (2005) compared two fine rice cultivars and reported that cultivar difference in number of productive tiller m^{-2}, number of panicles m^{-2}, number of grains panicle^{-1}. 1000-grain weight and paddy yield were significant. Higher number of productive tillers m^{-2}, number of panicles m^{-2}, number of grains panicle^{-1}, 1000-grain weight and paddy yield obtained in cv. Basmati-2000 was higher as compared to cv. Super Basmati. Maximum paddy yield was 3937 kg ha^{-1} and 3120 kg ha^{-1} for Basmati-2000 and Super Basmati, respectively.

Shamsuddula *et al*. (2004) was found that net Return from HYV-*boro* rice and Hybrid rice were calculated as Tk 9358.10 and Tk 21039.68 respectively. The BCR of Hybrid rice was also higher than the HYV-*boro* rice production and these were 1.33 and 1.20 for Hybrid rice production and HYV-*boro* rice production respectively. In efficiencies analysis, HYV-*boro* rice showed better performance than the Hybrid rice production. The Economic Efficiency (EE) of HYV-*boro* rice growers was 0.88 and 1Hybrid rice growers were 0.68. These indicated that there was more opportunity to increase EE of Hybrid rice production than HYV-*boro* rice production.

Hawlader *et al.* (2004) observed that BRRI hybriddhanl produced 12.8 t ha^{-1} and 10.7% increases in productivity were gained over BRRI dhan29 at on-station and the on-farm trials, respectively. At on-station, the highest productivity (50.3 kg ha^{-1} day^{-1}) was recorded for BRRI hybrid dhanl followed by BRRI dhan29 (44.6 kg ha^{-1} day^{-1}) and Sonar Bangla (44.5 kg ha^{-1} day^{-1}). At the on-farm, the increased productivity of BRRI hybrid dhanl over BRRI dhan29 ranged from 2.6 to 21.5% and the mean was 10.7%.

Guilani *et al.* (2003) studied on crop yield and yield components of rice cultivars (Anboori, Champa and LD183) in khusestan, Iran, during 1997. Grain number panicle^{-1} was not significantly different among cultivars. The highest grain number panicle^{-1} was obtained with Anboori. Grain fertility percentages were different among cultivars. Among cultivars LD183 had the highest grain weight.

Gomosta *et al.* (2001) observed that tillering duration of the crop varies because of different sowing dates or transplanting dates in the winter season. The different duration of tillering has a positive association with the duration of low temperature (below 20 degrees C), at which the vegetative phase of the crop is exposed. Longer crop duration allowed the tillers to become more mature, producing a higher number of panicles in the winter season. In the winter-season crop, the use of different-aged seedlings and time of seeding was more flexible for long-duration varieties than for short-duration varieties. A short-duration variety such as BRRIdhan28 could produce 6 t ha^{-1} of grain yield when 30-d-old seedlings from a November-seeded bed were used. Seedlings from an October-seeded bed produced only 1-2 t of grain yield. However, 30-90-d-old seedlings of BR29, a long-duration variety, produced 5-7 t of grain yield when seedlings from an October-seeded bed were used.

2.2 Effect of submerge condition on rice

Karim *et al.* (2019) conducted an experiment to evaluate morphological and phenological traits associated with submergence tolerance in rice. The experiment consisted of two factors-Rice cultivars (Binadhan-11, Binadhan-12, BRRI dhan51 and BRRI dhan52 as tolerant and BRRI dhan49 as susceptible) and submergence stress for 14 days at vegetative stage and control. Submergence stress was imposed by dipping of pots into a water tank with about 90 cm depth of water. After desubmergence, the plants were grown with proper care till maturity. Control plants are maintained in the pot house of field laboratory. Leaf greenness was measured after desubmergence to physiological maturity. The tolerant cultivars maintain higher leaf greenness for a long time than the susceptible cultivar after desubmergence. Reduction of grain filling rate and yield was significantly higher in susceptible cultivar than the tolerant cultivars. Among the five cultivars, BRRI dhan51 contributed the highest yield under stress treatment. Submergence tolerant rice cultivars (Binadhan-11, Binadhan-12, BRRI Dhan51 and BRRI Dhan52) had maintained higher tiller number, 1000-grain weight and the higher number of grains per panicle during submergence, as compared to susceptible rice cultivar BRRI Dhan49.

Hassan *et al.* (2019) conducted a pot experiment at the net house of Department of Crop Botany, Bangladesh Agricultural University, during Aman season from July to December, 2017 to evaluate the changes in root porosity and water soluble carbohydrates (WSCs) associated with submergence tolerance in rice. The experiment consisted of two factors-(i) Rice cultivars (Binadhan-11, Binadhan-12, BRRI dhan51 and BRRI dhan52 as tolerant and BRRI dhan49 as susceptible) and(ii) Submergence stress: Submergence for 14 days at vegetative stage and control. Submergence stress was imposed by dipping of pots into a water tank with about 90 cm depth of water while the control plants are maintained in the pot house of the field laboratory. The plants were sampled at seven days interval during submergence to determine the changes in root porosity and to examine the contribution of shoot reserves for their survival. The root porosity was measured by pycnometer method and water soluble carbohydrate was measured by the anthrone method. Tolerant cultivars showed greater root porosity development in both control and stress condition but the susceptible cultivar showed significantly lower root development in stress condition. Higher root porosity might help tolerant cultivars to survive in submergence stress more efficiently. Tolerant rice cultivars had high initial soluble carbohydrate than the susceptible one. Under submerged condition, the tolerant cultivars showed slow depletion of water soluble carbohydrate compared to susceptible cultivar. Higher carbohydrate contents in tolerant cultivars might act as buffer stock during submergence for their better survival and growth.

Nio *et al.* (2019) revealed that the partial-submergence-tolerant crop plants, including rice are required for fulfilling food needs when a flooding disaster occurs in Indonesia. The information of effective selection method for obtaining submergence tolerant rice is required for increasing the North Sulawesi capacity as a pillar of national food security. This study evaluated the partial-submergence-tolerance in 10 rice cultivars that are cultivated in North Sulawesi Province based on the morphological characters (plant height, shoot dry mass, shoot length, root dry mass, root length, root volume, shoot:root ratio and leaf number) at the vegetative phase. Materials and Methods: This experiment was conducted in the greenhouse using 10 rice cultivars (cv. Cigeulis, Seruni, Mekongga, Ciherang, TB, Ombong, Inpari 13, Burungan, Temo and Superwin). These cultivars were grown at the vegetative phase in partial submergence condition (the entire root system and 30 cm of above-ground shoot was under water) for 20 days, with 8 replicates, in a randomized block design. Results: The longer duration of partial-submergence treatment resulted in the decrease of leaf number, the increase of plant height and the increase of shoot elongation. There were three categories of partial-submergence tolerance, i.e., tolerant for Cigeulis and TB, semi tolerant for Seruni, Mekongga, Inpari 13, Burungan, Temo and Superwin and non-tolerant for Ciherang and Ombong. Conclusion: Rice cv. TB as tolerant cultivar showed better growth response under partial submergence rather than other rice cultivars at the vegetative phase.

Yadav *et. al.* (2018) conducted an experiment with rice genotypes Swarna Sub1 and Nagina 22 with its mapping population in pot during kharif season 2017 at the pond of department of crop physiology in Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P). Submergence treatment was given for 14 days at vegetative stage. The screening of rice genotypes was done on the basis of Shoot elongation, Survival percentage, estimation of catalase, peroxidase and chlorophyll content. The rice genotypes Swarna *Sub1* showed high percent increase in catalase and peroxidase whereas in case of chlorophyll content Swarna *Sub1* shower higher percent reduction in Nagina 22. Therefore, on the basis of their parents some mapping population showed less and higher percent reduction and also showed best tolerance in compare to other population.

Chu *et al.* (2018) observed flooding is a major threat to rice (*Oryza sativa* L.) yields. We wondered if basal Si and foliar spraying fertilizer had an influence on rice submerged at tillering stage. The results showed that basal Si application promoted rice growth and development at the tillering stage, improving rice seedling tolerance to submergence stress. After the occurrence of flooding, timely foliar spraying of N or Si had significant remedial effects, and spraying N along with Si had a better effect. The combination of basal Si and post-flooding N and Si spraying was the most promising method of nutrient application and as resistance to damage during submergence was enhanced, plants rapidly resumed growth and development. By maintaining a great number of green leaves and tillers as well as higher aboveground and belowground dry mass, sugar contents and antioxidant enzyme activities, these plants yielded significantly more grain. We conclude that reasonable use of Si leads to resistance and alleviation of the damaging effects of submergence and contributes to reducing yield losses in rice.

Kurokawa *et al.* (2018) observed that floods impede gas (O_2 and CO_2) exchange between plants and the environment. A mecha-nism to enhance plant gas exchange under water comprises gas films on hydrophobic leaves, but the genetic regulation of this mechanism is unknown.We used a rice mutant (dripping wet leaf 7, drp7) which does not retain gas films on leaves, and its wild-type (Kinmaze), in gene discovery for this trait. Gene complementation wastested in transgenic lines. Functional properties of leaves as related to gas film retention and underwater photosynthesis were evaluated. Leaf Gas Film 1(LGF1) was identified as the gene determining leaf gas films. LGF1regu-lates C30 primary alcohol synthesis, which is necessary for abundant epicuticular wax platelets, leaf hydrophobicity and gas films on submerged leaves. This trait enhanced under-water photosynthesis 8.2-fold and contributes to submergence tolerance. Gene function was verified by a complementation test of LGF1 expressed in the drp7 mutant background, which restored C30 primary alcohol synthesis, wax platelet abundance, leaf hydrophobicity, gas film retention, and underwater photosynthesis. The discovery of LGF1 provides an opportunity to better understand variation amongst rice genotypes for gas film retention ability and to target various alleles in breeding for improved submergence tolerance for yield stability in flood-prone areas.

Gribaldi *et al.* (2017) was conducted a research from July to October 2015, using Randomized Block Design with two treatment factors and three replications for each treatment. The first factor was rice varieties (V): V_1 = IR 64; V_2 = Inpara 5. The second factor was fertilizer (N): N0: without submergence, all N fertilizer was given during planting; N_1: all N fertilizer dose was given during planting; and N_2: 1/2 dose of N fertilizer was given during planting; the rest was given at 42 days after planting. The submergence was during 7–14 days after planting; N_3 = the entire dose of N fertilizer that was given during planting, N_4 = 1/2 the dose of N fertilizer that was given during planting, and the rest was given at 42 days after planting. The submergence was during 7–14 and 28–35 days after planting. The results showed that the management of nitrogen fertilizer application had effect on rice growth and production which experienced dirty water submergence stress; the application of 1/2 dose of N fertilizer given during planting had the best effect on rice growth and production; the longer the submergence period for rice variety, the higher the effect on rice growth and production.

Tejakhod *et al.* (2015) observed that flooding is a major constraint to rice production in many areas. The unpredictable nature of flooding events, including varying depth, duration and timing make it difficult to manage. Changes in the global climate are predicted to alter weather patterns resulting in more frequent heavy storms and sea level rise, which will exacerbate the problem. Therefore, improving our understanding of the impact this stress has on rice production and the development of methods for managing this stress are needed. This study set out to examine submergence effects at different ripening stages on subsequent rice seed quality. We grew japonica rice cv. Gleva and two indica cvs. IR64 and submergence-tolerant IR64Sub1, under controlled environment conditions. Plants were then subjected to full-submergence for 4d at 10, 30 and 40 days after anthesis (DAA), or not (no submergence control). Seeds were harvested 47 DAA and examined for agronomic traits. For all conditions and cultivars, submergence led to a decrease in seed weight, size and a substantial loss in yield. There was a 16-44% yield reduction, particularly when simulated flooding occurred at the initial stage of seed development (10 DAA). Pre-harvest sprouting (PHS) was detected from seeds submerged at 30 DAA or later in cv. Gleva. When submerged at 40 DAA, more than 65% of seeds of Gleva sprouted, compared to less than 1% from either IR64 or IR64Sub1. The impact of submergence was greatest on yield, seed weight and size, whereas the extent of any detrimental effect on subsequent seed storage longevity of non-sprouted seed storability was small. In conclusion, our data showed that submergence negatively affected rice seed production, but was dependent on genotype.

Zhang *et al.* (2015) conducted experiment to explore the effect of waterlogging at the rice tillering stage on rice growth and yield. The early-ripening late japonica variety Yangjing 4227 was selected for this study. The treatments included different submergence depths (submergence depth/plant height: 1/2 (waist submergence), 2/3 (neck submergence), and 1/1 (complete submergence)) and durations (1, 3, and 5 d). The control group was treated with the conventional alternation of drying and wetting. The effects of waterlogging at the tillering stage on root characteristics, dry matter production, nitrogen and phosphorus accumulation, yield, yield components, and 1-aminocyclopropane-1-carboxylic acid synthase (ACS) gene expression were explored. Compared with the control group, the 1/1 group showed significant increases in yield, seed-setting rate, photosynthetically efficient leaf area, and OS-ACS3 gene expression after 1 d of submergence. The grain number per panicle, dry weight of the aboveground and belowground parts, and number of adventitious roots also increased. Correlation analysis revealed a significant positive correlation between the panicle number and nitrogen content; however, no significant correlation was found for phosphorus content. If a decrease in rice yield of less than 10% is acceptable, half, 2/3, and complete submergence of the plants can be performed at the tillering stage for 1-3 d; this treatment will increase the space available for rice field water management/control and will improve rainfall resource utilization.

Ella *et al.* (2014) stated that flooding negatively affects rice production in over 20 million hectares of rainfed lowlands and flood-prone areas in Asia. While there are numerous reports on the response of rice shoots to flooding, scant information is available on the effect of flooding on rice roots. This study assessed the effect of complete submergence at the vegetative stage on growth and physiological responses of rice roots. Seedlings of four rice genotypes, tolerant varieties FR13A and Swarna-Sub1 and sensitive varieties Swarna and IR42, were completely submerged in a concrete tank for 12 d. Afterwards, water was drained and seedlings were allowed to recover. Survival was recorded 14 d after de-submergence. Seedlings were considered surviving when they are able to generate new leaves. Root measurements conducted during submergence were: elongation, root viability, peroxidase activity, and membrane damage assessed as concentrations of malondialdehyde and electrolyte leakage. Seedlings of tolerant genotypes had higher survival, and the roots were more viable with greater capacity to elongate. Moreover, they had higher peroxidase activity and lesser increases in both electrolyte leakage and malondialdehyde production during submergence. There were strong positive correlations between survival and some parameters measured during submergence such as root elongation ($r = 0.74^{**}$) and peroxidase activity ($r = 0.79^{**}$, at day 7 of submergence). Strong negative correlations were observed between survival and membrane damage during submergence ($r = -0.83^{**}$ and -0.79^{**} for malondialdehyde levels and electrolyte leakage, respectively). Data showed that tolerance to complete submergence at the vegetative stage may be associated with some root traits such as high viability and high activity, translated into greater elongation growth and lesser membrane damage during submergence. Such traits might play important roles in maintaining root function in rice seedlings exposed to complete submergence during the vegetative stage.

Mulbah (2010) affirmed that controlled flooding is beneficial to rice production since it enhanced the growth and yield of the plant. Shoot dry mass, tiller number increased significantly ($P < 0.001$) with early and continuous flooding, compared to the non-flooding and late flooding regimes. Grain yield under early flooding was slightly higher than that under continuous flooding probably because of better rhizhosphere aeration that led to more panicle the highest grain yield compared to those in the non-flooding and late flooding regimes. The harvest indices of the plants grown under continuous and early flooding were significantly higher than those grown under the no flooding and late flooding regimes.

Septiningsih *et al.* (2009) found that all mega varieties with *Sub1* introgression had a significantly higher survival rate than the original parents. An intolerant *Sub1C* allele combined with the tolerant *Sub1A-1* allele did not significantly reduce the level of tolerance, and the *Sub1C-1* expression appeared to be independent of the *Sub1A* allele; however, even when *Sub1C-1* expression is completely turned off in the presence of *Sub1A-2*, plants remained intolerant. Survival rates and *Sub1A* expression were significantly lower in heterozygotes compared with the homozygous tolerant parent. *Sub1* provided a substantial enhancement in the level of tolerance of all the sensitive mega varieties. *Sub1A* is confirmed as the primary contributor to tolerance, while *Sub1C* alleles do not seem important. Lack of dominance of *Sub1* suggests that the *Sub1A-1* allele should be carried by both parents for developing tolerant rice hybrids.

