EFFECT OF DOUGH STAGE SUBMERGENCE ON THE YIELD OF HIGH YIELDING RICE VARIETIES

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CERTIFICATE

This is to certify that the thesis entitled, **"*effect of dough stage submergence on the yield of high yielding rice varieties*"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN AGRICULTURAL BOTANY**, embodies the result of a piece of *bonafide* research work carried out by ***Shamima Shahriah***, Registration No. *08-02702* 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 during the course of this investigation has been duly acknowledged and style of this thesis have been approved and recommended for submission.

Dated- December, 2014
Dhaka, Bangladesh

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Dedicated To

My Beloved Parents

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EFFECT OF DOUGH STAGE SUBMERGENCE ON THE YIELD OF HIGH YIELDING RICE VARIETIES

ABSTRACT

The pot experiment was conducted at the Agricultural Botany field area of central research farm of Sher-e-Bangla Agricultural University, Dhaka, during the period from December, 2013 to April, 2014 to find out the effect of dough stage submergence on the yield of high yielding rice varieties. Treatments included in the two factors experiment were as follows: factor A: Submergence period- S_1 – Control/No submergence, S_2 – Submergence for 4 days, S_3 - Submergence for 9 days, S_4 - Submergence for 14 days and factor B: varieties- V_1 – BRRI dhan 28, V_2 – BRRI dhan 29, V_3 – BRRI hybrid dhan 2, V_4 – BRRI hybrid dhan 3, V_5 – TIA (an exotic variety). The experiment was laid out in Randomized Complete Block Design (RCBD) with five replications. Results showed that plant height, number of tiller plant^{-1}, number of fresh leaves plant^{-1}, number of rotten leaves plant^{-1}, 1%, 50%, 100% booting stage, 1%, 50% panicle initiation stage, 1%, 50%, 100% milking stage, days to maturity, weight of leaf, weight of leaf sheath, weight of root, weight of stem, panicle length, number of fertile panicles plant^{-1}, number of infertile panicles plant^{-1}, number of fertile seeds plant^{-1}, number of infertile seeds plant^{-1}, number of fertile grains tiller^{-1}, number of unfertile grains tiller^{-1}, 1000 grains weight, weight of fertile grains plant^{-1}, weight of unfertile grains plant^{-1} was significantly influenced by submergence and/or rice varieties. Among the treatment combinations maximum plant height, number of tillers plant^{-1} and panicle length were recorded from rice plants of S_1V_5 irrespective of growing condition. The maximum number of fertile seeds plant^{-1}, 1000 grains weight and weight of fertile grains plant^{-1} were found when no submergence with the normal cultivation of exotics hybrid variety TIA was practiced. Among the varieties BRRI hybrid dhan 2 can be suggested for possible submergence condition for 9 days and BRRI hybrid dhan 3 can be suggested for possible submergence condition up to 14 days.

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ABBREVIATIONS AND ACRONYMS

%	:	Percentage
@	:	At the Rate of
Abstr.	:	Abstract
AEZ	:	Agro-ecological Zone
Agric.	:	Agriculture
AVRDC	:	Asian Vegetables Research and Development
BARC	:	Bangladesh Agricultural Research Council
BARI	:	Bangladesh Agricultural Research Institute
BAU	:	Bangladesh Agricultural University
BBS	:	Bangladesh Bureau of Statistics
BCR	:	Benefit Cost Ration
cm.	:	Centimeter
cv.	:	Cultivar
DAS	:	Day After Sowing
et al.	:	et alii (and others)
FAO	:	Food and Agriculture Organization Of the United Nations
Fig.	:	Figure
FW	:	Fresh weight
FYM	:	Farm Yard Manure
G	:	Gram
Hort.	:	Horticulture
i.e.	:	That is
J.	:	Journal

K	:	Potassium
Kg	:	Kilogram
LSD	:	Least Significant Difference
M	:	Meter
MP	:	Murate of Potash
N	:	Nitrogen
NS	:	Non-significant
^{O}C	:	Degree Celsius
P	:	Phosphorus
RCBD	:	Randomized Complete Block Design
Sci.	:	Science
Soc.	:	Society
T	:	Tonne
ton/ha	:	Ton per hectare
Tk.	:	Taka
TSP	:	Triple Super Phosphate
UK	:	United Kingdom
UNDP	:	United Nations Development Program
Viz.	:	Namely

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Rice, *Oryza sativa* L. belonging to the family *Graminae* and subfamily *Oryzoideae* is the staple food for half of the world's population. With a compact genome, the cultivated rice species *Oryza sativa* represents model for other cereals as well as other monocot plants (Shimamoto and Kyozuka, 2002). Rainfed lowlands constitute highly fragile ecosystems, always prone to flash-floods (submergence). Among the 42 biotic and abiotic stresses affecting rice production, submergence has been identified as the 3rd most important constraint for higher rice productivity causes total yield loss (Sarkar *et al.*, 2006). Scientists have estimated that 4 million tons of rice is being lost every year because of flooding (IRRI, 2012).

Rice (*Oryza sativa* L.) is one of the most important staple food crops, which supplies major source of calories for above 45% of the world population. Particularly to the people of Asian countries. Rice the stands second in the world after wheat in area and population. It occupies an area of 153.76 m. ha with an annual production of 598.85 mt. with a productivity of 4895 kg ha^{-1} in the world (FAO, 2012). Asia produces and consumes 90% of world's rice. Among the rice growing countries, India ranks the 1st in area following by China and Bangladesh. Rice is a major cereal crop of India occupied an area of 41.91 m. ha and production of 83.13 mt. with average productivity of 8.84 t ha^{-1} (FAO, 2013).

Rice is the most important cereal crop in Bangladesh and it is also our staple food. Approximate 75% of the total cultivated land covering about 11.58 million ha produces approximate 30 million tons of rice annually (BBS 2012). The 2nd largest part of the total production of rice comes of Aman rice after Boro. Bangladesh earns about 31.6% of her Gross Domestic Product (GDP) from agriculture

(BBS, 2013) in which rice is the main crop. Agriculture in Bangladesh is characterized by intensive crop production with rice based cropping system. Rice is also the principal commodity of trade in our internal agricultural business. The average yield of rice in our country is around 4.57 t ha^{-1} which is less than the world average (7.48 t ha^{-1}) and frustratingly below the highest yield recorded (9.65 t ha^{-1}) in Australia (FAO, 2014). On the other hand, HYV (High Yielding Variety) is cultivated in 40,67,000 ha land and total production of rice is 156,32,000 m tons and the average rice production of hybrid varieties is 4.41 m tons and HYV varieties are 3.84 m ton in the year of 2013-2014 (BBS, 2014).

Although the soil and climate of Bangladesh are favorable for rice cultivation throughout the year but per ha yield of this crop is much below the potential yield level. The reasons are manifolds, some are varietals, some are technological and some are ecological. On the contrary every year thousands of ha of lands are bared and remain uncultivated due to different reasons, we can increase our rice production by utilizing these lands. But flash flood in Aman season is one of the main reason for remaining rice fields uncultivated. These lands become water free in the late season of the Aman. In this aspect variety of Aman rice which is able to escape the effect of submergence can help the farmers of Bangladesh.

Flash flood and submergence are widespread in south-east Asia, Bangladesh and north eastern India and affect at least 22 million ha (16% of world rice lands) including 15 million ha of potential short duration flash floods in rain fed lowlands and 5 million ha of deep water rice (Khush, 1984). Eastern India alone has approximately 10 million ha of rice lands affected by flash floods and complete submergence (Reddy and Sharma, 1992).

Submergence stress is a common environmental challenge for agriculture sustainability in many regions throughout the world. Partial-to-complete submergence of aerial organs considerably reduces the growth and survival of most crop plants. The negative impact of submergence on economic plants is mainly related to a poor gas exchange under water through impeding biochemical activities such as aerobic respiration and photosynthesis (Das *et al.*, 2005; Bailey-Serres and Voesenek, 2008; Colmer andVoesenek, 2009). Acclimation responses to these conditions are specific and genotype-specific. Modification of morphology and anatomy of shoots and switching the energy conversion modes from aerobic to anaerobic respiration can ameliorate the negative effects of submergence (Fukao *et al.*, 2006; Mommer *et al.*, 2007).