Das *et al.* (2009) hypothesize that warmer water increases seedling mortality, possibly through increased carbohydrate depletion during submergence and that turbid water will enhance plant mortality by effects similar to those caused by natural shading the common consequence of cloudiness during the wet season. This could be caused by reduction inlight penetration the subsequent chlorophyll degradation and reduced under-water photosynthesis. Kawano (2009) showed that suppression of underwater elongation brought about by the mutated from of *Sub-IA* in *O. sativa* is beneficial for the endurance of complete submergence. Consequently, non-shoot-elongation-cultivars during submergence show tolerance to short-term submergence, so-called flash flooding, for a few days or weeks.

A strategy with shoot elongation shows two different mechanisms: rapid shoot elongation in shallow floods in a short-term submergence and intermodal or stem elongation in deep water in long-term submergence. Based on our analysis, most *O. glaberrima* varieties adapt well when floods are deeper and when they entail long-term submergence. These mechanisms for plant survival under submergence are affected by the conservation of energy and carbohydrate accumulation (Perata and Voesenek, 2007).

Anaerobic response of the plant tissues is the adaptive metabolic mechanism of increasing rate of alcoholic fermentation (AF) which involves alcohol dehydrogenase (ADH) and pyruvate decarboxylase (PDC) as the two key enzymes. Submergence can shift aerobic respiration to the less efficient anaerobic fermentation pathway as the main source of energy production. Acetaldehyde is one of the intermediate of alcoholic fermentation which can be oxidized by aldehyde dehydrogenase (ALDH) and found to be low in plants having higher activities ALDH with concomitant increase in submergence tolerance (Sarkar *et al.*, 2006).

Belder (2005) found that Wetlands prone to late flooding on the other hand may not provide the best yield although they may still be a better option than upland rice production. The low efficiency of N use for grain production under late flooding and continuous aerobic conditions in comparison to the early or continuous flooding is consistent with results from other studies.

Pre-submergence stored carbohydrate are reported to be associated with enhanced survival under flooded conditions possibly by supplying energy for maintenance through anaerobic respiration which was found by Das *et al.*, (2005).

In case of adventitious root formation consists of three development steps, depth of the epidermal cells which cover adventitious root initials, penetration of the root from the epidermis and initiation of elongation growth. Ethephon treatment triggered all the developmental processes of adventitious root development in nodes of deepwater rice even under aerobic conditions (Steffens and Sauter, 2005).

Ella *et al.*, (2003) revealed that the effect of N treatment during submergence increase chlorophylls activity. Chlorophylls activity increase in the presence of ethylene, suggesting presence of higher leaf N in nitrogen treated seedling which enhances leaf senescence and greater chlorosis during submergence.

Singh *et al.*, (2001) found that submergence tolerance is related to high carbohydrate supply submergence. Carbohydrate metabolism during submergence seems to be an important factor in flash flood tolerance and this strategy is characterized by slow expansion growth that is presumed to conserve energy.

O. glaberrima, a monocarpic annual derived from *O. barthii* (Sakagami *et al.*, 1999), is grown in traditional rice production in the wetlands of West Africa. It is highly adapted to deepwater inundation in countries such as Gambia, Guinea, Mali, Niger, Senegal and Sierra Leone in West Africa (Inouye *et al.*, 1989). The first gene pool of *O. glaberrima* was inferred as an inland delta of the Niger River because of the high gene diversity among species. In Guinea, for example, coastal or lowland areas are heavily affected by submergence during the rainy season. Rice plants are often partially or completely submergence because of such advantageous traits as those explained above. Cultivars of *O. glaberrima*ar roughly divisible into two ecotypes: upland and lowland. However, it might be that *O. glaberrima* is a valuable rice species for flooding conditions in all cases. Tolerance of other abiotic and biotic stress such as drought, rice yellow mottle virus (Thiemele *et al.*, 2010), African rice gall midge (Nwilene *et al.*, 2009) and iron toxicity (Majerus *et al.*, 2007) has been foung in some cultivars of *O. glaberrima*. However, it is vulnerable to NaCl salinity (Awala *et al.*, 2010) and lodging (Dingkuhn, 1998). It is reasonable to presume that the indigenous cultivated species of African rice can provide useful genes improvement of tolerance to major stress in Africa.

CHAPTER III
MATERIALS AND METHODS

The pot experiment was conducted at the Agricultural Botany field of central research farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from June, 2018 to December, 2018 to find out the effect of submergence on the reproductive stage and yield of different *Aman* rice varieties. This chapter deals with the materials and methods of the experiment with a brief description on experimental site, climate, soil, pot soil preparation, planting materials, experimental design, fertilizer application, transplanting, irrigation and drainage, intercultural operations, data collection, data recording and their analysis. The details of investigation for achieving stated objectives are described below.

3.1 Site description

The experiment was conducted at the Sher-e-Bangla Agricultural University research farm, Dhaka, during the period from June, 2018 to December, 2018. The experimental site was located at 23°77′ N latitude and 88°01′ E longitudes with an altitude of 9 m.

3.2. Agro-Ecological Zone

The experimental site belongs to the agro-ecological zone of "Modhupur Tract", AEZ-28. 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. For better understanding, the experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.3. Soil

The experiment was carried out in a typical rice growing soil belongs to the Modhupur Tract. Top soil was silty clay in texture, red brown terrace soil type, olive–gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and had organic carbon 0.45%. The land was well drained with good irrigation facilities. The experimental site was a medium high land. It was above flood level and sufficient sunshine was available during the experimental period. The morphological characters of soil of the experimental plots are as follows - Soil series: Tejgaon, General soil: Non-calcareous dark grey. The physicochemical properties of the soil are presented in Appendix II. This soil was used for seedling raising as well as for growing rice plants in pots.

3.4. Climate and weather

The geographical location of the experimental site was under the sub-tropical climate that is characterized by three distinct seasons. The monsoon or rainy season extending from May to October which is associated with high temperature, high humidity and heavy rainfall, the winter or dry season from November to February which is associated with moderately low temperature and the pre-monsoon period or hot season from March to April which is associated with some rainfall and occasional gusty winds. Information regarding monthly maximum and minimum temperature, rainfall, relative humidity and sunshine as recorded by Bangladesh Meteorological Department, Agargaon, during the period of study of the experimental site have been presented in Appendix III.

3.5. Planting materials

In this experiment five rice varieties (FR13A, BR5, BRRI dhan52, BRRI dhan46 and BINA dhan 12) were used. BR5, BRRI dhan52, BRRI dhan46 were collected from Bangladesh Rice Research Institute (BRRI). FR13A was collected from SAU and BINA dhan 12 was collected from BINA.

3.6 Details of the Experiment

3.6.1 Experimental treatments

Treatments included in the experiment were as follows:

Factor A – Submergence period

S0 – Control (No submergence)

S1 – Submergence for 4 days

S2 - Submergence for 7 days

S3 - Submergence for 10 days

Factor B – Varieties

V_1= FR13A
V_2= BR5
V_3= BRRIdhan 52
V_4= BRRIdhan 46
V_5= BINAdhan 12

3.6.2 Experimental design

The experiment was laid out in 2 (Two) factors Split plot Design with five replications. The layout of the experiment was prepared for distributing the variety. The Experimental pot was divided into 4 blocks. Each block was again divided into 20 pots. The total numbers of unit pots of the experiment were 80. The treatments were randomly distributed to each block following the experimental design. In this case plant was grown following the Split Plot design to have a common environmental effect to the plants in order to reduce the experimental error. As this was a pot experiment the required pots were transferred to submergence pond with necessary environment and after the completion of required submergence duration. The pots were replaced according to the design. As the treatments are different for a particular period. Otherwise, the plants were placed in the same environment according to design to reduce the error. To maintain the proper sample size four replications were maintained. Considering the high cost of maintaining more pots. Proper care was taken for normal growth of each plant to have better data.

3.7 Growing of crops

Following cultivation procedures were practiced to grow the crop.

3.7.1 Raising Seedlings

Following steps were taken to raise the seedling.

3.7.1.1 Seed collection

The seeds of the test crops were collected from BRRI and FR13A was collected from SAU and BINA dhan 12 was collected from BINA.

3.7.1.2 Seed Sprouting

Healthy seeds were selected by specific gravity method and then immersed in water bucket for 24 hours and then it was kept tightly in gunny bags. The seeds started sprouting after 3 days and were sown in nursery bed after 6 days.

3.7.1.3 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m width. Adequate amount of seeds were sown in the seedbed on 9 July 2018 in order to have seedlings of 40 days old. No fertilizer was used in the seedbed.

3.7.2 Preparation of the pot

Thirteen inches diameter pots were selected and were filled with field soils in 20 July 2018 and was exposed to the sun for a week. Weeds and stubbles were 24

Element	Source	Dose (kg ha^{-1})	Dose (g pot^{-1})
N (Nitrogen)	Urea (46% N)	200	4
P (phosphorus)	TSP (20% P2O5)	30	1.5
K (potassium)	MoP (50% K2O)	100	2
S (Sulphur)	Gypsum (18% S)	75	0.5
Zn (Zinc)	Zinc sulphate (36% Zn)	15	0.5

3.7.3 Uprooting of seedlings

Forty days old seedlings were uprooted carefully and were kept in soft mud in shade. The seed beds were made wet by application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots.

3.6.4 Transplanting of seedlings in the pot

The seedlings were uprooted and then transplanted as per experimental treatment on the well puddled pots on 10 August 2018 without causing much mechanical injury to the roots. One seedling $hill^{-1}$ (pot) was used during transplanting which grew well due to proper care.

3.7.5 Intercultural operations

The details of different intercultural operations performed during the course of experimentation are given below:

3.7.5.1 Maintaining the submergence level

There is a submergence pond in SAU for this type of experiment. The plants were completely submerged keeping minimum 15 cm below the surface of water flooded. The water level was higher than the plant height. This was done to ensure conditions which occur during actual flooding in nature. After 4, 7 and 10 days of submergence the pots were removed from the water. The plants were submerged at panicle initiation stage. Controlled (S0) pot were irrigated as normal irrigation requirement as prescribed for the high yielding varieties of rice in Aman season. The pots of S_2 (4 days submergence), S_3 (7 days submergence) and S_3 (10 days submergence) were irrigated after submergence as normal irrigation schedule. The water in submergence pond containing different varieties of rice was made turbid like natural condition time to time by stirring the mud according to requirement inside the pond. During submergence period continuous observations were made to maintain the water level minimum 15 to 20 cm above the plant.

3.7.5.2 Irrigation and drainage

The experimental pots were irrigated properly and adequate water was ensured throughout the whole crop growth period. Flood irrigations were given as and when necessary to maintain 3–5 cm water in the rice pots.

3.7.5.3 Weeding

The experimental pots were infested with some common weeds, which were removed twice by uprooting. First weeding was done from each pot at 20 DAT and second weeding was done from each pot at 40 DAT. Mainly hand weeding was done to remove weed from each pot.

3.7.5.4 Plant protection measures

Plants were infested with rice stem borer, leaf roller and rice bug to some extent, which was successfully controlled by application of insecticides such as Diazinon, and Ripcord @ 10 ml/10 liter of water for 5 decimal lands. Crop was protected from birds and rats during the grain-filling period. For controlling the birds scarecrow was given and watching was done properly, especially during morning and afternoon. The plants were kept inside net to protect from birds.

3.6 General observation of the experimental pot

The pot was observed time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest should be minimized. The pot looked nice with normal green color plants. Incidence of stem borer, green leaf hopper, leaf roller and rice bug was observed during tillering stage. Bacterial sheath blight disease was observed scarcely in some pots. The flowering was not uniform. Empty or unfilled grain was seen in some varieties due to sudden fluctuation of temperature during the experiment. The effects of submergence was recorded.

3.7 Harvesting and post harvest operation

The rice plant was harvested depending upon the maturity of plant. Harvesting was done manually from each pot. Harvesting was started at 145 DAT. Maturity of crop was determined when 90% of the grains become golden yellow in color. The harvested crop of each pot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of rice seed. Fresh weight of grain and straw were recorded pot wise. The grains were cleaned and sun dried. The weight was adjusted to a moisture content of 14%. Straw was also sun dried properly. Finally grain and straw yield pot^{-1} were recorded and converted to t ha^{-1}. Pre-selected hills per pot from which different data were collected; harvested separately, bundled properly, tagged separately from outside and then brought to the threshing floor for recording grain and straw yield.

3.8 Recording of plant data

During the study period, data were recorded on morphophysiological, reproductive characters and yield components for all the entries on five randomly selected hills from each replication as follows:

3.8.1 Plant height at 20, 40, 60, 80 DAT and at harvest

3.8.2 Leaf number at 20, 40, 60, 80 DAT and at harvest

3.8.3 Number tillers per hill at 20, 40, 60, 80 DAT and at harvest

3.8.4 SPAD value

3.8.5 Leaf dry weight at harvest (g)

3.8.6 Stem dry weight at harvest (g)

3.8.7 Root dry weight at harvest (g)

3.8.8 No. of leaves before submergence

3.8.9 No. of leaves after submergence

3.8.10 No. of rotten leaf

3.8.11 1% Panicle emergence

3.8.12 50% of panicle emergence

3.8.13 100% of panicle emergence

3.8.14 No. of effective tillers hill^{-1}

3.8.15 No. of ineffective tillers hill^{-1}

3.8.16 No. of filled grains panicle^{-1}

3.8.17 No. of unfilled grains panicle^{-1}

3.8.18 Days to maturity

3.8.19 1000 grain weight (g)

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

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

3.8.22 Biological yield (t ha^{-1})

3.8.23 Harvest index (%)

3.9 Procedure of data collection

3.9.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 20, 40, 60, 80, 100, 120 DAT (days after transplanting) and at harvest. Data were recorded as the average of plants of different hills selected from each pot. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading and to the tip of panicle after heading.

3.9.2 Number of tillers plant^{-1}

The number of tillers plant^{-1} was recorded at 20, 40, 60, 80, 100, 120 DAT (days after transplanting) and at harvest by counting total tillers as the average of 5 plants from 5 pots.

3.9.3 Number of fresh and rotten leaves plant^{-1}

The number of fresh and rotten leaves plant^{-1} was recorded just before and after submergence by counting total fresh and rotten leaves as the average of 5 submerged plants from 5 pots.

3.9.4 Days to 1%, 50% and 100% panicle emergence

Days to 1%, 50% and 100% panicle initiation was considered when 1%, 50% and 100% of the plants showed panicle initiation stage. The number of days to 1%, 50% and 100% panicle initiation was recorded from the date of transplanting.

3.9.7 Days to maturity

Days to maturity was considered when 90% of the grains become golden yellow in color. The number of days to maturity was recorded from the date of transplanting.

3.9.8 Dry weight of leaf, leaf sheath, stem and root plant^{-1}

Total dry weight of leaf, leaf sheath, stem and root plant^{-1} were recorded at the time of harvest by drying plant sample from 72 hours in 70°C temperature inside drying oven.

3.9.9 Panicle length

The panicle length was recorded in centimeter (cm) at the time of harvest. Data were recorded as the average of selected panicles from each pot.

3.9.10 Effective tillers hill^{-1}

Total no. of panicle bearing tillers in a plant was counted at the time of harvesting.

3.9.11 Ineffective tillers hill^{-1}

The tiller having no panicle was regarded as ineffective tiller.

3.9.12 Fertile grains panicle^{-1}

Panicle was considered to be fertile if any kernel was present there in. The number of total filled grains present on each panicle was recorded.

3.9.13 Infertile grains panicle^{-1}

Panicle was considered to be sterile if no kernel was present there in. The number of total unfilled grains present on each panicle was recorded.

3.9.14 Weight of 1000-grains

One thousand cleaned dried seeds were counted randomly from the total cleaned harvested grains of each individual plant and then weighed with a digital electronic balance at the stage the grain retained 14% moisture and the mean weight were expressed in gram. The grains of each plant were weighed and was converted into weight of 100 grains weight counting the total number of grains in a plant.

3.10 Statistical Analysis

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

CHAPTER IV
RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of panicle initiation stage submergence on the yield of high yielding rice varieties. The results obtained from the study have been presented, discussed and compared in this chapter through different tables, figures and appendices. The analyses of variance of data in respect of all the parameters have been shown in Appendix IV-X. The results have been presented and discussed with the help of tables and graphs and possible interpretations have been given under the following headings.