Flood is the most damaging among the serious problems of agriculture. According to an estimate of National Bureau of Soil Survey and Land Use Planning nearly 33 m ha of land is affected by flood of varying degree. The flooded area, severity of flooding and the scale of damage are alarmingly increasing over the year. Moreover, under changing climatic scenarios, crops will be exposed more frequently to episodes of drought, high temperature and flood.

In Bangladesh, rainfed low land rice covers an area of 4.5 million ha (Islam *et al.*, 1997) and is grown by transplanting aman rice from June-September, the peak period of monsoon rainfall. As a result following its transplanting as well as at early growing stage the crop is often submerged by flash food due to continuous rainfall as well as due to onrush of flood water heavy damage to standing crop. As a result yield of rice grain is severely decreased (Zeigler and Puckridge, 1995). Dey *et al*. (1996) reported that the abiotic factors submergence and drought are the two constraints in rainfed aman rice. Submergence at the seedling stage causes deterioration in the seedling quality resulting in a poor stand and causes substantial yield loss. Dey and Upadhyaya (1996) reported that abiotic stress like drought, cold and submergence causes 93, 10 and 140 kg ha^{-1} yield loss, respectively in Bangladesh. Sometimes it causes total crop failure. So, flooding is an important constraint in T. Aman rice (Haque, 1980). The successful development of high yielding rice cultivars with submergence tolerance may be an effective alternative for saving huge losses of food crops.

The population of Bangladesh is still increasing by 2.3 million every year to its total of 160 milloin and may increase by another 30 million over the next 20 years. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020. During this time total rice area will also shrink to 10.28 million ha. Rice (clean) yield therefore, needs to be increasing from the present 2.45 to 3.74 t ha^{-1}. Therefore, it is an urgent need of the time to increase the production of rice through increasing the yield ha^{-1}. Among the various factors limiting rice yield through submergence is very important one. Nearly, a third of the country is susceptible to tidal inundation and nearly 70% of the country gets flooding during heavy monsoon (Rahman, 2011). About 2.6 million ha rice lands are unfavorably affected by excess water for incessant rainfall in aman season and periodically suffer from flash floods with complete submergence for 1-2 weeks or more cobering about 24% of the total rice areas (Mazid *et al.*, 2008).

Submergence stress tolerant varieties are the most desirable trait for rice farmers in our country, where flash flooding occurs frequently and unpredictable during monsoon. It has become farmer’s main objective to improve submergence tolerance in rice varieties. Specially, sudden flooding in early stage, reproductive stage and harvesting stage of rice is observed in Bangladesh occasionally, which causes un-repairable loss to the crop and production of rice is reduced to alarming rate in certain years. Thousands of hectares of Boro rice lands are inundated and submerged at Sylhet, Mymensingh, Kishorganj, larger Rangpur, tangail, Mainkganj, Munshiganj, Comilla and Noakhali districts during monsoon rainfull when Boro rice is flowering, maturing and ripening stage causing tremendous damage to the rice crop. So, it is a prime need to conduct research work on available commercial hybrid rice varieties. Considering the above proposition, this research work has been undertaken to investigate the effect of submergence stress on morphological attributes and yield of some selected yield rice varieties.

Based on the facts, the present study was undertaken with the following objectives:

(i) To find out the effect of different duration of dough stage submergence on the yield of some high yielding rice varieties,

(ii) To find out the tolerance level of some rice varieties in respect of grain weight reduction to dough stage submergence during Boro season.

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Variety and submergence are important factors that influences the plant population unit area^{-1}, availability of sunlight, nutrient competition, photosynthesis, respiration etc. which ultimately influence the growth and development of the crops. Research works relevant to variety and submergence effects on crop plants conducted in different parts of the world have been reviewed in this chapter.

2.1 Effect of variety

Variety itself is the genetical factor which contributes a lot for producing yield and yield components. Different researcher reported the effect of rice varieties on yield contributing component and grain yield. Some available information and literature related to the effect of variety on the growth and yield of rice are discussed below:

Colmer and Voesenek (2009) reported that hybrid IR58025A out yielded the IR62829A hybrids and the three control varieties Jaya, IR36 and hybrids IR58025A × 9761-191R and IR58025A × IR35366-62-1-2-2-3R.

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 and 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.

Swain *et al.* (2006) 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.

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 %.

Guilani *et al.* (2003) syudied 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.

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

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

Devaraju *et al.* (1998) in a study with two rice hybrids such as Karnataka Rice Hybrid 1 (KRH1) and Karnataka Rice Hybrid 2 (KRH2) using HYV IR20 as the check variety and that HRH2 out yielded than IR20. In IR20, the tiller number was higher than that of KRH2.

Kamal *et al.* (1998) evaluated BR3, IR20 and Pajam2 and found that number of grain panicle^{-1} were 107.6, 123.0 and 170.9, respectively, for the varieties.

Om *et al*. (1998) in an experiment with hybrid rice cultivars ORI 161 and PMS 2A × IR 31802 found taller plants, more productive tillers, in ORI 161 than in PMS 2A × IR 31802.

Son *et al.* (1998) reported that dry matter production of four inbred lines of rice (low-tillering large panicle type), YR15965ACP33, YR17104ACP5, YR16510-B-B-B-9 and YR16512-B-B-B-10 and cv. Namcheonbyeo and Daesanbyeo were evaluated at plant densities of 10 to 300 plants m^{-2} and reported that dry matter production of low-tillering large panicle type rice was lower than that of Namcheonbyeo regardless of plant density.

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

Nematzadeh *et al.* (1997) reported that local high quality rice cultivars Hassan Sarai and Sang-Tarom were crossed with improved high yielding cultivars Amol3, PND160-2-1 and RNR1446 in all possible combinations and released in 1996 under the name Nemat, it gives an average yield of 8 t ha^{-1}. Twice as much as local cultivars.

BRRI (1995) conducted an experiment to find out varietal performances of BR4, BR10, BR11, BR22, BR23 and BR25 varieties including to local Challiush and Nizersail produced yields of 4.38, 3.18, 3.12, 3.12, 2.70 and 5.0 t ha^{-1}, respectively.

Chowdhury *et al.* (1995) studied on seven varieties of rice of which three were native (Maloti, Nizersail and Chandrashail) and four were improved (BR3, BR11, Pasam and Mala). Straw and grain yields were recorded and found that both the grain and straw yields were higher in the improved that the native varieties.

Islam (1995) in an experiment with four rice cultivars *viz.* BR10, BR11, BR22 and BR23 found that the highest number of non bearing tillers hill^{-1} was produced by cultivar BR11 and the lowest number was produced by the cultivar BR10.

Liu (1995) conducted a field trial with new indica hybrid rice II-You 92 an found an average yield 7.5 t ha^{-1} which was 10% higher than that of standard hybrid Shanyou 64.

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

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

In field experimants at Gazipur in 1989-1990 rice cv. BR11 (weakly photosensitive), BR22, BR23 and Nizersail (strongly photosensitive) were sown at various intervals from July to September and transplant from August to October. Among the cv. BR22 gave the highest grain yield from most of the sowing dates in both years (Ali *et al.*, 1993)

Chowdhury *et al.* (1993) reported that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e., number of productive tillers hill^{-1}.

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

BRRI (1991) also reported that the filled grains penicle^{-1} of different modern varieties were 95-100 in BR3, 125 in BR4, 120-130 in BR22 and 110-120 in BR23 when they were cultivated in transplant *aman* season.

Hossain and Alam (1991a) found that the plant height in modern rice varieties in *boro* sesson BR3, BR11, BR14 and pajam were 90.4, 94.5, 81.3 and 100.7 cm, respectively.

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

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

Miah *et al.* (1990) conducted an experiment where rice cv. Nizersail and mutant lines Mut. NSI and Mut. NSS were planted and found that plant height were greater in Mut. NSI than Nizersail.

Singh and Gangwer (1989) conducted an experiment with rice cultivars C-14-8, CR-1009, IET-5656 and IET-6314 and reported that grain number panicle^{-1}, 1000 grain weight were higher for C-14-8 than those of any other three varieties.

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

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

Sawant *et al.* (1986) conducted an experiment with the new rice lines R-73-1-1, R-711 and the traditional cv. Ratna and reported that the traditional cv. Ratna was the shortest.