4.1 Plant height

The plant height of rice was significantly varied among the submergence treatments at 20, 40, 60, 80 days after transplanting (DAT) and harvest time (Appendix IV). At 20, 40, 60, 80 DAT, the highest (25.91, 40.22, 78.52, 102.40 and 102.57 cm, respectively) plant height was obtained from S_0 (control) treatment and the lowest plant height (22.80, 33.81, 65.89, 83.42 and 83.65 cm, respectively) was obtained from S_3 (submergence for 10 days) treatment (Figure 1). The study referred that the control treatment i.e.; no submergence produced the highest plant height of rice.

Different varieties significantly influenced the plant height of rice at 20, 40, 60, 80 days after transplanting (DAT) and harvest time (Appendix IV). At 20, 40, 60, 80 DAT and harvest time, the highest plant height (28.93, 40.88, 80.13, 105.15 and 106.15 cm, respectively) were recorded from V_3 (BRRIdhan 52). Whereas, the lowest plant height (20.21, 33.37, 65.05, 79.11 and 78.77 cm, respectively) were recorded from V_5 (BINAdhan 12) (Figure 2). Present study revealed that BRRIdhan52 variety produced the highest plant height. The variety are genetically different for which they are supposed to show different performance in different submergence duration. This difference may be seen any stage of life cycle of plant.

Interaction effect of submergence and varieties significantly influenced plant height at 20, 40, 60, 80 DAT and harvest time (Appendix IV). At 20, 40, 60, 80 DAT and harvest time, the highest plant height (30.75, 44.77, 88.55, 113.39 and 113.19, respectively) were recorded from the S_0V_3 (Control treatment with varity BRRIdhan 52) (Table 1). On the other hand, the lowest plant height (18.95, 28.52, 55.62, 65.34 and 65.05 cm, respectively) were recorded from S_3V_5 (Submergence for 10 days variety BINAdhan12).

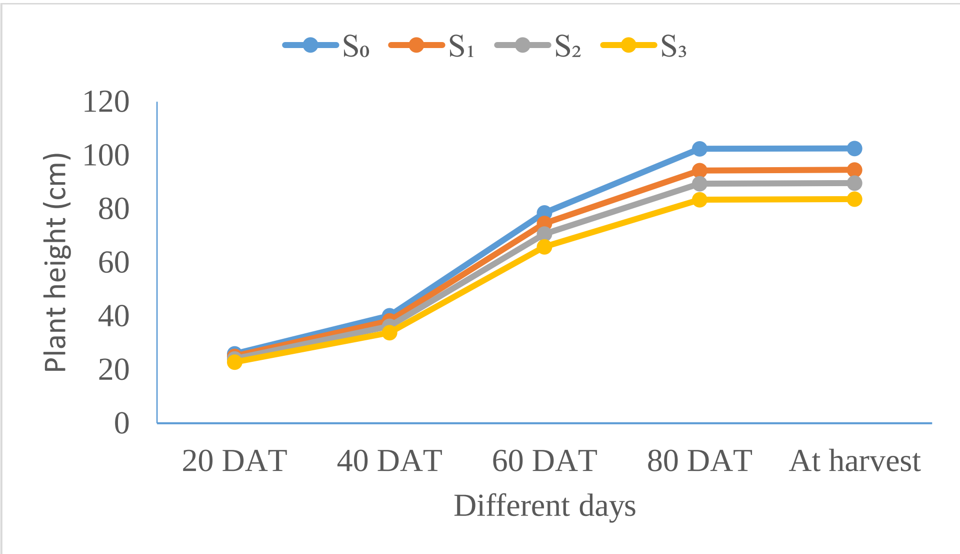


Figure 1. Effect of submergence on plant height of rice at different days after transplanting

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

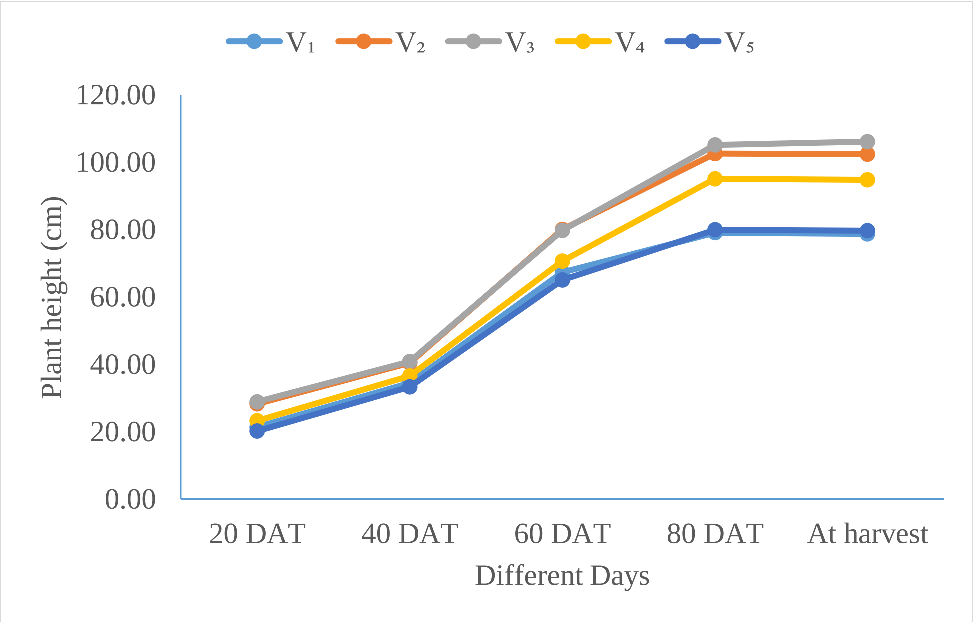


Figure 2. Effect of varieties on plant height of rice at different days after transplanting

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

Table 1. Interaction effect of submergence and varieties on plant height of rice at different days after transplanting

Interaction	Plant height (cm)				
	20 DAT	40 DAT	60 DAT	80 DAT	At harvest
S_0V_1	22.10	35.81f-h	69.86ef	82.06gh	81.70ij
S_0V_2	30.75	44.77a	88.55a	113.39a	113.19a
S_0V_3	30.22	42.70ab	82.65b	110.44ab	112.74a
S_0V_4	25.73	37.88d-f	73.79d	100.60c-e	99.90c-f
S_0V_5	20.74	39.95b-d	77.73c	105.52a-d	105.32b-d
S_1V_1	21.66	35.10f-h	68.46e-g	80.42gh	80.07j
S_1V_2	29.21	42.53ab	84.13b	107.72a-c	107.53ab
S_1V_3	29.46	41.63a-c	80.58bc	107.67a-c	109.92ab
S_1V_4	24.06	38.22d-f	73.76d	98.79de	98.60ef
S_1V_5	20.79	33.69g-i	65.72gh	77.20hi	76.87jk
S_2V_1	21.22	34.20g-i	66.70f-h	78.35hi	78.01jk
S_2V_2	27.75	39.13d-f	77.40c	99.10de	98.93ef
S_2V_3	28.73	40.18b-d	77.76c	103.91b-d	106.07bc
S_2V_4	22.23	36.31e-g	70.07de	93.85ef	93.67fg
S_2V_5	20.42	30.29ij	59.62i	71.41ij	71.10kl
S_3V_1	20.68	33.00hi	64.37hi	75.61hi	75.28jk
S_3V_2	25.53	35.61f-h	70.43de	90.18f	90.02gh
S_3V_3	27.72	38.17d-f	73.87d	98.71de	100.77c-e
S_3V_4	21.12	33.77g-i	65.17gh	87.28fg	87.11hi
S_3V_5	18.95	28.52j	55.62j	65.34j	65.05l
LS	NS	*	**	**	**
LSD (0.05)	2.86	3.37	3.69	8.23	7.06
CV (%)	8.76	5.67	4.98	7.23	5.98

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

4.2 Leaf number

The number of leaves of rice was significantly varied among the submergence treatments at 20, 40, 60, 80 days after transplanting (DAT) and harvest time (Appendix V). At 20, 40, 60, 80 DAT, the highest (5.45, 19.00, 31.05, 41.75 and 40.35, respectively) number of leaves were obtained from control (S_0) treatment and the lowest number of leaves (4.75, 15.00, 24.55, 32.80 and 30.60, respectively) were obtained from S_3 (submergence for 10 days) treatment (Figure 3). The study referred that the control treatment i.e.; no submergence produced the highest number of leaves of rice.

Different varieties significantly affected the number of leaves of rice at 20, 40, 60, 80 days after transplanting (DAT) and harvest time (Appendix V). At 20, 40, 60, 80 DAT and harvest time, the highest number of leaves (6.88, 19.75, 33.88, 47.00 and 45.94, respectively) were recorded from V_3 (BRRIdhan 52) whereas, the lowest number of leaf (3.94, 13.94, 22.81, 29.06 and 26.81) were recorded from V_2 (BR5) (Figure 4). Present study revealed that BRRIdhan52 variety produced the highest number of leaves. The variety are genetically different for which they are supposed to show different performance in different submergence duration.

Interaction effect of submergence and varieties significantly influenced number of leaves at 60, 80 DAT and harvest time but not significant at 20, 40 DAT (Appendix V). At 20, 40, 60, 80 DAT and harvest time, the highest number of leaves (7.25, 24.75, 37.50, 52.00 and 52.25, respectively) were recorded from the S_0V_3 (Control treatment with BRRIdhan 52) (Table 2). On the other hand, the lowest number of leaf (4.00, 12.25, 20.00, 25.25 and 23.00, respectively) were recorded from S_3V_2 (Submergence for 10 days in BR5).

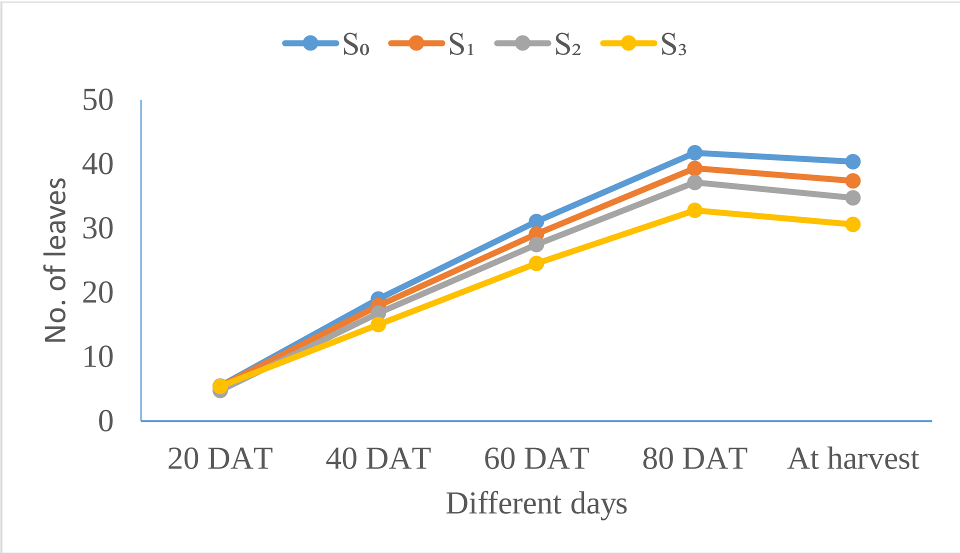


Figure 3. Effect of submergence on no. of leaves of rice at different days after transplanting

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

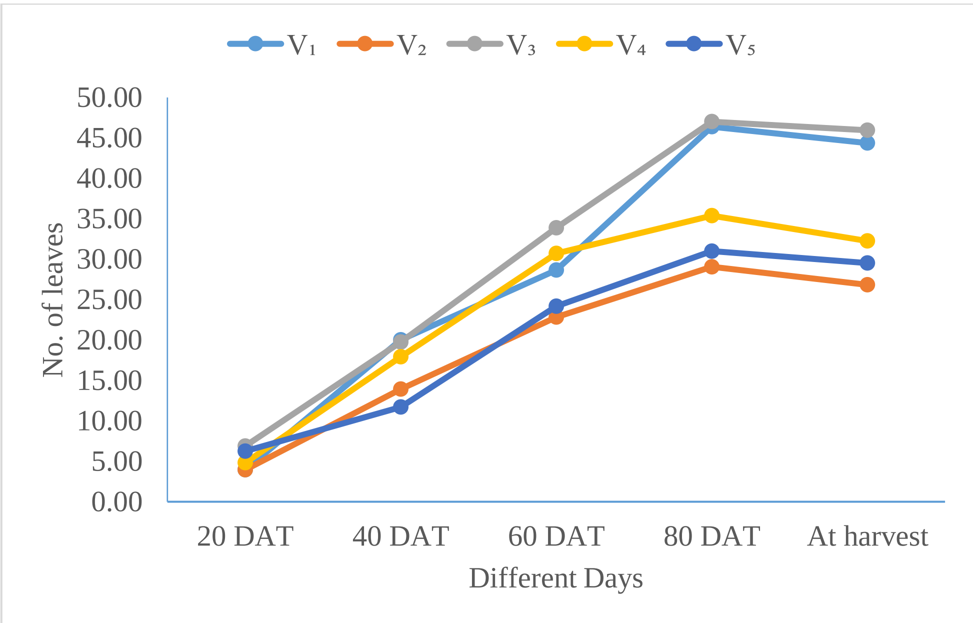


Figure 4. Effect of varieties on no. of leaves of rice at different days after transplanting

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

Table 2. Interaction effect of submergence and varieties on number of leaves of rice at different days after transplanting

Submergence level	Leaf number				
	20 DAT	40 DAT	60 DAT	80 DAT	At harvest
S_0V_1	4.00	22.00	31.75c-e	51.25ab	49.00b
S_0V_2	4.00	15.50	25.25g-i	32.25gh	30.50g-i
S_0V_3	7.25	24.75	37.50a	52.00a	52.25a
S_0V_4	5.50	19.75	34.00a-c	39.00de	37.50e
S_0V_5	6.50	13.00	26.75f-h	34.25fg	32.50fg
S_1V_1	4.00	21.00	29.75ef	48.25bc	46.25cd
S_1V_2	4.00	14.50	23.75h-j	30.25h-j	27.75i-k
S_1V_3	7.00	23.50	35.25ab	49.00a-c	47.50bc
S_1V_4	5.50	18.75	32.00b-e	37.00ef	34.25f
S_1V_5	6.50	12.00	24.75g-j	32.25gh	31.25gh
S_2V_1	3.75	19.50	28.00fg	45.75c	44.00d
S_2V_2	3.75	13.50	22.25i-k	28.50h-j	26.00jk
S_2V_3	6.25	21.75	33.25b-d	46.25c	44.75d
S_2V_4	4.50	17.50	30.00d-f	34.75fg	30.25g-i
S_2V_5	5.33	11.67	23.75h-j	30.50hi	28.75h-j
S_3V_1	4.00	17.50	25.00g-j	40.25d	38.25e
S_3V_2	4.00	12.25	20.00k	25.25k	23.00l
S_3V_3	5.50	19.50	29.50ef	40.75d	39.25e
S_3V_4	7.00	15.75	26.75fh	30.75hi	27.00i-k
S_3V_5	6.50	10.00	21.50jk	27.00jk	25.50kl
LS	NS	NS	*	*	**
LSD (0.05)	1.22	1.96	3.76	3.62	2.92
CV (%)	9.35	6.39	3.59	6.27	5.37

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

4.3 Number Tillers per hill

The number of tillers per hill of rice was significantly varied among the submergence treatment at 40, 60, 80 days after transplanting (DAT) and harvest time except at 20 DAT (Appendix VI). At 20, 40, 60, 80 DAT and at harvest time, the highest (8.80, 15.40, 22.00, 24.64 and 23.65, respectively) number of tillers per hill was obtained from control (S_0) treatment and the lowest number of tillers per hill (7.36, 12.03, 17.18, 19.25 and 18.48, respectively) was obtained from 10 days submergence (S_3) treatment (Figure 5). The study referred that the control treatment i.e.; no submergence produced the highest number of tillers per hill of rice.

Different varieties significantly affected the number of tillers per hill of rice at 20, 40, 60, 80 days after transplanting (DAT) and harvest time (Appendix VI). At 20, 40, 60, 80 DAT and harvest time, the highest number of tillers per hill (9.40, 16.13, 23.05, 25.81 and 24.78, respectively) was recorded from V_2 (BR5) whereas, the lowest number of leaf (5.51, 9.61, 13.73, 15.37 and 14.76) was recorded from V_3 (BRRIdhan 52) (Figure 6). Present study revealed that BRRIdhan52 variety produced the highest number of tillers per hill. The variety are genetically different for which they are supposed to show different performance in different submergence duration.

Interaction effect of submergence and varieties significantly influenced number of tillers per hill at 60, 80 DAT and harvest time but not significant at 20, 40, (Appendix VI). At 20, 40, 60, 80 DAT and harvest time, the highest number of tillers per hill (10.30, 18.03, 25.75, 28.84 and 27.69, respectively) was recorded from the S_1V_5 (Control treatment with BRRIdhan 52) (Table 3). On the other hand, the lowest number of tillers per hill (4.84, 8.36, 11.95, 13.38 and 12.85, respectively) was recorded from S3V5 (Submergence for 10 days in BINAdhan 12).

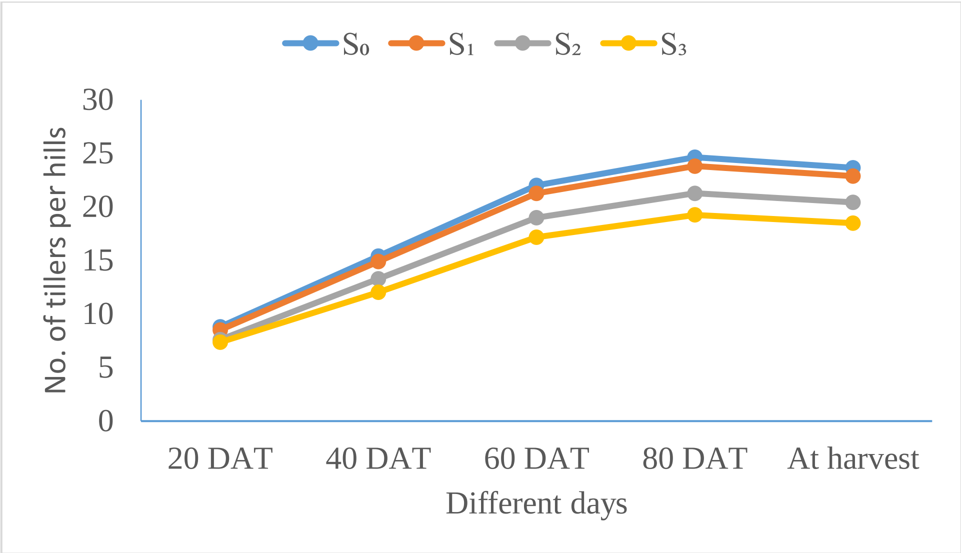


Figure 5. Effect of submergence on no. tillers per hill of rice at different days after transplanting

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

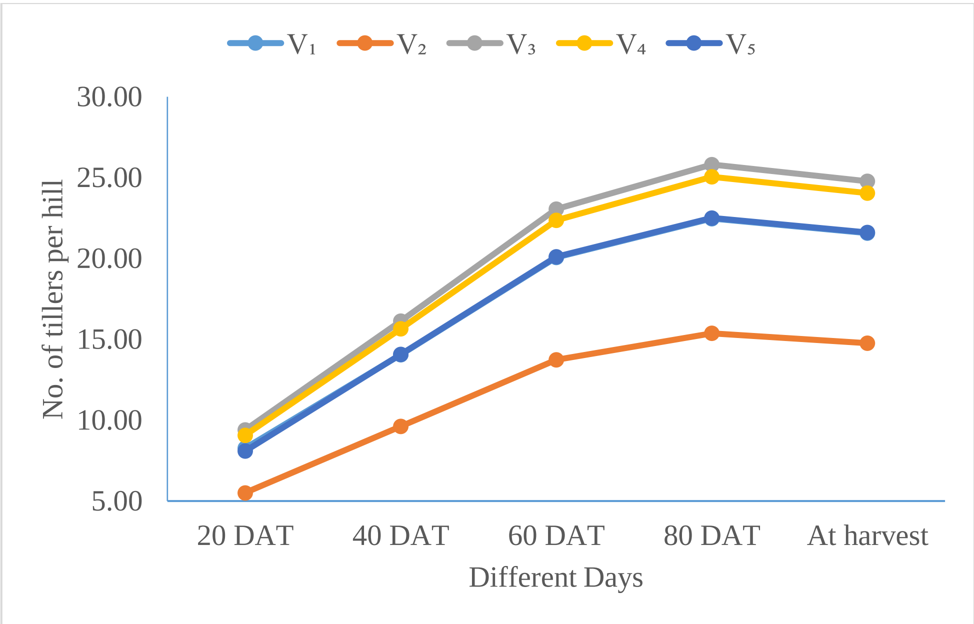


Figure 6. Effect of varieties on no. tillers per hill of rice at different days after transplanting

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

Table 3. Interaction effect of submergence and varieties on no. of tillers per hill of rice at different days after transplanting

Interaction	Number Tillers per hill				
	20 DAT	40 DAT	60 DAT	80 DAT	At harvest
S_0V_1	8.80	15.40a-d	22.00a-d	24.64a-d	23.65a-d
S_0V_2	6.20	10.85e-h	15.50e-h	17.36e-h	16.67e-h
S_0V_3	10.30	18.03a	25.75a	28.84a	27.69a
S_0V_4	9.30	16.28a-d	23.25a-d	26.04a-d	25.00a-d
S_0V_5	9.40	16.45a-d	23.50a-d	26.32 a-d	25.27 a-d
S_1V_1	8.62	15.09 a-d	21.56a-d	24.15 a-d	23.18 a-d
S_1V_2	5.89	10.31f-h	14.73f-h	16.49f-h	15.83f-h
S_1V_3	10.09	17.65ab	25.22ab	28.25ab	27.12ab
S_1V_4	9.65	16.89a-c	24.13a-c	27.03a-c	25.95a-c
S_1V_5	8.28	14.49a-e	20.70a-e	23.18a-e	22.25a-e
S_2V_1	7.90	13.82b-f	19.75b-f	22.12 b-f	21.23 b-f
S_2V_2	5.09	8.91gh	12.73gh	14.26gh	13.69gh
S_2V_3	9.01	15.77a-d	22.52a-d	25.22a-d	24.22a-d
S_2V_4	8.76	15.32 a-d	21.89a-d	24.52 a-d	23.54 a-d
S_2V_5	7.24	12.67d-g	18.09d-g	20.27d-g	19.45d-g
S_3V_1	7.74	11.87a-d	16.96a-d	18.99a-d	18.23a-d
S_3V_2	4.84	8.36h	11.95h	13.38h	12.85h
S_3V_3	8.58	14.15a-f	20.21a-f	22.64a-f	21.73a-f
S_3V_4	8.19	13.08c-f	18.69c-f	20.93c-f	20.10c-f
S_3V_5	7.43	12.68d-g	18.11d-g	20.29d-g	19.48d-g
LS	NS	*	*	*	*
LSD (0.05)	2.63	4.08	5.86	6.67	6.98
CV (%)	18.89	10.63	10.81	11.06	10.68

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

NS= Not significant, * = Significant at 5% level of probability, Significant at 5% level of probability

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12
S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

4.4 SPAD value

Significant variation was observed among the submergence in SPAD value of leaf (Appendix VII). The highest SPAD value of leaf (43.90) was obtained from control (S_0) treatment and the lowest SPAD value of leaf (42.80) was obtained from S_3 (submergence for 10 days) treatment (Table 4). The study referred that the control treatment i.e.; no submergence produced the highest SPAD value of leaf of rice.

The SPAD value of leaf significantly affected due to different varieties (Appendix VII). The highest SPAD value of leaf (46.81) was recorded from V_3 (BRRIdhan 52) whereas, the lowest SPAD value of leaf (40.87) was recorded from V_2 (BR5) (Table 5). Present study revealed that BRRIdhan52 variety produced the highest SPAD value of leaf.

Interaction effect of different levels of submergence and varieties significantly influenced by SPAD value of leaf (Appendix VII). The highest SPAD value of leaf (49.00) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest SPAD value of leaf (40.25) was recorded from S_3V_2 (Submergence for 10 days in BR5) (Table 6).

Table 4. Effect of submergence on SPAD value, submergence leaf number and rotten leaf of rice at different days after transplanting

Level of submergence	SPAD value	No. of leaves before submergence	No. of leaves After submergence	Rotten leaves
S_0	43.90a	164.50a	164.50a	0.00d
S_1	42.10b	149.45b	134.80b	14.65c
S_2	43.00b	138.59bc	115.34c	23.25b
S_3	42.80b	137.84c	109.29c	28.55a
LS	**	**	**	**
LSD (0.05)	0.54	11.05	14.75	2.12
CV (%)	1.81	15.57	17.18	17.87

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly by LSD at 0.05 level of probability.
S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

Table 5. Effect of varieties on SPAD value, submergence leaf number and rotten leaf of rice at different days after transplanting

Varieties	SPAD Value	Leaf no. before submergence	leaf no. just after submergence	Rotten leaf
V_1	44.18b	148.75bc	132.63b	16.13ab
V_2	40.88d	129.39b	110.39c	19.00a
V_3	46.81a	170.50a	154.69a	15.75b
V_4	40.94d	159.47ab	143.72ab	15.81b
V_5	43.18c	129.86d	113.48c	16.38ab
	**	**	**	*
LSD (0.05)	0.57	18.96	17.81	2.94
CV (%)	2.14	17.82	18.03	24.92

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

Table 6. Interaction effect of submergence and varieties on SPAD value, submergence leaf number and rotten leaf of rice at different days after transplanting

Interaction	SPAD Value	Leaf no. before submergence	leaf no. just after submergence	Rotten leaf
S_0V_1	47.50b	184.00ab	184.00ab	0.00g
S_0V_2	41.00f-h	127.75d-f	127.75d-h	0.00g
S_0V_3	49.00a	189.75a	189.75a	0.00g
S_0V_4	41.25f-h	171.25a-c	171.25a-c	0.00g
S_0V_5	40.75f-h	149.75b-f	149.75b-d	0.00g
S_1V_1	43.75e	148.50b-f	132.00d-g	16.50e-f
S_1V_2	40.50gh	124.50ef	111.75e-h	12.75f
S_1V_3	47.75b	186.25ab	173.00a-c	13.25f
S_1V_4	40.25h	159.00a-e	144.00c-e	15.00ef
S_1V_5	41.75f	129.00d-f	113.25e-h	15.75ef
S_2V_1	40.50gh	132.38d-f	109.88e-h	22.50bc
S_2V_2	41.75f	119.96f	93.96h	26.00bc
S_2V_3	46.00c	163.96a-d	141.96c-f	22.00bc
S_2V_4	41.50fg	149.70b-f	129.45d-g	20.25c-e
S_2V_5	46.00c	126.97d-f	101.47gh	25.50bc
S_3V_1	45.25cd	130.13d-f	104.63gh	25.50bc
S_3V_2	40.25h	145.36c-f	108.11f-h	37.25a
S_3V_3	44.50de	142.05c-f	114.05e-h	27.75b
S_3V_4	40.50gh	157.95a-e	130.20d-g	28.00b
S_3V_5	44.25de	113.72f	89.47h	24.25bc
LS	*	*	*	*
LSD (0.05)	1.12	37.93	35.09	5.88
CV (%)	2.14	17.82	18.03	24.92

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

4.5 No. of leaf before submergence

Significant variation observed among the submergence level in no. of leaf before sub mergence (Appendix VII). The highest no. of leaf before submergence (164.50) was obtained from control (S_0) treatment and the lowest no. of leaf before emergence (137.84) was obtained from S_3 (submergence for 10 days) treatment (Table 4). The study referred that the control treatment i.e.; no submergence produced the highest no. of leaf before submergence of rice.

No. of leaf before submergence significantly affected due to different varieties (Appendix IV). The highest no. of leaf before submergence (170.50) was recorded from V_3 (BRRIdhan 52) whereas, the lowest no. of leaf before submergence (129.86) was recorded from V_5 (BINA 1dhan 12) (Table 5). Present study revealed that BRRIdhan52 variety produced the highest no. of leaf before submergence.

Interaction effect of different level of submergence and varieties significantly influenced by no. of leaf before submergence (Appendix VII). The highest no. of leaf before submergence (189.75) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest No. of leaf before submergence (113.72) was recorded from S_3V_5 (Submergence for 10 days in BINAdhan 12) (Table 6).

4.6 No. of leaf just after submergence

Significant variation was observed among the desubmergence level in case of no. of leaves after desubmergence (Appendix VII). The highest no. of leaf after desubmergence (164.50) was obtained from control (S_0) treatment and the lowest no. of leaf after desubmergence (109.29) was obtained from S_3 (submergence for 10 days) treatment (Table 4). The study referred that the control treatment i.e.; no submergence condition produced the highest no. of leaves after desubmergence of rice.

No. of leaves after desubmergence was significantly affected due to different varieties (Appendix VII). The highest no. of leaves after desubmergence (154.69) was recorded from V_3 (BRRIdhan 52) whereas, the lowest no. of leaves after desubmergence (110.39) was recorded from V_2 (BR5) (Table 5). Present study revealed that BRRIdhan52 variety produced the highest no. of leaves after desubmergence.

Interaction effect of different levels of submergence and varieties significantly influenced by no. of leaf after desubmergence (Appendix VII). The highest no. of leaf after desubmergence (189.75) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest no. of leaf after emergence (89.47) was recorded from S_3V_5 (Submergence for 10 days in BINAdhan 12) (Table 6).

4.7 No. of rotten leaf

Significant variation was observed among the submergence levels in case of no. of rotten leaves (Appendix VII). The lowest no. of rotten leaves (0.00) was obtained from control (S_0) treatment and the highest no. of rotten leaf (28.55) was obtained from S_3 (submergence for 10 days) treatment (Table 4). The study referred that the control treatment i.e.; no submergence produced the lowest no. of rotten leaf of rice.

No. of rotten leaf was significantly affected due to different varieties (Appendix VII). The lowest no. of rotten leaf (15.75) was recorded from V_3 (BRRIdhan 52) whereas, the highest no. of rotten leaf (19.00) was recorded from V_2 (BR5) (Table 5). Present study revealed that BRRIdhan52 variety produced the highest no. of rotten leaf.

Interaction effect of different level of submergence and varieties were significantly influenced by no. of rotten leaves (Appendix VII). The lowest no. of rotten leaf (189.75) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the highest no. of rotten leaf (37.25) was recorded from S_3V_5 (Submergence for 10 days in BINAdhan 12) (Table 6).

4.8 Days required for the 1st Panicle emergence

Significant variation was observed among the submergence level in days required for the 1st panicle emergence (Appendix VIII). The lowest days required for the 1st panicle emergence (77.25 days) was obtained from control (S_0) treatment and the highest 1st panicle emergence (87.60 days) was obtained from S_3 (submergence for 10 days) treatment (Table 7). The study referred that the control treatment i.e.; no submergence required the lowest time for 1st panicle emergence of rice.

The 1st panicle emergence was significantly influenced due to different varieties (Appendix VIII). The lowest time for the 1st panicle emergence (72.50 days) was recorded from V_5 (BINAdhan 12) whereas, the highest time for the 1st panicle emergence (86.94 days) was recorded from V_4 (BRRIdhan 46) (Table 8).

Interaction effect of different level of submergence and varieties were significantly influenced by time for the 1st panicle emergence (Appendix VIII). The lowest time for the 1st panicle emergence (68.25 days) was recorded from the S_0V_5 (Control treatment with BINAdhan 12) and the highest time for the 1st panicle emergence (100.50 days) was recorded from S_3V_2 (Submergence for 10 days in BR5) (Table 9).