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

BRRI (1979) reported that weight of 1000 grains of HAloi, Tilocha-Chari, Nizersail and Latisail were 26.5, 27.7, 19.6 and 25.0 g, respectively. Haloi gave the highest yield (2.64 t ha^{-1}) which was not different from Nizersail (2.64 t ha^{-1}) and Latisail (2.74 t ha^{-1}).

2.2 Effect of submergence

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.

Losses of productivity of flooded rice in the State of Rio Grande do Sul, Brazil, may occur in the Coastal Plains and in the Southern region due to the use of saline water from coastal rivers, ponds and the Laguna dos Patos lagoon and the sensibility of the plants are variable according to its stage of development. The purpose of this research was to evaluate the production of rice grains and its components, spikelet sterility and the phonological development of rice at different levels of salinity in different periods of its cycle. The experiment was conducted in a greenhouse, in pots filled with 11 dm^3 of an Albaqualf. The levels of salinity were 0.3 (control), 0.75, 1.5, 3.0 and 4.5 dS m^{-1} kept in the water layer by adding a salt solution of sodium chloride, except for the control, in different periods of rice development: tillering initiation to panicle initiation, tillering initiation to full flowering, panicle initiation to physiological maturity and full flowering to physiological maturity. The number of anicles per pot, the number of spikelets per panicle, the 1000 kernel weight, the spikelet sterility, the grain yield and phenology were evaluated. All characteristics were negatively affected in a quadratic manner, with increased salinity in all periods of rice development. Among the yield components evaluated, the one most closely related to grain yields of rice was the spikelet sterility (Tanksley and Jones, 1981).

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.

Setter and Laureles (1996) emphasized that this trait is inappropriate when selecting and breeding cultivars of *O. sativa* or *O. glaberrima* in cultivated rice for resilience to longer term submergence. Under these circumstances, a vigorous ethylene-mediated underwater elongation response by leaves is necessary to return leaves to air contact and full photosynthetic activity for long-term complete submergence.

In rice, young rice seedling after transplanting are particularly vulnerable to submergence stress (Joho *et al.*, 2008). The reproductive stage is the most sensitive to complete submergence followed by the seedling and the maximum tillering stages (Reddy and Mittra, 1985). The stage most susceptible to partial submergence of at least 50% of plant height was the reduction division stage of the pollen mother cells following by the heading stage, the spikelet differentiation stage and all part of the reproductive stage (Matsushima, 1962). Flooding during the seedling stage, increasing the water depth inhibited the production of basal tillers and reduced tiller number, thereby decreasing eventual grain yiled (Lockard, 1958). The reduction inyield has been attributed to a decrease in the proportion of ripened grains due to fertilization failure. Death in rice plants occurs when complete submergence lasts longer than 1-2 weeks (Palada and Vergara, 1972).

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), grain shttering (Koffi, 1980) 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.

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).

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 (De Datta et al., 1983; Belder, 2005).

Pre-submergence stored carbohydrate are reported to be associated with enhanced survival under flooded conditions possibly by supplying energy for maintenance through anaerobic respiration (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).

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 (Ella *et al.*, 2003).

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 (Singh *et al.*, 2001).

Singh *et al.* (1990) reported that flooding led to an increase in the amylase content of rice grains while decreasing its protein content. Consistent with results from studies done in Asia (Wei and Song, 1989; Mao *et al.*, 2000 and Cabangon *et al.*, 2004), the effects of early and continuous flooding were practically the same in terms of increased tillering, panicle production and grain yield, suggesting that the former flooding pattern is better than the latter in terms of water use.

Ramakrishnayya *et al.* (1999) reported that applying phosphate to the plant at the time of submergence reduce plant survival by 35%. The adverse effects of high phosphorous concentration in flood water were mainly attributed to a promotion of algal growth resulting competition between algae and submerged plant for CO_2 and light.

The rate of gas exchange is very slow in water because of small diffusion co-efficient for gases (Oxygen, 0.201 cm^{-2} s^{-1} in air, 2.1 × 10-5 cm^{-2} s^{-1} in water) (Armstrong, 1979). When water becomes stagnant, the oxygen concentration becomes especially low at night because of the nighttime respiration of algae. Rice plants increase the rate of alcoholic fermentation under low oxygen environments. However, alcoholic fermentation produces only two molecules of ATP per glucose molecule, which is not efficient when compared with aerobic respiration, through which 32 molecules of ATP are produced per glucose molecule. Therefore, rice cannot survive in a low oxygen environment for a long period because of the shortage of carbohydrates in the rice plants for use in energy production. For the more, photosynthesis is limited by low irradiance when the plant is submerged. It is necessary to improve photosynthetic capacity and the effective use of photosynthetic products as well as to survive under water.

Among several factors which affect growth, metabolic and survival of submergence plants, limited gas diffusion is the most crucial components because gas diffuse 10^4 times more slowly in solution than in air (Armstrong, 1979). Reduced movement of gasses to and away from submerged plant surfaces alters the concentration of O_2, CO_2 and ethylene inside the plants. The depletion of O_2 is a major facture of flooding, inducing hypoxia (low O_2) or anoxia (zero O_2) around the shoot and root tissues or germinating seeds (Kennedy and Rumpho, 1992; Collis and Melville, 1974).

The importance of reduce gas diffusion during submergence was clearly demonstrated in glasshouse experiments where increased in CO_2 pressure to completely submerged rice (IR42) increased survival from about 10 days to 3 months. Following submergence, these plants survived, flowered and set grain (Setter *et al.*, 1989). Interpretation of the beneficial effects in this experiment is complication from photosynthesis and from aeration of solution and reduce ethylene due to degassing solution using high CO_2 pressures in air (Setter *et al.*, 1989). Measurement of the gases in floodwater during submergence is therefore relevant to understand the mechanisms of plant death and the potential for cultivar improvement.

Light is another important environmental factor which affects growth and survival of rice during submergence. Variable light profiles in floodwater were obtained in Thailand (Setter *et al.*, 1987) and India (Ram *et al.*, 1999). In the brightest profile, photosynthesis was 50% if the maximum rate at 0.75 m water depth from the surface while the most turbid profile reduced photosynthesis to the compensation point at 0.25 m water depth (Setter *et al.*, 1987). Floodwater turbidity reduces light transmission and deposits sultan the leaves of submerged plants. Irradiance in floodwater in Bangladesh was due to surface algal colonies as well as turbidity.

Reddy and Mittra (1985) showed that complete plant submergence for 6 or 9 days at 20 days after transplanting effected the same decrease in grain yield as submergence for 12 days at 40 days after transplanting. With increasing duration of submergence, tiller number, green leaves and dry weight of all varieties tested decreasing. The decrease was less in the flood tolerant variety FR 13A than in other varieties. Contents of reducing sugars and amylase activity also decreased with increasing during of submergence. The reducing sugar contents and amylase activity were higher and peroxidase activity was lower in flood tolerant variety FR 13A than in other varieties. The N contents increased and P and K contents decreased with duration of submergence.

Plant survival in submergence is greatly affected not only by depth of floodwater but also by its physic-chemical characteristics (O_2 and CO_2 concentration, pH, turbidity etc.). The adverse effect on growth and metabolism are likely due to limited gas diffusion (Setter *et al.*, 1988) and light penetration (Palada and Vergara, 1972).

Mazaredo and Vergara (1982) supported that the shoots of tolerant lines viz., FR 13A were found to be richer in nitrate, containing 70 mg per plant shoot.

Palada and Vergara (1972) found that the increase in the percentage of N content that normally course between 10 and 20 days after germination (from 3.1 to 4.3 %) to be abolished by submergence even reversed if the water is turbid.

Submergence strongly affects protein content which N and P availability and assimilation can influence submergence response. Protein reserves rapidly depletes due to submergence through hydrolysis to amino acids and other soluble N containing compounds (Yamada, 1959).

Limited gas diffusion is the most important factor during flooding (Setter *et al.*, 1995). Since gas diffusion is in 104-fold slower in solution than in air (Armstrong, 1979). Reduced movement of gases to and away from submerged plant surface alters the concentration of O_2, CO_2 and ethylene inside the plants. The depletion of O_2 is a major feature of the flooded field which creates a condition of low O_2 or no

O_2 at all around the plant tissues such as seeds or root apices and stele. Though floodwater O_2 concentration during flash floods is generally high, floodwater may become anoxic in some environments for respiration. O_2 concentration in stagnant air saturated water (0.25 mol m^{-2}) was considered a reasonable threshold value required for respiration in germinating rice seeds, coleoptiles and embryos (Taylor, 1942).

Chapter III

Materials & Methods

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 December, 2013 to April, 2014 to find out the the effect of dough stage submergence on the yield of high yielding 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 operation, 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 December, 2013 to April, 2014. 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 (BRRI dhan 28, BRRI dhan 29, BRRI hybrid dhan 2, BRRI hybrid dhan 3 and TIA) were used. BRRI dhan 28, BRRI dhan 29, BRRI hybrid dhan 2, BRRI hybrid dhan 3 were collected from

Bangladesh Rice Research Institute (BRRI). TIA was collected from ACI Seed Enterprise Limited, which was a hybrid variety.

3.6 Details of the Experiment

3.6.1 Experimental treatments

Treatments included in the experiment were as follows:

A. Submergence period

S_1 – Control/No submergence (Normal irrigation with other normal practices were applied in this treatment)

S_2 – Submergence for 4 days

S_3 - Submergence for 9 days

S_4 - Submergence for 14 days

B. Varieties

V_1 – BRRI dhan 28

V_2 – BRRI dhan 29

V_3 – BRRI hybrid dhan 2

V_4 – BRRI hybrid dhan 3

V_5 – TIA (TIA is an exotic hybrid rice variety collected from lal Teer seed company)

3.6.2 Experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with five replications. The layout of the experiment was prepared for distributing the variety. The Experimental pot was divided into 5 blocks. Each block was again divided into 20 pots. The total numbers of unit pots of the experiment were 100. The treatments were randomly distributed to each block following the experimental design. In this case plant was grown following the RCBD 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 five replications were maintained. Considering the high cost of maintaining more pots. Proper case 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 Lal Teer Seed Company. Lal Teer introduced this variety (TIA) from Philippines to test the performance in Bangladesh for Boro Season.

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 December 2013 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 5 January 2014 and was exposed to the sun for a week. Weeds and stubbles were removed and a desirable tilth was obtained finally for transplanting of seedlings. The soil described in 3.3 were used to growth rice plants in pots.

3.7.3 Fertilizer application

Recommended doses of fertilizers were applied to each pot. Fertilizers such as Urea, TSP, MoP, Gypsum and Zinc sulphate were used as sources for N, P, K, S and Zn respectively. The full doses of all fertilizers and one third of urea were applied as basal dose to the individual pot during final soil preparation on 12 January 2014 at the time of final soil preparation through transplanting method. The first split of Urea was applied 25 days after transplanting (DAT) and the second split of Urea was applied at 45 DAT, i.e., at maximum tillering stage. The doses of fertilizers with their sources are given below:

Nutrient	**Source**	**Dose(kg ha^{-1})**	**Dose (g pot^{-1})**
N (Nitrogen)	Urea (46% N)	200	4
P (phosphorus)	TSP (20% P_2O_5)	30	1.5
K (potassium)	MoP (50% K_2O)	100	2
S (Sulphur)	Gypsum (18% S)	75	0.5
Zn (Zinc)	Zinc sulphate (36% Zn)	15	0.5

3.7.4 Uprooting 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.

3.6.5 Transplanting of seedlings in the pot

The seedlings were uprooted and then transplanted as per experimental treatment on the well puddled pots on 20 January 2014 without causing much mechanical injury to the roots. One seedling hill^{-1} (pot) was used during transplanting which grow well due to proper care.

3.7.6 Intercultural operations

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

3.7.6.1 Maintaining the submergence level

There is a submergence pond in SAU for this type of experiment. The plant was 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, 9 and 14 days of submergence the pots were removed from the water. The plants were submerged at dough stage. Controlled (S_1) pot were irrigated as normal irrigation requirement as prescribed for the high yielding varieties of rice in Boro season. The pots of S_2 (4 days submergence), S_3 (9 days submergence) and S_3 (14 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. Dough stage of plants starts after milking stage, which has two stages soft dough stage and hard dough stage.

3.7.6.2 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.

3.7.6.3 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.

3.7.6.4 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.

3.8 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. The plants in some pots lodged during pre-ripening and ripening stage due to heavy rainfall with gusty winds. Empty or unfilled grain was seen in some varieties due to sudden fluctuation of temperature during the experiment. The effects of submergence was recorded.

3.9 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.

3.10 Recording of plant data

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

a) Plant height (cm)
b) Number of tillers plant^{-1}
c) Number of fresh and rotten leaves plant^{-1}
d) 1%, 50% and 100% booting stage
e) 1% and 50% panicle initiation stage
f) 1%, 50% and 100% milking stage
g) Days to maturity
h) Dry weight of leaf, leaf sheaths, stem and root (g)
i) Panicle length (cm)
j) Number of fertile and infertile panicles plant^{-1}
k) Number of fertile and infertile seeds plant^{-1}
l) Number of fertile and infertile grains tiller^{-1}
m) 1000 grains weight (g)
n) Weight of fertile and infertile grains (g)
o) Percentage of grain weight reduction due to submergence

Percentage (%) of grain weight reduction for each variety =

$$\frac{Yield\ in\ control\ treatment - Yield\ in\ submergence\ treatment}{Yield\ in\ controlled\ treatment} \times 100$$

p) Data on susceptible and tolerance were devoted by the calculation of percentage of grain weight reduction as follows:

Highly tolerant	Reduction of yield in between 2 % to 14 %
Medium tolerant	Reduction of yield in between 15 % to 21 %
Tolerant	Reduction of yield in between 22 % to 25 %
Susceptible	Reduction of yield in between 26 % to 46 %
Highly susceptible	Reduction of yield in between 52 % to 79 %

3.10.1 Procedure of recording data

3.10.1.1 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.

3.10.1.2 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.

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

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

3.10.1.4 Days to 1%, 50% and 100% booting stage

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

3.10.1.5 Days to 1% and 50% panicle insertion stage

Days to 1% and 50% panicle insertion was considered when 1% and 50% of the plants within a pot showed panicle insertion. The number of days to 1% and 50% panicle insertion was recorded from the date of transplanting.

3.10.1.6 Days to 1%, 50% and 100% milking stage

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

3.10.1.7 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.

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

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

3.10.1.9 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.

3.10.1.10 Effective tillers hill^{-1}

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

3.10.1.11 Ineffective tillers hill^{-1}

The tiller having no panicle was regarded as ineffective tiller.

3.10.1.12 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.

3.10.1.13 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.

3.10.1.14 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 weighted and was converted into weight of 100 grains weight counting the total number of grains in a plant.

3.11 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment 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 was estimated by the Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the effect of dough 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 treatment at 20, 40, 60, 100, 120 days after transplanting (DAT) and harvest time except 80 DAT (Appendix IV and Table 1). At 20, 40, 60 DAT, the highest (15.93, 31.00 and 45.20 cm, respectively) plant height was obtained from control (S_1) treatment and the lowest plant height (12.67, 25.47 and 39.87 cm, respectively) was obtained from 14 days submergence (S_4) treatment. At 80 DAT, the numerically highest (70.67 cm) plant height was obtained from 4 days submergence (S_2) treatment and the lowest plant height (69.40 cm) was obtained from the control (S_1) treatment. At 100, 120 DAT and harvest time, the highest (84.93, 90.47 and 97.93 cm, respectively) plant height was obtained from control (S_1) treatment and the lowest plant height (72.93, 78.73 and 85.00 cm, respectively) was obtained from 14 days submergence (S_4) treatment. The study referred that the control treatment i.e.; no submergence produced the highest plant height of rice.

Different varieties significantly affected the plant height of rice at 20, 40, 60, 100, 120 days after transplanting (DAT) and harvest time (Appendix IV and Table 2). At 20, 40, 60, 80, 100 and 120 DAT and harvest time, the highest plant height (17.58, 35.75, 47.20, 76.92, 85.00, 90.00 and 96.75 cm, respectively) was recorded from 'TIA' variety (V_5) treatment whereas, the lowest plant height (12.08, 23.33, 39.20, 61.75, 71.50, 78.75 and 84.50 cm, respectively) was recorded from 'BRRI dhan 28' (V_1) treatment. Present study revealed that 'TIA' 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.