Table 7. Effect of submergence on panicle emergence of rice

Submerse level	Panicle emergence (days)		
	1st	50%	100%
S_0	77.25c	80.75d	87.15d
S_1	78.95c	83.75c	92.35c
S_2	82.55b	87.75b	99.95b
S_3	87.60a	97.00a	111.30a
LS	**	**	**
LSD (0.05)	2.62	1.38	1.56
CV (%)	4.49	2.21	5.21

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

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

Table 8. Effect of varieties on panicle emergence of rice

Varieties	Panicle emergence (days)		
	1st	50%	100%
V_1	85.25a	90.06c	98.81c
V_2	86.63a	92.94b	103.44b
V_3	77.69b	81.56d	88.44d
V_4	86.94a	97.19a	112.69a
V_5	72.50c	75.94e	85.31d
LS	**	**	**
LSD (0.05)	2.67	2.04	3.31
CV (%)	4.60	3.30	4.77

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

Table 9. Interaction effect of submergence and varieties on panicle emergence of rice

Interaction	Panicle emergence (days)		
	1st	50%	100%
S_0V_1	83.50c-e	87.25c-e	93.75d-g
S_0V_2	80.25d-f	82.25f-h	89.00f-i
S_0V_3	72.00gh	75.25ij	81.00jk
S_0V_4	82.25c-e	87.25c-e	92.50d-g
S_0V_5	68.25h	71.75j	79.50k
S_1V_1	85.00cd	88.25cd	93.00d-g
S_1V_2	80.50d-f	83.75f-h	89.50f-h
S_1V_3	76.25fg	79.25h	87.00g-j
S_1V_4	83.25c-e	94.50b	109.75h-k
S_1V_5	69.75h	73.00j	82.50j-k
S_2V_1	85.50cd	90.75bc	98.50d
S_2V_2	85.25cd	92.50b	108.75c
S_2V_3	79.25ef	81.75f-h	88.50f-i
S_2V_4	87.50c	94.75b	119.25b
S_2V_5	75.00fg	78.67h	84.33h-k
S_3V_1	87.00c	94.00b	110.00c
S_3V_2	100.50a	113.25a	126.50a
S_3V_3	79.00ef	85.50d-f	96.25de
S_3V_4	94.75b	112.25a	129.25a
S_3V_5	76.75fg	80.00gh	94.50d-f
LS	**	**	**
LSD (0.05)	5.34	4.09	6.62
CV (%)	4.60	3.30	4.77

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

4.9 50% of panicle emergence

Significant variation was observed among the influence of submergence levels in case of time for 50% panicle emergence (Appendix VIII). The lowest time for50% panicle emergence (80.75 days) was obtained from control (S_0) treatment and the highest 50% panicle emergence (97.00 days) was obtained from S_3 (submergence for 10 days) treatment (Table 7). The study referred that the control treatment i.e.; no submergence produced the lowest 50% panicle emergence of rice.

Time for 50% panicle emergence was significantly affected due to different varieties (Appendix VIII). The lowest time for 50% panicle emergence (75.94 days) was recorded from V_5 (BINAdhan 12) whereas, the highest time for 50% panicle emergence (97.19) was recorded from V_4 (BRRIdhan 46) (Table 8).

Interaction effect of different level of submergence and varieties significantly influenced the time for 50% panicle emergence (Appendix VIII). The lowest time for 50% panicle emergence (71.25) was recorded from the S_0V_5 (Control treatment with BINAdhan 12) and the highest time for 50% panicle emergence (113.25) was recorded from S_3V_2 (Submergence for 10 days in BR5) (Table 9).

4.10 Days required for 100% of panicle emergence

Significant variation were observed among the submergence level in case of days required for 100% panicle emergence (Appendix VIII). The lowest time for 100% panicle emergence (87.15 days) was obtained from control (S_0) treatment and the highest time for 100% panicle emergence (111.30 days) was obtained from S_3 (submergence for 10 days) treatment (Table 7). The study referred that the control treatment i.e.; no submergence required the lowest time for 100% panicle emergence of rice.

Days required for 100% panicle emergence was significantly influenced due to different varieties (Appendix VIII). The lowest time for 100% panicle emergence (85.31 days) was recorded from V_5 (BINAdhan 12) which is statistically similar to V_3 (BIRRIdhan 52). The highest time for 100% panicle emergence (112.69 days) was recorded from V_4 (BRRIdhan 46) (Table 8).

Interaction effect of different level of submergence and varieties significantly influenced the time for 100% panicle emergence (Appendix VIII). The lowest time for 100% panicle emergence (79.50 days) was recorded from the S_0V_5 (Control treatment with BINAdhan 12) and the highest time for 100% panicle emergence (126.50 days) was recorded from S_3V_2 (Submergence for 10 days in BR5) (Table 9).

4.11 Leaf dry weight (g) per plant

The leaf dry weight of rice was significantly varied among the submergence treatments at harvest time (Appendix IX). The highest (15.54 g) leaf dry weight was obtained from control (S_0) treatment and the lowest leaf dry weight (12.75 g) was obtained from 10 days submergence (S_3) treatment. The study referred that the control treatment i.e.; no submergence produced the highest leaf dry weight of rice.

Different varieties significantly affected the leaf dry weight of rice at harvest time (Appendix IX). The highest leaf dry weight (17.38 g) was recorded from V_3 (BRRIdhan 52) whereas, the lowest leaf dry weight (10.10 g) was recorded from V_2 (BR5).

Interaction effect of submergence and varieties significantly influenced leaf dry weight at harvest time (Appendix IX). The highest leaf dry weight (18.6 g) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) (Table 3). On the other hand, the lowest leaf dry weight (7.89 g) was recorded from S_3V_2 (Submergence for 10 days in BR5).

Table 10. Effect of submergence on leaf, stem and root dry weight of rice

Submergence level	Leaf dry weight (g)		Stem dry weight (g)	Root dry weight (g)
S_0	15.54a		18.49a	4.33a
S_1	14.49b		17.23b	3.99b
S_2	13.90c		16.30c	3.82c
S_3	12.75d		15.16d	3.55d
LS	**		**	**
LSD (0.05)	0.21		0.33	0.09
CV (%)	2.10		2.89	3.14

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

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

Table 11. Effect of varieties on leaf, stem and root dry weight of rice

Varieties	Leaf dry weight (g)	Stem dry weight (g)	Root dry weight (g)
V_1	15.30b	20.68b	4.68b
V_2	10.10e	11.71e	2.75e
V_3	17.38a	16.58a	3.78a
V_4	14.31c	17.02c	4.22c
V_5	13.75d	16.36d	3.83d
LS	**	**	**
LSD (0.05)	0.23	0.44	0.11
CV (%)	2.56	2.32	2.54

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

Table 12. Interaction effect of submergence and varieties on leaf, stem and root dry of rice

Interaction effect	Leaf dry weight (g)	Stem dry weight (g)	Root dry weight (g)
S_0V_1	16.61cd	19.76de	4.46cd
S_0V_2	12.14m	14.44m	3.39k
S_0V_3	18.66a	22.20a	5.02a
S_0V_4	15.78ef	18.77ef	4.69b
S_0V_5	14.52hi	17.27hi	4.10f-h
S_1V_1	14.95gh	17.78gh	4.12fg
S_1V_2	10.63o	12.64o	2.97l
S_1V_3	16.86c	20.05c	4.53c
S_1V_4	13.81jk	16.42jk	3.95hi
S_1V_5	16.18de	19.24de	4.35de
S_2V_1	15.28fg	18.17fg	4.10f-h
S_2V_2	9.71p	10.37p	2.43m
S_2V_3	17.45b	20.76c	4.70b
S_2V_4	14.28ij	16.98ij	4.25ef
S_2V_5	12.78l	15.19l	3.61j
S_3V_1	14.37i	17.09ij	3.86i
S_3V_2	7.89q	9.39q	2.20n
S_3V_3	16.57cd	19.70cd	4.46cd
S_3V_4	13.37k	15.90k	3.98g-i
S_3V_5	11.54n	13.73n	3.26k
LS	**	**	**
LSD (0.05)	0.52	0.63	0.15
CV (%)	2.56	2.32	2.54

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

4.12 Stem dry weight (g) per plant

The stem dry weight of rice was significantly varied among the submergence treatment at harvest time (Appendix IX). The highest (18.49 g) stem dry weight was obtained from control (S_0) treatment and the lowest stem dry weight (15.16 g) was obtained from 10 days submergence (S_3) treatment (Table 10). The study referred that the control treatment i.e.; no submergence produced the highest stem dry weight of rice.

Different varieties significantly influenced the stem dry weight of rice at harvest time (Appendix IX). The highest stem dry weight (20.68 g) was recorded from V_3 (BRRIdhan 52) whereas, the lowest stem dry weight (11.71 g) was recorded from V_2 (BR5) (Table 11).

Interaction effect of submergence and varieties significantly influenced stem dry weight at harvest time (Appendix IX). The highest stem dry weight (22.20 g) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) (Table 12). On the other hand, the lowest stem dry weight (9.39 g) was recorded from S_3V_2 (Submergence for 10 days in BR5).

4.13 Root dry weight (g) per plant

The root dry weight of rice was significantly varied among the submergence treatment at harvest time (Appendix IX). The highest (4.33 g) root dry weight was obtained from control (S_0) treatment and the lowest root dry weight (3.55 g) was obtained from 10 days submergence (S_3) treatment (Table 10). The study referred that the control treatment i.e.; no submergence produced the highest root dry weight of rice.

Different varieties significantly influenced the root dry weight of rice at harvest time (Appendix IX). The highest root dry weight (4.68 g) was recorded from V_3 (BRRIdhan 52) whereas, the lowest root dry weight (2.75 g) was recorded from V_2 (BR5) (Table 11).

Interaction effect of submergence and varieties significantly influenced root dry weight at harvest time (Appendix IX). The highest root dry weight (5.02 g) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) (Table 12). On the other hand, the lowest root dry weight (2.20 g) was recorded from S_3V_2 (Submergence for 10 days in BR5).

4.14 Panicle length (cm)

The panicle length of rice was significantly varied among the submergence treatment at harvest time (Appendix X). The highest (23.05 cm) panicle length was obtained from control (S_0) treatment and the lowest panicle length (20.09 cm) was obtained from 10 days submergence (S_3) treatment (Table 10). The study referred that the control treatment i.e.; no submergence produced the highest panicle length of rice.

Different varieties significantly influenced the panicle length of rice at harvest time (Appendix X). The highest panicle length (23.91 cm) was recorded from V_3 (BRRIdhan 52) whereas, the lowest panicle length (20.10 cm) was recorded from V_1 (FR13A) (Table 11).

Interaction effect of submergence and varieties significantly influenced panicle length at harvest time (Appendix X). The highest panicle length (25.95 cm) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) (Table 12). On the other hand, the lowest panicle length (17.53 cm) was recorded from S_3V_2 (Submergence for 10 days in BR5).

Table 13. Effect of submergence on yield contributing characters of rice

Level of submergence	Panicle length (cm)	No. of effective tiller	No. of ineffective tiller
S_0	23.05a	12.35a	2.54c
S_1	22.85a	11.97b	2.66c
S_2	21.00b	11.35b	3.00b
S_3	20.09b	11.80c	3.28a
LS	**	**	**
LSD (0.05)	0.93	0.28	0.18
CV (%)	6.00	3.32	8.87

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

Table 14. Effect of varieties on yield contributing characters of rice

Varieties	Panicle length (cm)	No. of effective tiller	No. of ineffective tiller
V_1	20.10d	12.54a	3.13a
V_2	21.62c	10.78c	2.98a
V_3	23.91a	12.65a	2.52b
V_4	22.64b	11.78b	2.96a
V_5	20.31d	11.57b	2.94a
LS	**	**	**
LSD (0.05)	0.92	0.44	0.20
CV (%)	5.98	5.25	10.00

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

Table 15. Interaction effect of submergence and varieties on yield contributing characters of rice

Interaction	Panicle length (cm)	No. of effective tiller	No. of ineffective tiller
S_0V_1	19.75ij	12.84bc	2.83c-g
S_0V_2	23.60b-f	11.77d-f	2.46g-i
S_0V_3	25.95a	13.85a	2.05j
S_0V_4	25.45a-c	11.43e-g	2.64f-h
S_0V_5	21.40f-i	12.19c-e	2.72e-h
S_1V_1	22.33d-g	12.58cd	2.89c-f
S_1V_2	24.03a-d	11.19fg	2.80d-g
S_1V_3	24.38a-c	13. 35ab	2.16f-h
S_1V_4	22.95c-f	11.15fg	2.82c-g
S_1V_5	20.58g-i	12.08c-e	2.65f-h
S_2V_1	18.23jk	12.26c-e	3.03c-f
S_2V_2	21.33f-i	10.29hi	3.57ab
S_2V_3	23.82a-d	12.21c-e	2.35-j
S_2V_4	21.90e-h	10.76gh	2.81c-g
S_2V_5	20.00ij	11.18fg	3.18b-d
S_3V_1	20.11h-i	12.49cd	3.78a
S_3V_2	17.53k	9.88i	3.08c-e
S_3V_3	23.01c-f	12.85bc	2.78f-h
S_3V_4	20.28hi	11.99d-f	3.56ab
S_3V_5	19.55ij	10.79gh	3.20bc
LS	**	**	**
LSD (0.05)	1.84	0.84	0.41
CV (%)	5.98	5.25	10.00

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

4.15 No. of effective tillers per plant

Significant variation was observed among the submergence levels in case of no. of effective tillers per plant (Appendix X). The highest no. of effective tillers (12.35) was obtained from control (S_0) treatment and the lowest no. of effective tiller (11.80) was obtained from S_3 (submergence for 10 days) treatment (Table 13). The study referred that the control treatment i.e.; no submergence influenced the highest no. of effective tillers of rice.

No. of effective tillers was significantly influenced due to different varieties (Appendix X). The highest no. of effective tiller (12.65) was recorded from V_3 (BRRIdhan 52) whereas, the lowest no. of effective tiller (10.78) was recorded from V_2 (BR5) (Table 14). Present study revealed that BRRIdhan52 variety produced the highest no. of filled grain.

Interaction effect of different levels of submergence and varieties were significantly influenced by no. of effective tillers (Appendix X). The highest no. of effective tillers (13.85) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest no. of effective tillers (9.88) was recorded from S_3V_2 (Submergence for 10 days in BR 5) (Table 15).

4.16 No. of ineffective tillers per plant

Significant variation was observed among the submergence level in case of no. of ineffective tillers per plant (Appendix X). The lowest no. of ineffective tillers (2.54) was obtained from control (S_0) treatment which was statistically similar to S_1 and the highest no. of ineffective tiller (3.28) was obtained from S_3 (submergence for 10 days) treatment (Table 13). The study referred that the control treatment i.e.; no submergence influenced the lowest no. of ineffective tiller of rice.

No. of ineffective tillers waas significantly influenced due to different varieties (Appendix IV). The lowest no. of ineffective tiller (2.52) was recorded from V_3 (BIRRIdhan 52) which was statistically similar to V_2, V_4 and V_5. The highest no. of ineffective tillers (3.13) was recorded from V_1 (FR13A) (Table 14).

Interaction effect of different level of submergence and varieties significantly influenced the no. of ineffective tillers (Appendix IV). The lowest no. of ineffective tillers (2.05) was recorded from the S_0V_5 (Control treatment with BINAdhan 12) and the highest no. of ineffective tillers (3.78) was recorded from S_3V_1 (Submergence for 10 days in FR13A) (Table 15).

4.17 No. of filled grain per plant

Significant variation were observed among the submergence levels in case of no. of filled grains (Appendix XI). The highest no. of filled grains (120.19 g) was obtained from control (S_0) treatment and the lowest no. of filled grains (94.33 g) was obtained from S_3 (submergence for 10 days) treatment (Table 16). The study referred that the control treatment i.e.; no submergence produced the highest no. of filled grain of rice.

No. of filled grains was significantly influenced due to different varieties (Appendix XI). The highest no. of filled grains (138.49 g) was recorded from V_3 (BRRIdhan 52) whereas, the lowest no. of filled grains (75.64 g) was recorded from V_2 (BR5) (Table 17). Present study revealed that BRRIdhan52 variety produced the highest no. of filled grain.

Interaction effect of different levels of submergence and varieties significantly influenced the no. of filled grains (Appendix XI). The highest no. of filled grains (150.39 g) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest no. of filled grains (64.25 g) was recorded from S_3V_2 (Submergence for 10 days in BR 5) (Table 18).