Table 1. Effect of submergence on plant height of rice

Treatments	Plant height (cm) at						
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT	120 DAT	Harvest
S_1	15.93 a	31.00 a	45.20 a	69.40	84.93 a	90.47 a	97.93 a
S_2	14.68 b	28.80 b	42.80 b	70.67	78.67 b	84.93 b	91.20 b
S_3	14.33 b	27.60 b	42.27 b	70.60	76.73 b	82.73 b	91.73 b
S_4	12.67 c	25.47 c	39.87 c	69.53	72.93 c	78.73 c	85.00 c
$LSD_{(0.05)}$	1.37	2.00	1.55	NS	3.02	3.91	4.20
CV (%)	7.05	5.32	2.82	2.86	3.01	3.64	3.60

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence.

Table 2. Effect of variety on plant height of rice

Treatments	Plant height (cm) at						
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT	120 DAT	Harvest
V_1	12.08 d	23.33 d	39.20 d	61.75 d	71.50 d	78.75 c	84.50 d
V_2	14.97 bc	26.84 c	45.80 b	65.83 c	76.58 c	82.92 b	89.58 c
V_3	15.42 b	31.75 b	42.27 c	70.83 b	82.00 b	86.58 b	90.33 bc
V_4	13.83 c	29.67 b	42.87 c	72.91 b	80.50 b	85.58 b	90.67 b
V_5	17.58 a	35.75 a	47.20 a	76.92 a	85.00 a	90.00 a	96.75 a
$LSD_{(0.05)}$	1.53	2.45	1.74	2.87	3.37	4.37	4.69
CV (%)	7.05	5.32	2.82	2.86	3.01	3.64	3.60

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

Note: V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

Interaction effect of submergence and varieties significantly influenced plant height at 20, 40, 60, 100, 120 days after transplanting (DAT) and harvest time (Appendix IV and Table 3). At 20, 40, 60, 80, 100 and 120 DAT and harvest time, the highest plant height (20.00, 44.00, 64.00, 81.00, 95.00, 100. And 105.00 cm, respectively) was recorded from the control treatment with 'TIA variety' (S_1V_5) treatment. On the other hand, the lowest plant height (12.00, 20.00, 33.00, 54.00, 60.00, 72.00 and 79.00 cm, respectively) was recorded from the 14 days submergence with 'BRRI dhan 28' (S_4V_1) treatment at same DAT.

Table 3. Interaction effect of submergence and variety on plant height of rice

Treatments	Plant height (cm) at						
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT	120 DAT	Harvest
S_1V_1	15.33 c-f	23.00 k	37.00 kl	64.00 hi	78.00 de	85.00 bc	90.00 de
S_1V_2	14.33 ef	25.67 ij	42.00 f-h	70.33 f	71.67 gh	76.67 ef	81.00 fg
S_1V_3	15.33 c-f	36.67 bc	44.67 de	61.00 i	90.00 b	94.33 b	91.67 d
S_1V_4	14.67 d-f	25.67 ij	38.33 j-l	70.67 f	90.00 b	94.33 b	92.00 d
S_1V_5	20.00 a	44.00 a	64.00 a	81.00 a	95.00 a	100.0 a	105.0 a
S_2V_1	15.00 c-f	24.33 jk	36.67 l	67.00 gh	74.00 f-h	80.00 c-e	86.00 ef
S_2V_2	16.55 bc	29.33 d-f	40.33 g-j	62.00 i	77.33 d-f	86.67 b	98.33 bc
S_2V_3	15.67 b-f	34.67 c	44.67 de	76.00 b-d	79.00 d	86.00 b	97.67 bc
S_2V_4	14.33 ef	31.67 d	45.67 d	72.33 ef	79.00 d	84.00 bc	99.00 b
S_2V_5	17.33 b	39.00 b	51.67 b	76.00 b-d	84.00 c	88.00 b	95.00 b-d
S_3V_1	14.00 fg	26.00 h-j	40.33 g-j	70.00 fg	74.00 f-h	78.00 de	85.00 f
S_3V_2	14.00 fg	25.67 ij	36.67 l	61.00 i	70.67 h	78.67 de	99.00 b
S_3V_3	14.67 d-f	28.33 f-h	43.33 ef	72.00 ef	84.00 c	87.00 b	90.00 de
S_3V_4	14.33 g	27.00 f-i	48.67 c	72.33 ef	75.00 e-g	80.00 c-e	93.67 b-d
S_3V_5	16.67 bc	31.00 de	42.33 fg	77.67 b	80.00 d	85.00 bc	93.00 cd
S_4V_1	12.00 h	20.00 l	33.00 m	54.00 j	60.00 i	72.00 f	79.00 g
S_4V_2	15.00 c-f	26.67 g-j	40.67 g-i	70.00 fg	74.67 e-g	77.67 e	85.00 f
S_4V_3	16.00 b-e	27.33 f-i	39.00 i-k	74.33 c-e	75.00 e-g	78.00 de	85.00 f
S_4V_4	14.00 fg	34.33 c	51.67 b	76.33 bc	78.00 de	83.00 b-d	94.00 b-d
S_4V_5	16.33 b-d	29.00 e-g	40.00 h-j	73.00 d-f	77.00 d-f	83.00 b-d	90.00 de
$LSD_{(0.05)}$	1.77	2.59	2.00	3.31	3.89	5.05	5.42
CV (%)	7.05	5.32	2.82	2.86	3.01	3.64	3.60

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence. V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

4.2. Number of tillers plant^{-1}

The number of tillers plant^{-1} of rice was significantly varied among the submergence treatment at 20, 40, 60, 100, 120 days after transplanting (DAT) and harvest time (Appendix V and Table 4). At 20, 40, 60, 80, 100 and 120 DAT and harvest time, the maximum number of tillers plant^{-1} (2.07, 6.20, 30.53, 52.07, 63.20, 67.73 and 73.07, respectively) was found on the control treatment (S_1) treatment. On the other hand, the minimum number of tillers plant^{-1} (1.20, 3.93, 20.40, 43.93, 53.33, 60.20 and 65.73, respectively) was found on 14 days submergence (S_4) treatment at same DAT. The study referred that the control treatment i.e.; no submergence recorded maximum number of tillers plant^{-1} of rice.

Different varieties significantly influenced the number of tillers plant^{-1} of rice at 20, 40, 60, 100, 120 days after transplanting (DAT) and harvest time (Appendix V and Table 5). At 20, 40, 60, 80, 100 and 120 DAT and harvest time, the maximum number of tillers plant^{-1} (2.83, 5.42, 33.08, 51.50, 59.83, 66.42 and 72.42, respectively) was recorded from 'TIA' variety (V_5) treatment and the minimum (0.81, 4.00, 23.50, 38.58, 54.25, 57.75 and 61.42, respectively) was counted from 'BRRI dhan 28' (V_1) treatment. Present study revealed that the maximum number of tillers plant^{-1} was produced by 'TIA' variety.

Interaction effect of submergence and varieties significantly influenced number of tillers plant^{-1} at 20, 40, 60, 100, 120 days after transplanting (DAT) and harvest time (Appendix V and Table 6). At 20, 40, 60, 80, 100 and 120 DAT and harvest time, the highest number of tillers plant^{-1} (4.33, 8.00, 40.00, 65.33, 70.00, 77.00 and 83.33, respectively) was found on the control treatment with 'TIA variety' (S_1V_5) treatment whereas, the lowest (0.33, 2.33, 17.00, 34.00, 44.00, 48.00, 52.67, respectively) was counted from the 14 days submergence with 'BRRI dhan 28' (S_4V_1) treatment.

Table 4. Effect of submergence on number of tillers plant^{-1} of rice

Treatments	Number of tillers plant^{-1} at						
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT	120 DAT	Harvest
S_1	2.07 a	6.20 a	30.53 a	52.07 a	63.20 a	67.73 a	73.07 a
S_2	1.60 b	5.13 b	26.20 b	46.00 b	56.87 b	64.20 b	68.40 b
S_3	1.67 b	4.59 c	25.93 b	46.80 b	55.87 b	63.53 b	68.07 b
S_4	1.20 c	3.93 d	20.40 c	43.93 c	53.33 c	60.20 c	65.73 c
$LSD_{(0.05)}$	0.23	0.22	1.71	1.98	1.77	2.16	2.45
CV (%)	11.26	3.63	4.65	3.30	2.40	2.70	2.87

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence.

Table 5. Effect of variety on number of tillers plant^{-1} of rice

Treatments	Number of tillers plant^{-1} at						
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT	120 DAT	Harvest
V_1	0.81 e	4.00 d	23.50 d	38.58 d	54.25 c	57.75 c	61.42 d
V_2	1.08 cd	4.75 bc	29.50 b	48.17 b	57.00 b	62.58 b	66.33 b
V_3	1.16 c	4.58 c	26.83 c	45.50 c	57.00 b	62.50 b	65.75 bc
V_4	2.00 b	4.83 b	27.92 bc	48.00 b	57.75 b	63.08 b	69.17 b
V_5	2.83 a	5.42 a	33.08 a	51.50 a	59.83 a	66.42 a	72.42 a
$LSD_{(0.05)}$	0.26	0.24	1.91	2.22	1.98	2.12	2.74
CV (%)	11.26	3.63	4.65	3.30	2.40	2.70	2.87

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

Note: V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

Table 6. Interaction effect of submergence and variety on number of tillers plant^{-1} of rice

Treatments	Number of tillers plant^{-1} at						
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT	120 DAT	Harvest
S_1V_1	1.00 h	4.67 e	29.00 e-g	31.00 j	62.00 bc	64.00 ef	67.00 e-g
S_1V_2	1.00 h	4.67 e	28.67 fg	57.33 b	63.33 b	67.33 bc	70.33 cd
S_1V_3	1.00 h	4.33 f	23.00 j	51.67 c	60.67 cd	66.00 c-e	67.67 d-f
S_1V_4	1.00 h	4.33 f	29.00 e-g	55.00 b	60.00 cd	64.33 d-f	67.00 e-g
S_1V_5	4.33 a	8.00 a	40.00 a	65.33 a	70.00 a	77.00 a	83.33 a
S_2V_1	1.00 h	5.00 d	25.00 ij	45.33 ef	56.00 fg	60.00 h-j	63.00 hi
S_2V_2	1.33 g	5.33 c	32.00 cd	44.67 f	59.67 d	63.00 fg	66.00 f-h
S_2V_3	1.00 h	4.67 e	33.33 bc	42.00 gh	53.67 hi	58.00 j	62.00 i
S_2V_4	3.00 c	6.00 b	25.67 hi	44.33 fg	62.00 bc	67.00 b-d	72.00 bc
S_2V_5	2.67 d	4.67 e	30.00 d-f	43.33 f-h	53.00 hi	58.00 j	64.00 g-i
S_3V_1	1.00 h	4.00 g	35.00 b	44.00 fg	55.00 f-h	59.00 ij	63.00 hi
S_3V_2	1.00 h	4.67 e	27.00 g-i	42.00 gh	52.00 i	57.67 j	61.33 i
S_3V_3	1.67 f	5.00 d	25.00 ij	47.33 de	60.67 cd	63.33 e-g	67.00 e-g
S_3V_4	1.00 h	4.33 f	31.00 de	47.67 de	54.67 gh	61.67 f-i	70.00 c-e
S_3V_5	3.67 b	5.00 d	34.67 b	48.00 d	57.00 ef	61.00 g-i	64.00 g-i
S_4V_1	0.33 i	2.33 h	17.00 k	34.00 i	44.00 j	48.00 k	52.67 j
S_4V_2	1.00 h	4.33 f	30.33 d-f	48.67 gh	57.00 ef	62.33 f-h	67.67 d-f
S_4V_3	1.00 h	4.33 f	26.00 hi	41.00 h	57.00 ef	62.67 f-h	66.33 fg
S_4V_4	1.67 f	4.67 e	26.00 hi	57.00 b	58.67 de	63.33 e-g	67.67 d-f
S_4V_5	2.00 e	4.00 g	27.67 gh	49.33 cd	55.00 f-h	69.67 b	74.33 b
$LSD_{(0.05)}$	0.29	0.28	2.21	2.56	2.28	2.79	3.17
CV (%)	11.26	3.63	4.65	3.30	2.40	2.70	2.87

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence. V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

4.3. Number of fresh leaves plant^{-1}

Number of fresh leaves of rice were significantly affected by the submergence (Appendix VI and Table 7). Number of fresh leaves plant^{-1} decreased with the increase of the submergence days (Table 7). The maximum number of fresh leaves plant^{-1} (252.9) was recorded from S_1 treatment and the minimum (151.5) was recorded from S_4 treatment.

Number of fresh leaves of rice were significantly affected by varieties (Appendix VI and Table 8). The maximum number of fresh leaves plant^{-1} (255.8) was recorded from 'TIA' whereas, the minimum (155.4) was recorded from the variety 'BRRI dhan 29'.

Interaction effect of different submergence and variety in terms of number of fresh leaves plant^{-1} also showed significant variation (Appendix VI and Table 9). The maximum number of fresh leaves plant^{-1} (340.00) was recorded from the combination of no submergence and 'TIA' (S_1V_5) and the minimum (119.00) was recorded from the combination of 14 days submergence and 'BRRI dhan 28' (S_4V_1) treatment which was statistically identical to S_3V_2 (122.00) and S_4V_2 (122.00).

4.4. Number of rotten (dead) leaves plant^{-1}

Number of rotten leaves of rice were significantly affected by the submergence (Appendix VI and Table 7). Number of rotten leaves plant^{-1} increased with the increase of the submergence days (Table 7). The maximum number of rotten leaves plant^{-1} (44.20) was recorded from S_4 treatment and the minimum (00.00) was recorded from S_1 treatment.

Number of rotten leaves of rice were significantly affected by varieties (Appendix VI and Table 8). The maximum number of rotten leaves plant^{-1} (34.83) was recorded from 'BRRI dhan 28' whereas, the minimum (19.42) was recorded from the variety 'TIA' variety.

Interaction effect of different submergence and variety in terms of number of rotten leaves plant^{-1} also exposed significant variation (Appendix VI and Table 9). The maximum number of rotten leaves plant^{-1} (56.33) was recorded from the combination of 14 days submergence and 'BRRI dhan 28' (S_4V_1) treatment and the minimum (00.00) was recorded from the combination of no submergence with all rice varieties (S_1V_1, S_1V_2, S_1V_3, S_1V_4 and S_1V_5). Present study revealed that the only submergence affected the rotten leaves of rice variety.

Table 7. Effect of submergence on number of leaves and booting stage of rice

Treatments	Number of leaves		Booting stage		
	Fresh	Rotten (dead)	1 % booting	50 % booting	100 % booting
S_1	252.9 a	0.0 d	70.98	93.27 a	99.20 a
S_2	194.7 b	27.27 c	69.67	91.67 b	98.33 a
S_3	166.3 c	38.13 b	70.13	91.07 b	93.93 b
S_4	151.5 d	44.20 a	69.13	89.20 c	98.60 a
$LSD_{(0.05)}$	7.74	0.74	NS	1.41	1.47
CV (%)	3.16	2.12	2.28	1.12	1.18

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence.

Table 8. Effect of variety on number of leaves and booting stage of rice

Treatments	Number of leaves		Booting stage		
	Fresh	Rotten (dead)	1 % booting	50 % booting	100 % booting
V_1	209.0 b	34.83 a	66.83 b	87.50 c	92.58 c
V_2	155.4 d	31.17 b	84.47 a	106.7 a	114.3 a
V_3	168.8 c	27.83 c	68.83 b	91.08 b	95.50 b
V_4	167.9 c	23.75 d	67.83 b	89.83 b	95.08 b
V_5	255.8 a	19.42 e	61.92 c	85.17 d	90.17 d
$LSD_{(0.05)}$	8.65	0.83	2.82	1.60	1.64
CV (%)	3.16	2.12	2.28	1.12	1.18

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

Note: V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

4.5. 1% booting stage

Submergence did not significantly influenced 1% booting stage of rice (Appendix VI and Table 7). The numerically highest 1% booting stage (70.98 days) was found in S_1 treatment and the lowest (69.13 days) was found in S_3 treatment.

Varietal effect significantly influenced 1% booting stage of rice (Appendix VI and Table 8). The highest 1% booting stage (84.47 days) was found in the variety 'BRRI dhan 29' and the lowest (61.92 days) was found in the 'TIA'. Study referred that the rice variety 'BRRI dhan 29' showed best result in terms of 1% booting stage.