Table 16. Effect of submergence on yield contributing characters of rice

Level of submergence	No. of filled grains	No. of unfilled grains	Days to maturity (days)	1000 grain weight (g)
S_0	120.19a	25.71c	115.95c	24.00a
S_1	111.45b	26.78c	122.65bc	22.33b
S_2	102.54c	29.95b	130.20b	21.73b
S_3	94.33d	35.98a	140.15a	20.33c
LS	**	**	**	**
LSD (0.05)	1.34	2.05	8.59	1.03
CV (%)	1.22	9.70	9.44	6.56

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

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

Table 17. Effect of varieties on yield contributing characters of rice

Varieties	No. of filled grains	No. of unfilled grains	Days to maturity (days)	1000 grain weight (g)
V_1	111.90b	31.89ab	128.75b	27.24a
V_2	75.64d	32.37a	128.44b	15.17d
V_3	138.49a	23.76c	119.44c	26.28a
V_4	110.21b	30.09b	145.19a	23.34b
V_5	99.41c	29.92b	114.38c	18.45c
	**	**	**	**
LSD (0.05)	1.82	2.01	7.90	1.36
CV (%)	3.40	9.55	8.74	8.69

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

Table 18. Interaction effect of submergence and varieties on yield contributing characters of rice

Interaction	No. of filled grains	No. of unfilled grains	Days to maturity (days)	1000 grain weight (g)
S_0V_1	124.32d	28.31fg	122.00c-g	29.23a
S_0V_2	92.57k	26.19gh	122.50c-g	16.68gh
S_0V_3	150.39a	20.51i	106.50gh	26.88bc
S_0V_4	121.50d	26.37gh	127.00c-e	25.60c-e
S_0V_5	112.17f	27.17gh	101.75h	21.63f
S_1V_1	116.86d	28.88fg	125.00c-e	29.58a
S_1V_2	75.91m	28.81fg	125.50c-e	14.25hi
S_1V_3	145.88b	21.55i	116.50e-h	26.90bc
S_1V_4	115.43ef	28.17gh	137.25bc	23.00d-f
S_1V_5	103.19h	26.47gh	109.00f-h	17.93g
S_2V_1	107.51g	30.25e-g	131.00b-e	25.33c-e
S_2V_2	69.83n	35.73b-d	133.75b-d	17.00g
S_2V_3	134.21c	23.53hi	121.25c-g	26.30c
S_2V_4	106.19gh	28.11g	146.00b	22.88ef
S_2V_5	94.94jk	32.15d-f	119.00d-g	17.15g
S_3V_1	98.91i	40.10a	137.00bc	24.85c-e
S_3V_2	64.25o	38.76ab	132.00b-e	12.75i
S_3V_3	123.47d	29.46fg	133.50b-d	25.05c-e
S_3V_4	97.70ij	37.69a-c	170.50a	21.88f
S_3V_5	87.34l	33.89c-e	127.75c-e	17.11g
LS	**	**	*	*
LSD (0.05)	3.65	4.02	15.80	2.73
CV (%)	3.40	9.55	8.74	8.69

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

4.18 No. of unfilled grains per plant

Significant variation were observed among the submergence levels in case of no. of unfilled grains (Appendix XI). The lowest no. of unfilled grain (27.71) was obtained from control (S_0) treatment which was statistically similar to S_1 and the highest no. of unfilled grain (35.98) was obtained from S_3 (submergence for 10 days) treatment (Table 16). The study referred that the control treatment i.e.; no submergence influenced the lowest no. of unfilled grains of rice.

No. of unfilled grains was significantly influenced due to different varieties (Appendix XI). The lowest no. of unfilled grains (23.76) was recorded from V_3 (BIRRIdhan 52) which was statistically similar to V_2, V_4 and V_5. The highest no. of unfilled grains (32.27) was recorded from V_1 (FR13A) (Table 17).

Interaction effect of different levels of submergence and varieties significantly influenced the no. of unfilled grains (Appendix XI). The lowest no. of unfilled grains (20.51) was recorded from the S_0V_5 (Control treatment with BINAdhan 12) and the highest no. of unfilled grains (40.10) was recorded from S_3V_1 (Submergence for 10 days in FR13A) (Table 18).

4.19 Days to maturity

Significant variation were observed among the submergence levels in case of days required to maturity (Appendix XI). The lowest days to maturity (115.95 days) was obtained from control (S_0) treatment and the highest days to maturity (140.15 days) was obtained from S_3 (submergence for 10 days) treatment (Table 16). The study referred that the control treatment i.e.; no submergence influenced the lowest days to maturity of rice.

Days to maturity was significantly influenced by different varieties (Appendix XI). The lowest days to maturity (114.38 days) was recorded from V_5 (BINAdhan 12) which was statistically similar to V_3 (BIRRIdhan 52). The highest days to maturity (145.19 days) was recorded from V_4 (BRRIdhan 46) (Table 17).

Interaction effect of different level of submergence and varieties significantly influenced the days to maturity (Appendix XI). The lowest days to maturity (101.75 days) was recorded from the S_0V_5 (Control treatment with BINAdhan 12) and the highest days to maturity (170.50 days) was recorded from S_3V_4 (Submergence for 10 days in BRRIdhan 46) (Table 18).

4.20 1000 grain weight (g)

Significant variation was observed among the submergence levels in case of 1000 grain weight (Appendix XI). The highest 1000 grain weight (24.00 g) was obtained from control (S_0) treatment and the lowest 1000 grain weight (20.33 g) was obtained from S_3 (submergence for 10 days) treatment (Table 16). The study referred that the control treatment i.e.; no submergence produced the highest 1000 grain weight of rice.

1000 grain weight significantly influenced by the different varieties (Appendix XI). The highest 1000 grain weight (27.24 g) was recorded from V_1 (FR13A) whereas, the lowest 1000 grain weight (15.17 g) was recorded from V_2 (BR5) (Table 17). Present study revealed that BRRIdhan52 variety produced the highest 1000 grain weight.

Interaction effect of different level of submergence and varieties significantly influenced the 1000 grain weight (Appendix XI). The highest 1000 grain weight (29.23 g) was recorded from the S_0V_1 (Control treatment with FR13A) and the lowest 1000 grain weight (12.75 g) was recorded from S_3V_2 (Submergence for 10 days in BR 5) (Table 18).

4.21 Grain Yield (t ha^{-1})

Significant variation were observed among the results of submergence level in case of grain yield (Appendix XII). The highest grain yield (3.95 t ha $^{-1}$) was obtained from control (S_0) treatment and the lowest grain yield (3.21 t ha^{-1}) was obtained from S_3 (submergence for 10 days) treatment (Table 19). The study referred that the control treatment i.e.; no submergence produced the highest grain yield of rice.

Grain yield was significantly influenced due to different varieties (Appendix XII). The highest grain yield (4.58 t ha^{-1}) was recorded from V_3 (BRRIdhan 52) whereas, the lowest grain yield (2.36 t ha^{-1}) was recorded from V_2 (BR5) (Table 20). Present study revealed that BRRIdhan52 variety produced the highest Grain yield.

Interaction effect of different levels of submergence and varieties significantly influenced the grain yield (Appendix XII). The highest grain yield (4.81 t ha^{-1}) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest grain yield (1.70 t ha^{-1}) was recorded from S_3V_2 (Submergence for 10 days in BR 5) (Table 21).

Table 19. Effect of submergence on yield parameters of rice

Level of submergence	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_0	3.95a	5.93a	9.88a	39.80a
S_1	3.66b	5.72b	9.38b	38.72b
S_2	3.43c	5.59c	9.03c	37.51c
S_3	3.21d	5.33d	8.54d	36.94d
LS	**	**	**	**
LSD (0.05)	0.011	0.05	0.05	0.31
CV (%)	3.23	4.23	4.32	6.61

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

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

Table 20. Effect of varieties on yield parameters of rice

Varieties	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1	3.67c	5.77b	9.44b	38.81c
V_2	2.36e	4.76c	7.12e	32.81e
V_3	4.58a	6.32a	10.90a	42.05a
V_4	3.83b	5.76b	9.58c	39.92b
V_5	3.38d	5.60b	8.99d	37.64d
LS	**	**	**	**
LSD (0.05)	0.05	0.10	0.13	0.53
CV (%)	3.73	4.85	4.65	5.54

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

Table 21. Interaction effect of submergence and varieties on yield parameters of rice

Interaction	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_0V_1	3.99f	6.02b-d	10.00cd	39.85cd
S_0V_2	3.09l	5.50gh	8.58k	35.95jk
S_0V_3	4.81a	6.17b	10.98a	43.84a
S_0V_4	4.13e	5.89c-e	10.02c	41.23b
S_0V_5	3.74g	6.06bc	9.80c-e	38.16f-h
S_1V_1	3.75g	5.91c-e	9.66ef	38.80e-g
S_1V_2	2.53m	4.71j	7.24l	34.94k
S_1V_3	4.67b	6.50a	11.17a	41.79b
S_1V_4	3.93f	5.85d-f	9.77de	40.17c
S_1V_5	3.44ij	5.64f-h	9.08hi	37.92gh
S_2V_1	3.55h	5.71e-g	9.26gh	38.30f-h
S_2V_2	2.07n	4.61j	6.68m	30.96l
S_2V_3	4.52c	6.44a	10.96a	41.28b
S_2V_4	3.74g	5.77ef	9.51fg	39.33c-e
S_2V_5	3.29k	5.44hi	8.73jk	37.70gh
S_3V_1	3.39jk	5.46hi	8.84ij	38.30f-h
S_3V_2	1.76o	4.23k	5.99o	29.39m
S_3V_3	4.33d	6.16b	10.49b	41.28b
S_3V_4	3.51hi	5.51gh	9.02hi	38.94d-f
S_3V_5	3.07l	5.27i	8.33l	36.79hi
LS	**	**	**	**
LSD (0.05)	0.11	0.21	0.27	1.07
CV (%)	3.73	4.85	4.65	5.54

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

V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12

S_0= Control (No submergence), S_1= Submergence for 4 days, S_2= Submergence for 7 days =, S_3= Submergence for 10 days

4.22 Straw Yield (t ha^{-1})

Significant variation was observed among the submergence levels in straw yield (Appendix XII). The highest straw yield (5.93 t ha^{-1}) was obtained from control (S_0) treatment and the lowest straw yield (5.33 t ha^{-1}) was obtained from S_3 (submergence for 10 days) treatment (Table 19). The study referred that the control treatment i.e.; no submergence produced the highest straw yield of rice.

Straw yield was significantly influenced due to different varieties (Appendix XII). The highest straw yield (6.32 t ha^{-1}) was recorded from V_3 (BRRIdhan 52) whereas, the lowest straw yield (4.66 t ha^{-1}) was recorded from V_2 (BR5) (Table 20). Present study revealed that BRRIdhan52 variety produced the highest Straw yield.

Interaction effect of different levels of submergence and varieties significantly influenced the Straw yield (Appendix XII). The highest straw yield (6.17 t ha^{-1}) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest straw yield (4.23 t ha^{-1}) was recorded from S_3V_5 (Submergence for 10 days in BINAdhan 12) (Table 21).

4.23 Biological Yield (t ha^{-1})

Significant variation was observed among the result of submergence in case of biological yield (Appendix XII). The highest biological yield (9.88 t ha^{-1}) was obtained from control (S_0) treatment and the lowest biological yield (8.54 t ha^{-1}) was obtained from S_3 (submergence for 10 days) treatment (Table 19). The study referred that the control treatment i.e.; no submergence produced the highest biological yield of rice.

Biological yield was significantly influenced due to different varieties (Appendix XII). The highest biological yield (10.90 t ha^{-1}) was recorded from V_3 (BRRIdhan 52) whereas, the lowest biological yield (7.12 t ha^{-1}) was recorded from V_2 (BR5) (Table 20). Present study revealed that BRRIdhan52 variety showed the highest Biological yield.

Interaction effect of different level of submergence and varieties significantly influenced the Biological yield (Appendix XII). The highest biological yield (10.98 t ha^{-1}) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest biological yield (5.99 t ha^{-1}) was recorded from S_3V_5 (Submergence for 10 days in BINAdhan 12) (Table 21).

4.24 Harvest Index (%)

Significant variation was observed among the submergence levels in case of harvest index (Appendix XII). The highest harvest index (39.80 %) was obtained from control (S_0) treatment and the lowest harvest index (36.94 %) was obtained from S_3 (submergence for 10 days) treatment (Table 19). The study referred that the control treatment i.e.; no submergence contributed to produced the highest harvest index of rice.

Harvest index was significantly affected due to different varieties (Appendix XII). The highest harvest index (42.05 %) was recorded from V_3 (BRRIdhan 52) whereas, the lowest harvest index (32.81 %) was recorded from V_2 (BR5) (Table 20). Present study revealed that BRRIdhan52 variety showed the highest harvest index.

Interaction effect of different levels of submergence and varieties significantly influenced by harvest index (Appendix XII). The highest harvest index (43.84 %) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest harvest index (29.39 %) was recorded from S_3V_5 (Submergence for 10 days in BINAdhan 12) (Table 21).

4.25 Tolerance level

Result from the study revealed that variety V_3 highly tolerant to S_1, medium tolerant to S_2 and susceptible to S_3 in terms of weight of filled grain per plant. Variety V_1 is highly tolerate to S_1, V_4 is tolerate to S_1 and V_5 was medium tolerate to S_1. V_2 variety is almost susceptible to different period of submergence.

Table 22. Tolerance level of different varieties

Treatment	Weight of filled grains plant^{-1} (gm)	Reduction % of grain weight due to submergence	Remarks	Mean of grain weight reduction % due to different period of submergence
V_1S_0	46.66	-		23.15
V_1S_1	43.49	6.80	Highly tolerant	
V_1S_2	33.39	28.45	Susceptible	
V_1S_3	30.70	34.20	Susceptible	
V_2S_0	18.17	-		40.55
V_2S_1	12.10	33.40	Susceptible	
V_2S_2	12.22	32.79	Susceptible	
V_2S_3	8.09	55.47	Highly susceptible	
V_3S_0	55.99	-		19.26
V_3S_1	52.78	5.73	Highly tolerant	
V_3S_2	43.10	23.02	Medium tolerant	
V_3S_3	39.74	29.01	Susceptible	
V_4S_0	35.55	-		23.70
V_4S_1	29.60	16.74	Tolerant	
V_4S_2	26.14	26.47	Susceptible	
V_4S_3	25.63	27.91	Susceptible	
V_5S_0	29.58	-		36.12
V_5S_1	22.35	24.43	Medium tolerant	
V_5S_2	18.20	38.45	Susceptible	
V_5S_3	16.12	45.48	Susceptible	

Highly tolerant	Reduction of yield in between 0 % to 14 %
Tolerant	Reduction of yield in between 15 % to 20 %
Medium tolerant	Reduction of yield in between 21 % to 25 %
Susceptible	Reduction of yield in between 26 % to 46 %
Highly susceptible	Reduction of yield in between 47 % to 100%

CHAPTER V
SUMMARY AND CONCLUSION

The pot experiment was conducted at the Agricultural Botany field of central research farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from June, 2018 to December, 2018 to find out the effect of submergence on the reproductive stage and yield of different *Aman* rice varieties. Four Submergence condition viz. S_0 – Control (No submergence), S_1 – Submergence for 4 days, S_2 - Submergence for 7 days, S_3 - Submergence for 10 days and five varieties viz. V_1= FR13A, V_2= BR5, V_3= BRRIdhan 52, V_4= BRRIdhan 46, V_5= BINAdhan 12 were used as treatment of the experiment. The experiment was laid out in Split Plot Design having two factors and replicated four times. Data were collected on plant height, leaf number, number of tiller, leaf, shoot and root, SPAD value, leaf number, 1^{st}, panicle emergence time, effective tiller, ineffective tiller, filled grain, unfilled grain, days to maturity, 1000 grain weight, grain yield, straw yield, biological yield and harvest index.

At 20, 40, 60, 80 DAT and at harvest the highest plant height (25.91, 40.22, 78.52, 102.40 and 102.57 cm, respectively), number of leaves (5.45, 19.00, 31.05, 41.75 and 40.35, respectively) and number of tillers (8.80, 15.40, 22.00, 24.64 and 23.65, respectively) was obtained from S_0 (control) treatment and the lowest plant height (22.80, 33.81, 65.89, 83.42 and 83.65 cm, respectively), number of leaves (4.75, 15.00, 24.55, 32.80 and 30.60, respectively), number of tillers (7.36, 12.03, 17.18, 19.25 and 18.48, respectively) was obtained from S_3 (submergence for 10 days) treatment. At 20, 40, 60, 80 DAT and harvest time, the highest plant height (28.93, 40.88, 80.13, 105.15 and 106.15 cm, respectively), number of leaves (6.88, 19.75, 33.88, 47.00 and 45.94, respectively) and number of tillers (9.40, 16.13, 23.05, 25.81 and 24.78, respectively) was recorded from V_3 (BRRIdhan 52). In Interaction effect at 20, 40, 60, 80 DAT and harvest time, the highest plant height, number of leaves and number of tillers was recorded from the S_0V_3 (Control treatment with variety BRRIdhan 52).

The highest SPAD value of leaf (43.90) was obtained from control (S_0) treatment and the lowest (42.80) was obtained from S_3 (submergence for 10 days) treatment. The highest

SPAD value of leaf (46.81) was recorded from V_3 (BRRIdhan 52) whereas, the lowest (40.87) was recorded from V_2 (BR5) (Table 5). The highest SPAD value of leaf (49.00) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest (40.25) was recorded from S_3V_2 (Submergence for 10 days in BR5).