1% booting stage of rice was significantly influenced by the interaction effect of submergence and variety (Appendix VI and Table 9). The highest 1% booting stage (86.00 days) was recorded from S_2V_2 and S_3V_2 treatment, which was statistically identical to S_4V_2 (84.33 days) treatment whereas, the lowest (61.00 days) was recorded from S_4V_5 treatment, which was statistically identical to S_2V_5 (62.00 days), S_3V_5 (62.00 days) and statistically similar to S_1V_5 (62.67 days) treatment.

4.6. 50% booting stage

Submergence significantly influenced 50% booting stage of rice (Appendix VI and Table 7). 50% booting stage decreased with increasing submergence days (Table 7). The highest 50% booting stage (93.27 days) was found in S_1 treatment and the lowest (89.20 days) was found in S_4 treatment.

Varietal effect significantly influenced 50% booting stage (Appendix VI and Table 8). The highest 50% booting stage (106.7 days) was found in the variety 'BRRI dhan 29' whereas, the lowest (85.17 days) was found in the 'TIA'. Study referred that the rice variety 'TIA' showed best result in terms of 50% booting stage.

50% booting stage of rice significantly influenced by the interaction effect of submergence and variety (Appendix VI and Table 9). The highest 50% booting stage (108.00 days) was recorded from S_2V_2 treatment whereas, the lowest (83.00 days) was recorded from S_3V_1 treatment which was statistically identical to S_2V_5 (84.00 days), S_3V_5 (84.00 days) and S_1V_5 (84.33 days) treatment.

4.7. 100% booting stage

Submergence significantly influenced 100% booting stage of rice (Appendix VI and Table 7). The highest 100% booting stage (99.20 days) was found in S_1 treatment which was statistically identical to S_4 (98.60 days), S_2 (98.33 days). On the other hand, the lowest 100% booting stage (93.93 days) was found in S_3 treatment.

Varietal effect significantly influenced 100% booting stage (Appendix VI and Table 8). The highest 100% booting stage (114.30 days) was found in the variety 'BRRI dhan 29' whereas, the lowest (90.17 days) was found in the 'TIA'.

100% booting stage of rice significantly influenced by the interaction effect of submergence and variety (Appendix VI and Table 9). The highest 100% booting stage (120.00 days) was recorded from S_2V_2 treatment whereas, the lowest (87.00 days) was recorded from S_3V_1 treatment which was statistically similar to S_3V_5 (88.00 days) treatment.

Table 9. Interaction effect of submergence and variety on number of leaves and booting stage of rice

Treatments	Number of leaves		Booting stage		
	Fresh	Rotten (dead)	1 % booting	50 % booting	100 % booting
S_1V_1	316.0 b	0.0 o	69.67 cd	91.67 d	98.00 d
S_1V_2	226.7 d	0.0 o	81.55 b	104.3 b	111.7 b
S_1V_3	200.0 fg	0.0 o	71.00 c	94.00 c	98.00 d
S_1V_4	182.0 h	0.0 o	70.00 cd	92.00 d	96.33 d-f
S_1V_5	340.0 a	0.0 o	62.67 hi	84.33 g	92.00 ij
S_2V_1	205.3 e-g	34.33 h	66.33 fg	88.33 f	94.33 gh
S_2V_2	151.0 j	30.67 j	86.00 a	108.0 a	120.0 a
S_2V_3	178.0 h	27.00 k	65.67 g	87.67 f	92.00 ij
S_2V_4	173.0 hi	24.33 m	68.33 d-f	90.33 de	96.00 e-g
S_2V_5	266.0 c	20.00 n	62.00 i	84.00 g	89.33 kl
S_3V_1	195.7 g	48.67 c	66.33 fg	83.00 g	87.00 m
S_3V_2	122.0 k	43.33 e	86.00 a	104.8 b	106.3 c
S_3V_3	153.0 j	39.33 f	69.67 cd	91.67 d	95.00 f-h
S_3V_4	150.0 j	33.67 h	66.67 e-g	88.67 ef	93.33 hi
S_3V_5	211.0 e	25.67 l	62.00 i	84.00 g	88.00 lm
S_4V_1	119.0 k	56.33 a	65.00 gh	87.00 f	91.00 jk
S_4V_2	122.0 k	50.67 b	84.33 a	104.0 b	111.0 b
S_4V_3	144.0 j	45.00 d	69.00 c-e	91.00 d	97.00 de
S_4V_4	166.7 i	37.00 g	66.33 fg	88.33 f	94.67 f-h
S_4V_5	206.0 ef	32.00 i	61.00 i	88.33 f	91.33 j
$LSD_{(0.05)}$	9.99	0.96	2.64	1.82	1.90
CV (%)	3.16	2.12	2.28	1.12	1.18

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence. V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

4.8. 1% panicle insertion stage

1% panicle insertion stage was significantly influenced by submergence (Appendix VII and table 10). The control treatment i.e.; no submergence produced higher 1% panicle insertion (78.47 days) which was statistically identical to 4 days submergence (78.20 days) treatment whereas, the lowest (75.33 dyas) was recorded from 14 days submergence treatment which was statistically identical to 9 days submergence (75.93 days) treatment.

1% panicle insertion stage significantly influenced by the varieties (Appendix VII and Table 11). 'BRRI dhan 29' produced higher 1% insertion initiation (96.33 days) whereas, the lowest (69.17 days) was recorded from the variety 'BRRI dhan 28' which was statistically identical with variety 'TIA' (69.83 days) treatment.

Interaction effect of submergence and variety influenced 1% panicle insertion stage (Appendix VII and Table 12). It was observed that the highest 1% panicle insertion (103.70 days) was obtained from the combination of 4 days submergence and BRRI dhan 29 treatment whereas, the lowest (60.67 days) was recorded from the combination of 9 days submergence and BRRI dhan 28 treatment.

4.9. 50% panicle insertion stage

50% panicle insertion stage significantly influenced by submergence (Appendix VII and table 10). The control treatment i.e.; no submergence produced maximum 50% insertion initiation (101.50 days) which was statistically identical to 4 days submergence (101.20 days) treatment whereas, the minimum (97.93 dyas) was recorded from 14 days submergence treatment which was statistically identical to 9 days submergence (97.47 days) treatment.

50% insertion initiation stage significantly influenced by the varieties (Appendix VII and Table 11). 'BRRI dhan 29' produced maximum 50% insertion initiation (119.30 days) whereas, the minimum (92.17 days) was recorded from the variety

‘BRRI dhan 28’ which was statistically identical with variety ‘TIA’ (92.83 days) treatment.

Interaction effect of submergence and variety influenced 50% panicle insertion stage (Appendix VII and Table 12). It was observed that the maximum 50% panicle insertion (126.70 days) was obtained from the combination of 4 days submergence and BRRI dhan 29 treatment whereas, the minimum (83.67 days) was recorded from the combination of 9 days submergence and BRRI dhan 28 treatment.

Table 10. Effect of submergence on panicle insertion stage and milking stage of rice

Treatments	Panicle insertion stage		Milking stage		
	1 % panicle	50 % panicle	1 % milking	50 % milking	100 % milking
S_1	78.47 a	101.5 a	83.80 a	107.2 a	117.3 a
S_2	78.20 a	101.2 a	80.80 b	103.9 b	106.0 b
S_3	75.93 b	97.47 c	77.53 c	100.5 c	103.8 b
S_4	75.33 b	97.93 c	77.00 c	100.5 c	106.2 b
$LSD_{(0.05)}$	1.95	2.29	2.35	2.35	2.37
CV (%)	1.98	1.79	2.34	1.78	1.71

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence.

Table 11. Effect of variety on panicle insertion stage and milking stage of rice

Treatments	Panicle insertion stage		Milking stage		
	1 % panicle	50 % panicle	1 % milking	50 % milking	100 % milking
V_1	69.17 c	92.17 c	73.42 c	98.42 c	101.3 c
V_2	96.33 a	119.3 a	91.33 a	116.3 a	127.8 a
V_3	74.83 b	98.00 b	76.75 b	100.0 c	102.9 c
V_4	74.75 b	97.75 b	77.83 b	102.8 b	107.8 b
V_5	69.83 c	92.83 c	72.58 c	97.58 c	101.8 c
$LSD_{(0.05)}$	2.18	2.56	2.62	2.62	2.64
CV (%)	1.98	1.79	2.34	1.78	1.71

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

Note: V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

4.10. 1% milking stage

Submergence significantly influenced 1% milking stage of rice (Appendix VII and Table 10). The highest 1% milking stage (83.80 days) was found in S_1 treatment and the lowest (77.00 days) was found in S_4 treatment which was statistically identical to S_3 (77.53 days) treatment.