Control (S_0) treatment found the highest no. of leaf before and after emergence (164.50 and 164.50) and the lowest no. of leaf before emergence (137.84 and 109.29) was obtained from S_3 (submergence for 10 days). BRRIdhan 52 found the highest no. of leaf before emergence (170.50 and 154.69) and the lowest (129.86 and 110.39) was recorded from V_5 (BINAdhan 12). The highest no. of leaf before emergence (189.75 and 189.75) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest (113.72 and 89.47) was recorded from S_3V_5 (Submergence for 10 days in BINAdhan 12).

No rotten leaf was observed from control (S_0) treatment and the highest no. of rotten leaf (28.55) was obtained from S_3 (submergence for 10 days) treatment. The lowest no. of rotten leaf (15.75) was recorded from V_3 (BRRIdhan 52) and the highest (19.00) was recorded from V_2 (BR5) (Table 5). The lowest no. of rotten leaf (189.75) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the highest (37.25) was recorded from S_3V_5 (Submergence for 10 days in BINAdhan 12).

Plant was submerged for 0, 4, 7 and 10 days in panicle initiation stage and the result found that the lowest 1st, 50% and 100% panicle emergence (77.25, 80.75 and 87.15 days) was obtained from control (S_0) treatment and the highest (87.60, 97.00 and 111.30 days) was obtained from S_3 (submergence for 10 days) treatment. V_5 (BINAdhan 12) found the lowest 1st, 50% and 100% emergence panicle emergence (72.50, 75.94 and 85.31 days) and the highest (86.94, 97.19 and 112.69 days) was recorded from V_4 (BRRIdhan 46). In combined effect, the lowest 1st panicle emergence (68.25, 71.25 and 79.50 days) was recorded from the S_0V_5 (Control treatment with BINAdhan 12) and the highest 1st panicle emergence (100.50, 113.25 and 126.50 days) was recorded from S_3V_2 (Submergence for 10 days in BR5).

Control (S_0) treatment obtained the highest leaf, stem and root (15.54 g, 18.49 g and 4.33 g, respectively) dry weight at harvest time and the lowest dry weight (12.75 g, 15.16 g and 3.55 g, respectively) was obtained from 10 days submergence (S_3) treatment. The highest leaf, stem and root (0.38 g, 20.68 g and 4.68 g, respectively) dry was recorded from V_3 (BRRIdhan 52) whereas, the lowest (10.10 g, 11.71 g and 2.75 g, respectively) dry weight was recorded from V_2 (BR5). Interaction effect, the highest leaf, stem and root (18.6 g, 22.20 g, and 5.02 g, respectively) dry weight (was recorded from the S_0V_3 (Control treatment with BRRIdhan 52). On the other hand, the lowest leaf (7.89 g, 9.39 g and 2.20 g, respectively) was recorded from S_3V_2 (Submergence for 10 days in BR5).

The highest no. of effective tiller and filled grain (12.35 and 120.19) was obtained from control (S_0) treatment and the lowest no. of effective tiller (11.80 and 94.33) was obtained from S_3 (submergence for 10 days) treatment. The highest no. of effective tiller and filled grain (12.65 and 75.64) was recorded from V_3 (BRRIdhan 52) whereas, the lowest no. of effective tiller (10.78 and 138.49) was recorded from V_2 (BR5). The highest no. of effective tiller and filled grain (13.85 and 150.39) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest no. of effective tiller (9.88 and64.25) was recorded from S_3V_2 (Submergence for 10 days in BR 5).

The highest 1000 grain weight (24.00 g) was obtained from control (S_0) treatment and the lowest 1000 grain weight (20.33 g) was obtained from S_3 (submergence for 10 days) treatment. The highest 1000 grain weight (27.24 g) was recorded from V_1 (FR13A) and the lowest 1000 grain weight (15.17 g) was recorded from V_2 (BR5). Interaction effect, the highest 1000 grain weight (29.23 g) was recorded from the S_0V_1 (Control treatment with FR13A) and the lowest 1000 grain weight (12.75 g) was recorded from S_3V_2 (Submergence for 10 days in BR 5).

Control treatment produced the lowest no. of ineffective tiller and unfilled grain (2.54 and 27.71) was obtained from control (S_0) and the highest (3.28 and 35.98) was obtained from S_3 (submergence for 10 days) treatment. The lowest no. of ineffective tiller and unfilled grain (2.52 and 23.76) was recorded from V_3 (BIRRIdhan 52) and the highest (3.13 and 32.27) was recorded from V_1 (FR13A). The lowest no. of ineffective tiller and unfilled grain (2.05 and 20.51) was recorded from the S_0V_5 (Control treatment with BINAdhan 12) and the highest no. of ineffective tiller (3.78 and 40.10) was recorded from S_3V_1 (Submergence for 10 days in FR13A) (Table 9).

The lowest days to maturity (115.95 days) was obtained from control (S_0) treatment. The lowest days to maturity (114.38 days) was recorded from V_5 (BINAdhan 12). In interaction effect, the lowest days to maturity (101.75 days) was recorded from the S_0V_5 (Control treatment with BINAdhan 12) and the highest (170.50 days) was recorded from S_3V_4 (Submergence for 10 days in BRRIdhan 46).

Control treatment i.e.; no submergence produced the highest grain, straw and biological yield (3.95, 5.93 and 9.88 t ha^{-1}) was obtained from control (S_0) treatment and the lowest grain yield (3.21, 5.33 and 8.54 t ha^{-1}) was obtained from S_3 (submergence for 10 days) treatment. BRRIdhan52 variety produced the highest grain straw and biological yield (4.58, 6.32 and 10.90 t ha^{-1}) was recorded from V_3 (BRRIdhan 52) whereas, the lowest grain yield (2.36, 4.66 and 7.12 t ha^{-1}) was recorded from V_2 (BR5). Interaction effect, the highest grain straw and biological yield (4.81, 6.17 and 10.98 t ha^{-1}) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest (1.70, 4.23 and 5.99 t ha^{-1}) was recorded from S_3V_2 (Submergence for 10 days in BR 5).

The highest harvest index (39.80 %) was obtained from control (S_0) treatment and the lowest (36.94 %) was obtained from S_3 (submergence for 10 days) treatment. The highest harvest index (42.05 %) was recorded from V_3 (BRRIdhan 52) whereas, the lowest (32.81 %) was recorded from V_2 (BR5). The highest harvest index (43.84 %) was recorded from the S_0V_3 (Control treatment with BRRIdhan 52) and the lowest (29.39 %) was recorded from S_3V_5 (Submergence for 10 days in BINAdhan 12).

Conclusion:

Considering the results of the present experiment, it could be concluded that-

- In submerged condition plant was submerged for 0, 4, 7 and 10 days at panicle initiation stage. Results reflected that submerged condition was not good for all the varieties. Plants of submergence showed the best yield and better yield contributing characters.
- In case of variety, BRRIdhan 52 was superior followed by FR13A> BRRIdhan 46> BINAdhan 12> BR5 in *Aman* season in consideration of growth and yield attributes among the afore-mentioned five varieties. BRRIdhan 52 ultimately leaded to the higher dry matter production. Panicles hill^{-1}, effective tiller, filled grain and 1000-grain weight were the determinants for the higher grain yield of the BRRIdhan 52.

Recommendations:

Considering the results of the present experiment, it could be recommended that-

- However, to reach a specific conclusion and to provide reasonable recommendation, more research works on different rice varieties regarding the influence of submergence levels in *Aman* season are needed.

REFERENCES

Ahmad, S.T., Awan, H, Hussain, A., Ahmad, A., and Ali, H. (2005). Effect of plant density and nitrogen rates on growth radiation use efficiency and yield of fine rice. Proceedings of the International Seminar on Rice Crop, Oct. 2-3, 2005.

Ahmed, A.U. and Mirza, M.M.Q. (2000). Review of causes and dimensions of floods with particular reference to Flood 1998: National Perspectives. In Ahmed, Q.K., Chowdhury, A.K.A., Imam, S.H., Sarker, M. (Eds.), Perspectives on Flood 1998 (65-89), Dhaka: University Press Limited.

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

Awala, S.K.; Nanhapo, P.I.; Sakagami, J-I.; Kanyomeka, L. and Iijima, M. (2010). Differential Salinity Tolerance among *Oryza glaberrima*, *Oryza sativa* and Their Interspecies Including NERICA. *Plant Prod. Sci.,***13** (1): 3–10.

BBS (Bangladesh Bureau of Statistics). (2012). Statistical year book of Bangladesh. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Govt. of the people’s Republic of Bangladesh. pp. 17-20.

BBS (Bangladesh Bureau of Statistics). (2019). Statistical year book of Bangladesh. Bangladesh Bureau of Statistics, Statistics Division, Ministry of Planning, Govt. of the people’s Republic of Bangladesh. pp. 27-29.

BRRI (Bangladesh Rice Research Institute). (2012). Adhunik Dhaner Chash (in Bengali). Pub No. 5. Bangladesh Rice Res. Inst., Joydebpur, Gazipur. pp. 12-23.

Chu, M., Liu, M., Ding, Y., Wang, S., Liu, Z., Tang, S., ... & Li, G. (2018). Effect of nitrogen and silicon on rice submerged at tillering stage. *Agron. J.*, **110**(1), 183-192.

Das, K.K.. Sarkar. R.K. and Ismail, A.M. (2005). Eiongation ability and non-structural carbohydrate lcvels in relation to submergence tolerance in rice. *Plant. Sci.,* **168**: 13 1-13 6.

Das. K. K., Panda. D.. Sarkar, R.K., Reddy, J.N. and Ismail, A. M. (2009). Submergence tolerance in relation to variable floodwater conditions in rice. *Em'. and Erpi. Rot.,* **66**: 425-434.

Debnath, A., Biswas, P.K., Sardar, M.S.A. AND Rahman, A. (2012). Influence of mother and clonal tillers on yield performance of inbred and hybrid boro rice. *Bangladesh Agron. J.* **15**(1):1-7.

Dewan, A.M., Nishigaki, M., Komatsu, M. (2003). Floods in Bangladesh: A comparative hydrological investigation on two catastrophic events. *J. Faculty Environment. Sci. Technol.*, **8**(1): 53-62.

Dewan, T.H. (2015). Societal impacts and vulnerability to floods in Bangladesh and Nepal. *Weather and Climate Extremes*, **7**: 36-42.

Dey, M.M. and Upadhyaya, H.K. (1996). Yield loss due to drought, cold and submergence in Asia, In: Rice Research in Asia; Progress and Priorities, CAB International Wallingford, UK. pp. 291-303.

Dingkuhn, M., jones, M.P., Johnson, D.E. and sow, A. (1998). Growth and yield potential of *Oryza glaberrima* and *Oryza sativa* upland rice cultivars and their interspecific progenies. *Field Crops Res.,* **57**(1): 57-69.

Ella, E.S., Bui, L.T. and Ismail, A.M. (2014). Effect of submergence at the vegetative stage on rice roots. Conference: 4th International Rice Congress, Bangkok, Thailand.

Ella, E.S., Kawano. N., Yamauchi, Y.. Tanaka K. and Ismail, A.M. (2003). Blocking cthylene perception enhances flooding tolerance in rice seedlings. *Func. Plant Biu.,* **30**: 8I3-819.

Garibaldi, R., Stone, M. J., Wolf, E., and Pozzi, A. (2017). Wine travel in the United States: A profile of wine travellers and wine tours. *Tourism management perspectives.*, **23**: 53-57.

Gomosta, A.R., Quayyum, H.A. and Mahbub, A.A. (2001) Tillering duration and yielding ability of rice varieties in the winter rice season of Bangladesh. Ed. Peng, S and Hardy, B. Rice research for food security and poverty alleviation proceedings of the International Rice Research Conference, Los Banos, Philippines, 31 March 3 April, 2000. 87-94.

Goswami, S., Labar, R., Paul, A., Adak, M.K. and Dey, N. (2015). Physio Biochemical and Genetic Exploration for Submergence Tolerance in Rice (*Oryza sativa* L.) Landraces with Special References to Sub1 Loci, *American J. Plant Sci.,***6**, 1893-1904.

Guilani, A.A., Siadat, S.A. and Fathi, G. (2003). Effect of plant density and seedling age on yield and yield components in three rice culitvars in Khusestan growth conditions. *Iranian J. Agric. Sci.* **34**(2): 427-438.

Hassan, M. J., Karim, M. M., Islam, M. A., Pramanik, M. H. R., & Hossain, M. A. (2019). Changes in root porosity and water soluble carbohydrates in rice (Oryza sativa L.) under submergence stress. *J. Bangladesh Agril. Univ.*, **17**(4), 539-544.

Hawlader, M.S.H., Sarkar, B.K. and Nessa, Z. (2004). Participatory evaluation of 'BRRI hybrid dhanl' in Faridpur District of Bangladesh. *Bulletin of the Institute of Tropical Agriculture*, Kyushu University. **26**: 17-22.

Inouye, J., Hakoda, H. and Ng, N.Q. (1989). Per-limitary studies on some ecological characteristics of African deep water rice. *Japanese J. Trop. Agric.*, **33**(3): 158-163.

Islam, M.S., Haque, M.Z., Jabber, M.A., Basak, A.K. and Paul, P.K. (1997). Effect of simulated rainfall at reproductive to ripening stages on the growth and yield of transplant aman rice. *Ann. J. Bangladesh Agric.* **7**(2): 105-110.

Islam, M.S.H., Bhuiya, M.S.U., Gomosta, A.R., Sarkar, A.R. and Hussain, M.M. (2009). Evaluation of growth and yield of selected hybrid and inbred rice varieties grown in net-house during transplanted aman season. *Bangladesh J. Agric. Res.* **34**(1): 34-45.

Karim, M. M., Hassan, M. J., Pramanik, M. H. R. and Hossain, M. A. (2019). Morpho-phenological traits and yield performance of rice cultivars as affected by submergence stress. *J. Bangladesh Agril. Univ.*, **17**(4), 545-550.

Kawano, N., Ito, 0. and Sakagami, J. (2009). Morphological and physiological responses of rice seedlings to complete submergence (flash flooding). *Ann. Sot.*, **103**:161-169.

Kreft, S., Eckstein, D. and Melchior, I. (2016). Global Climate Risk Index 2017: Who suffers most from extreme weather events? Weather-related Loss Events in 2015 and 1996 to 2015. Briefing Paper, Germanwatch e.V., Bonn.

Kurokawa, Y., Nagai, K., Huan, P. D., Shimazaki, K., Qu, H., Mori, Y., ... and Itoh, J. I. (2018). Rice leaf hydrophobicity and gas films are conferred by a wax synthesis gene (LGF 1) and contribute to flood tolerance. *New Phytologist.*, ***218***(4), 1558-1569.

Mahmud, S. U. J. A. N., Hassan, M. M., Rahman, M. M., and Jannat, M. (2017). Response of short duration aman rice varieties to date of transplanting. *J. Bangladesh Agril. Univ.*, **15**(1): 1-6.

Majerus, V.; Bertin, P. and Lutts, S. (2007) Effects of iron toxicity on osmotic potential, osmolytes and polyamines concentrations in Africa rice (*Oryza glaberrima* Steud.). *Plant Sci.*,**173** (2): 96–105.

Maplecroft (2016). Climate Change Vulnerability Index 2017. Available at https://maplecroft.com/about/news/ccvi.html.

Michael, B. and Phool, C. (2001). Physiology and Molecular Basis of Susceptibility Tolerance of rice plant to complete submergence, *Annals Bot.*, **35**: 18-35.

Mulbah, Q. S. (2010). Effect of Simulating Flooding Pattern on Nitrogen Management In Rice (*Otyza Sativa* L.) Production.

Murshida, S., Uddin, M. R., Anwar, M. P., Sarker, U. K., Islam, M. M., and Haque, M. M. I. (2017). Effect of variety and water management on the growth and yield of Boro rice. *Progressive Agriculture,* **28**(1): 26-35.

Nagarathna, T.K. and Prakasha, H.C. (2007). Relative nitrogen use efficiency in hybrids and inbred cultivars of rice (*Oryza sativa*). *Environ. Ecol.* **25**S (Special 3A): 820-822.

Nio, S.A., Siahaan, R. and Ludong, D.P.M. (2019). Partial Submergence Tolerance in Rice (*Oryza sativa* L.) Cultivated in North Sulawesi at the Vegetative Phase. *Pakistan J. Biol. Sci.,* **22**: *95-102.*

Nwilene, F.E.; Traore, A.K.; Asidi, A.N.; Sere, Y.; Onasanya, A. and Abo, M.E. (2009). New records of insect vectors of rice yellow mottle virus (RYMV) in Cote d'Ivoire, West Africa. *J. Entom.,* **6** (4): 189–197.

Perata, P. and Voesenek, L.A.C.J. (2007). Submergence tolerance in rice requires Sub/A,an ethylene-response- factor-like gene. *Plant Sci.,* **12**: 43-45.

Rahman, M. M., Samanta, S. C., Rashid, M. H., Abuyusuf, M., Hassan, M. Z., and Sukhi, K. F. N. (2016). Urea super granule and NPK briquette on growth and yield of different varieties of aus rice in tidal ecosystem. *Asian J. Crop Sci.,* **8**(1), 1-8.

Rahman, R.B. and Zhang, J. (2016). Flood and drought tolerance in rice: Opposite but may coexist. *Food and Energy Security,* **5**(2): 76-88.

Rana, M. M., Al Mamun, M. A., Zahan, A., Ahmed, M. N., and Mridha, M. A. J. (2014). Effect of planting methods on the yield and yield attributes of short duration Aman rice. *American J. Plant Sci.,* **20**: 1-14.

Rautaray, S.K. (2006). Yield and economics of promising rice (*Oryza sativa)* hybrids under double transplanting in late spring summer (boro) situation. *Indian J. Agril. Sci.,* **76**(8): 469-471.

Ray, S., Sarkar, M. A. R., Paul, S. K., Islam, A. K. M. M., and Yeasmin, S. (2015). Variation of growth, yield and protein content of transplant Aman rice by three agronomic practices. *Agril. Biol. Sci. J.*, **1**(4), 167-176.

Sakagami, J.I., Isoda, A., Nojima, H. and Takasaki, Y. (1999). Growth and survival rate after maturity in *Oryza sativa* L. and *O. glaberrima* Stead. *Japanese J. Crop Sci.* **68**(2): 257-265.

Salam, M.A., Siddique, M.A.B. and Parvin, J. (2012) Assessment of technical efficiency of inbred HYV and hybrid rice cultivation at farm level. *Bangladesh J. Agril. Res.* **37**(2): 235-250.

Salma, M. U., Salam, M. A., Hossen, K., and Mou, M. R. J. (2017). Effect of variety and planting density on weed dynamics and yield performance of transplant Aman rice. *J. Bangladesh Agril. Univ.*, **15**(2), 167-173.

Sarkar, R. K., Reddy, J. N.. Sharma, S. G. and Ismail, A. M. (2006). Physiological basis of submcrgcnce tolerance in rice and implications for crop improvement. *Current Sci.*, **91**: 899-906.

Septiningsih, E. M., Pamplona, A. M., Sanchez, D. L., Neeraja, C. N., Vergara, G. V., Heuer, S., ... and Mackill, D. J. (2009). Development of submergence-tolerant rice cultivars: the Sub1 locus and beyond. *Annal. Bot.*, **103**(2), 151-160.

Setter. T. 1., Ellis, M.. Laureles, P. V., Ella. E. S., Senadhira, D., Nlishra, S. B., Sarkarung. S.. and Datta. S. (1997). Physiology and Genetics of Submergence Tolerance in Rice. *Ann. of Hot.*, **79**: 67-77.

Singh, I.T.P., Singh, B.B. and Ram. P.C. (2001). Submergence tolerance of rainfed lowland rice: search for physiological marker traits. *J. Plant Physiol.*, **158**: 883-889.

Steffens, B. and Sauter, M. (2005). Epidermal Ccli Death in Rice Is Regulated by Ethylene, Gibberellin and Abseisic Acid. *Plant Physiol.*, **139**: 713-721.

Swain, P., Annie, P., Ndjiondjop, M.N., Cheron, S., sere, Y., Ake, S., Ghesquiere, A. and Albar, L. (2010). Identification of a second major resistance gene to Rice yellow mottle virus (RYMV) in the African cultivated rice species. *Theor. Appli. Genetics* **121**(1): 169-179.

Tejakhod, S., and Ellis, R. H. (2018). Effect of simulated flooding during rice seed development and maturation on subsequent seed quality. *Seed Sci. Res.*, **28**(1), 72-81.

Thiemele, D.; Boisnard, A.; Ndjiondjop, M.N.; Cheron, S.; Sere, Y.; Ake, S.; Ghesquiere, A. and Albar, L. (2010). Identification of a second major resistance gene to Rice yellow mottle virus, RYMV2, in the African cultivated rice species, *O. Glaberrima*. *Theoret. Applied Genet.*,**121** (1): 169–179.

Wang, J.L., Xu, Z.J. and Yi, X.Z. (2006). Effects of seedling quantity and row spacing on the yields and yield components of hybrid and conventional rice in northern Chain. *Chinese J. Rice Sci.* **20**(6): 631-637.

Xia, W., Wang, G. and Zhang, Q. (2007). Potential production simulation and optimal nutrient management of two hybrid rice varieties in Jinhua, Zhejiang Province. *J. Zhejiang Univ. Sci.* **8**(7): 486–492.

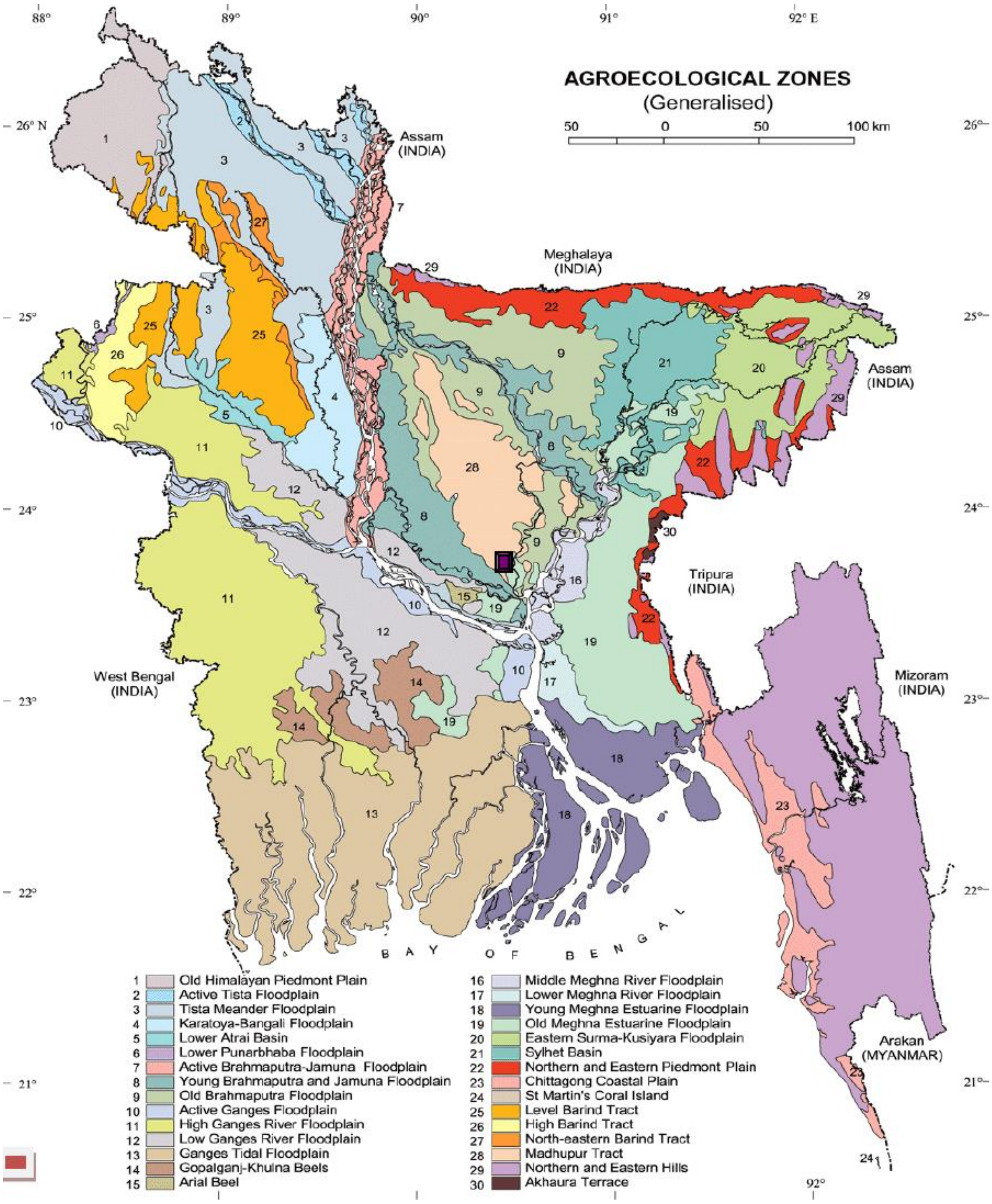
Yadav, V., Prasad, S., Singh, S., and Verma, O. P. (2018). Effect of submergence stress on yield and yield components of various rice (Oryza sativa L.) genotypes with its mapping population. *J. Pharmacog. Phytochem.*, **7**(6), 2386-2389.

Zeigler, R.S. and Puckridge, D.W. (1995). Improving sustainable productivity in rice based rainfed lowland systems of south and southeast Aisa. *Geo. Journal.* **35**: 307-324.

Zhang, Y., Wang, Z., Li, L., Zhou, Q., Xiao, Y., Wei, X., and *et al.* (2015). Short-Term Complete Submergence of Rice at the Tillering Stage Increases Yield. *Plos One* **10**(5): e0127982. https://doi.org/10.1371/journal.pone.0127982

Appendices

Appendix I. Map showing the experimental site under the study



The experimental site under study

Appendix II: Morphological, physical and chemical characteristics of initial soil (0-15 cm depth) of the experimental site

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University, 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 composition of the soil

Soil separates	%	Methods employed
Sand	36.90	Hydrometer method (Day, 1915)
Silt	26.40	Do
Clay	36.66	D0
Texture class	Clay loam	Do

C. Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.82	Walkley and Black, 1947
2	Total N (kg/ha)	1790.00	Bremner and Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lanester, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner, 1965
6	Available P (kg/ha)	69.00	Olsen and Dean, 1965
7	Exchangeable K (kg/ha)	89.50	Pratt, 1965
8	Available S (ppm)	16.00	Hunter, 1984
9	pH (1:2.5 soil to water)	5.55	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Source: Central library, Sher-e-Bangla Agricultural University, Dhaka.

Appendix III. Monthly average Temperature, Relative Humidity and Total Rainfall and sunshine of the experimental site during the period from July, 2018 to January, 2019

Month	Air temperature (ºc)		Relative humidity (%)	Rainfall (mm) (total)
	Maximum	Minimum		
July, 2018	34.7	24.6	65	185.0
August, 2018	32.6	23.8	68	162.2
September, 2018	30.6	21.8	75	82.2
October, 2018	29.1	18.2	81	39.1
November, 2018	25.82	16.0	78	0
December, 2018	22.4	13.5	74	0
January, 2019	24.5	12.4	68	0

Appendix IV: Analysis of variance of plant height of aman rice at different days after transplanting

Source of variance	d.f.	Mean square of plant height (cm)				
		20	40	60	80	At harvest
Replication	3	26.461	56.725	143.525	39.06	92.64
Factor A	3	35.58**	150.77**	583.47**	1289.35**	1282.14**
Error-I	9	0.603	1.668	2.396	3.06	2.90
Factor B	4	257.85**	180.78**	728.29**	2424.64**	2711.49**
A×B	12	2.41NS	11.51*	42.19**	163.47**	165.68**
Error-II	48	5.225	5.634	6.747	33.52	24.72
Total	72					

d.f. = Degree of freedom

Appendix V: Analysis of variance of leaves number of aman rice at different days after transplanting

Source of variance	d.f.	Mean square of leaf number				
		20 DAT	40 DAT	60 DAT	80 DAT	At harvest
Replication	3	3.3000	7.546	11.546	42.45	21.08
Factor A	3	2.2333**	111.413**	151.413**	289.48**	342.68**
Error-I	9	0.1778	0.159	0.179	0.17	1.27
Factor B	4	28.3437**	134.243**	334.269**	1146.51**	1237.46**
A×B	12	0.1604^{NS}	1.194^{NS}	17.194*	14.02*	55.13*
Error-II	48	0.7396	4.021	7.021	6.52	4.25
Total	72					

d.f. = Degree of freedom

Appendix VI: Analysis of variance of tiller number of aman rice at different days after transplanting

Source of variance	d.f.	Mean square of tiller number				
		20 DAT	40 DAT	60 DAT	80 DAT	At harvest
Replication	3	1.045	12.246	25.946	33.350	29.383
Factor A	3	9.145^{NS}	48.913*	98.579*	122.350*	107.417*
Error-I	9	2.734	12.357	23.135	29.828	26.394
Factor B	4	38.487**	106.094**	209.687**	273.019**	254.125**
A×B	12	0.562	22.569*	43.829*	64.152*	44.542*
Error-II	48	3.427^{NS}	8.267	16.994	22.010	19.537
Total	72					

d.f. = Degree of freedom

Appendix VII: Analysis of variance of SPAD value, emergence leaf number and rotten leaf of aman rice

Source of variance	d.f.	Mean square			
		SPAD value	Leaf no. before emergence	leaf no. After emergence	Rotten leaf
Replication	3	0.73	206.05	678.90	13.05
Factor A	3	4.06**	5843.88**	4918.03**	3109.25**
Error-I	9	0.52	485.58	467.67	8.81
Factor B	4	98.92**	6592.08**	6553.71**	29.51*
A×B	12	18.36*	1627.15*	1687.77*	36.33*
Error-II	48	0.82	635.50	514.84	17.14
Total	72				

d.f. = Degree of freedom

Appendix VIII: Analysis of variance of panicle emergence time leaf of aman rice

Source of variance	d.f.	Mean square of panicle emergence		
		1st	50%	100%
Replication	3	0.412	4.98	23.81
Factor A	3	418.979**	998.65**	2199.65**
Error-I	9	13.424	3.72	25.91
Factor B	4	698.487**	1253.50**	2010.87**
A×B	12	48.937**	112.04**	158.62**
Error-II	48	14.108	8.30	21.72
Total	72			

d.f. = Degree of freedom

Appendix IX: Analysis of variance of leaf, stem and root of aman rice

Source of variance	d.f.	Mean square		
		Leaf dry weight	Stem dry weight	Root dry weight
Replication	3	3.548	4.676	0.2782
Factor A	3	27.192**	46.157**	2.1444**
Error-I	9	0.091	0.306	0.0083
Factor B	4	113.655**	213.959**	8.3517**
A×B	12	3.333**	3.167**	0.2326**
Error-II	48	0.132	0.162	0.012
Total	72			

d.f. = Degree of freedom

Appendix X: Analysis of variance of yield contributing characters of aman rice

Source of variance	d.f.	Panicle length	In effective tillers	Effective tillers
Replication	3	0.705	0.698	3.627
Factor A	3	41.422**	2.236**	3.467**
Error-I	9	1.701	0.064	0.155
Factor B	4	43.773**	1.527**	9.303**
A×B	12	7.549**	0.220**	2.815**
Error-II	48	1.689	0.082	0.387
Total	72			

d.f. = Degree of freedom

Appendix XI: Analysis of variance of yield contributing characters of aman rice

Source of variance	d.f.	Filled grain	Unfilled grain	Days to Maturity	1000 grain weight (g)
Replication	3	16.52	77.100	113.25	5.453
Factor A	3	2493.90**	426.129**	2159.75**	46.28**
Error-I	9	0.05	8.238	144.35	2.099
Factor B	4	8268.52**	189.402**	2208.86**	427.27**
A×B	12	18.94**	14.217**	232.84*	9.68*
Error-II	48	6.61	7.999	123.64	3.687
Total	72				

Appendix XII: Analysis of variance of yield characters of aman rice

Source of variance	d.f.	Grain yield	Straw Yield	Biological Yield	Harvest Index
Replication	3	0.0104	0.0165	0.0205	1.168
Factor A	3	2.0033**	1.2587**	6.4146**	32.628**
Error-I	9	0.0003	0.0069	0.006	0.192
Factor B	4	10.4075**	5.0529**	29.859**	189.900**
A×B	12	0.0910**	0.2050**	0.5089**	5.083**
Error-II	48	0.0069	0.0236	0.0362	0.573
Total	72				

d.f. = Degree of freedom