Varietal effect significantly influenced 1% milking stage of rice (Appendix VII and Table 11). The highest 1% milking stage (91.33 days) was found in the variety 'BRRI dhan 29' whereas, the lowest (72.58 days) was found in the 'TIA' which was statistically identical to 'BRRI dhan 28' (73.42 days) treatment.

1% milking stage of rice significantly influenced by the interaction effect of submergence and variety (Appendix VII and Table 12). The highest 1% milking stage (98.00 days) was recorded from S_2V_2 treatment, which was statistically identical to S_1V_2 (95.00 days) treatment whereas, the lowest (69.00 days) was recorded from S_3V_1 treatment, which was statistically identical to S_2V_5 (69.67 days) treatment.

4.11. 50% milking stage

Submergence significantly influenced 50% milking stage of rice (Appendix VII and Table 10). 50% milking stage decreased with increase of submergence days (Table 10). The highest 50% milking stage (107.20 days) was found in S_1 treatment whereas, the lowest (100.5 days) was found in S_3 and S_4 treatment.

Varietal effect significantly influenced 50% milking stage (Appendix VII and Table 11). The highest 50% milking stage (116.30 days) was found in the variety 'BRRI dhan 29' whereas, the lowest (97.58 days) was found in the 'TIA' which was statistically identical was 'BRRI dhan 28' (98.42 days) treatment.

50% milking stage of rice significantly influenced by the interaction effect of submergence and variety (Appendix VII and Table 12). The highest 50% milking stage (123.00 days) was recorded from S_2V_2 treatment, which was statistically identical to S_1V_2 (120.00 days) treatment whereas, the lowest (93.67 days) was recorded from S_4V_3 treatment which was statistically identical to S_3V_1 (94.00 days), S_2V_5 (94.67 days) and statistically similar to S_3V_5 (96.33 days) treatment.

4.12. 100% milking stage

Submergence significantly influenced 100% milking stage of rice (Appendix VII and Table 10). The highest 100% milking stage (117.30 days) was found in S_1 treatment whereas, the lowest (103.80 days) was found in S_3 treatment, which was statistically identical to S_2 (106.00 days) and S_4 (106.20 days) treatment.

Varietal effect significantly influenced 100% milking stage (Appendix VII and Table 11). The highest 100% milking stage (127.80 days) was found in the variety 'BRRI dhan 29' whereas, the lowest (101.30 days) was found in the 'BRRI dhan 28' which was statistically identical of 'BRRI hybrid dhan 2' (102.90 days) and 'TIA' (101.80 days) treatment.

100% milking stage of rice was significantly influenced by the interaction effect of submergence and variety (Appendix VII and Table 12). The highest 100% milking stage (134.30 days) was recorded from S_1V_2 treatment whereas, the lowest (96.00 days) was recorded from S_2V_5 treatment which was statistically similar to S_3V_1 (96.67 days) treatment.

Table 12. Interaction effect of submergence and variety on panicle insertion stage and milking stage of rice

Treatments	Panicle insertion stage		Milking stage		
	1 % panicle	50 % panicle	1 % milking	50 % milking	100 % milking
S_1V_1	77.67 d	100.7 d	80.67 c	105.7 c	109.3 d
S_1V_2	91.33 c	114.3 c	95.00 a	120.0 a	134.3 a
S_1V_3	76.33 de	99.33 d-f	80.00 c	105.0 c	115.0 c
S_1V_4	77.00 d	100.0 de	81.00 c	106.0 c	118.0 c
S_1V_5	70.00 ij	93.00 i-k	74.33 e-g	99.33 e-g	109.7 d
S_2V_1	70.67 hi	93.67 ij	73.33 f-h	98.33 f-h	101.0 fg
S_2V_2	103.7 a	126.7 a	98.00 a	123.0 a	125.0 b
S_2V_3	72.67 gh	95.67 g-i	75.00 d-f	100.3 d-f	102.0 f
S_2V_4	75.33 d-f	98.33 d-g	78.00 cd	103.0 cd	106.0 e
S_2V_5	68.67 i-k	91.67 j-l	69.67 i	94.67 i	96.00 hi
S_3V_1	60.67 l	83.67 m	69.00 i	94.00 i	96.67 hi
S_3V_2	97.33 b	120.3 b	84.67 b	109.7 b	126.7 b
S_3V_3	76.00 d-f	99.67 de	76.00 d-f	101.0 d-f	109.0 d
S_3V_4	75.67 d-f	98.67 d-f	76.67 de	101.7 de	103.3 ef
S_3V_5	67.00 k	90.00 l	71.33 g-i	96.33 g-i	98.67 gh
S_4V_1	67.67 jk	90.67 kl	70.67 hi	95.67 hi	98.33 gh
S_4V_2	93.00 c	116.0 c	87.67 b	112.7 b	125.1 b
S_4V_3	74.33 e-g	97.33 e-g	76.00 d-f	93.67 i	101.0 fg
S_4V_4	71.00 hi	94.00 h-j	75.67 d-f	100.7 d-f	103.7 ef
S_4V_5	73.67 fg	96.67 f-h	75.00 d-f	100.0 d-f	102.7 f
$LSD_{(0.05)}$	2.52	2.95	3.02	3.03	3.05
CV (%)	1.98	1.79	2.34	1.78	1.71

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence. V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

4.13. Days to maturity

Days to maturity was significantly influenced by different submergence treatments (Appendix VIII and Table 13). The maximum days to maturity (130.40 days) was recorded from 14 days submergence (S_4) treatment whereas, the minimum (115.70 days) was found from no submergence (S_1) treatment.

Days to maturity significantly influenced by the rice varieties (Appendix VIII and Table 14). The maximum days to maturity (133.20 days) was recorded from the

‘BRRI dhan 29’ variety whereas, the minimum (116.60 days) was found from the ‘TIA’ variety.

Interaction effect of submergence and variety showed significant variation in respect of days to maturity (Appendix VIII and Table 15). The maximum days to maturity (149.30 days) was recorded from the combination of 14 days submergence and ‘BRRI dhan 29’ variety (S_4V_2) treatment whereas, the minimum (110.00 days) was recorded from the combination of no submergence and ‘TIA’ variety (S_1V_5) treatment.

4.14. Dry weight of leaf

The dry weight of leaf varied significantly due to different submergence treatment (Appendix VIII and Table 13). The maximum dry weight of leaf (21.93 g) was recorded from S_1 treatment whereas, the minimum (15.01 g) was obtained from S_3 treatment.

The dry weight of leaf varied significantly due to different rice varieties (Appendix VIII and Table 14). The maximum dry weight of leaf (30.22 g) was recorded from the ‘BRRI dhan 29’ whereas, the minimum (11.54 g) was obtained from the ‘BRRI dhan 28’ variety.

Interaction effect of different submergence and rice variety was significant on dry weight of leaf (Appendix VIII and Table 15). The maximum dry weight of leaf (35.56 g) was recorded from V_1S_2 treatment whereas, the minimum (10.41 g) was recorded from V_3S_4 treatment.

Table 13. Effect of submergence on days to maturity, dry weight of leaf, dry weight of leaf sheath, dry weight of stem and dry weight of root of rice

Treatments	Days to Maturity	Dry weight of leaf (g)	Dry weight of leaf sheath (g)	Dry weight of stem (g)	Dry Weight of root (g)
S_1	115.7 d	21.93 a	27.96 a	14.01 a	15.70 d
S_2	120.9 c	18.85 c	16.82 c	13.14 b	22.06 c
S_3	127.1 b	15.01 d	13.49 d	6.89 d	29.13 b
S_4	130.4 a	19.05 b	18.26 b	7.34 c	39.68 a
$LSD_{(0.05)}$	2.81	0.15	0.23	0.42	0.44
CV (%)	1.78	2.61	1.92	3.17	1.29

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence.

Table 14. Effect of variety on days to maturity, dry weight of leaf, dry weight of leaf sheath, dry weight of stem and dry weight of root of rice

Treatments	Days to Maturity	Dry weight of leaf (g)	Dry weight of leaf sheath (g)	Dry weight of stem (g)	Dry weight of root (g)
V_1	126.3 b	11.54 e	13.00 e	13.49 a	23.48 e
V_2	133.2 a	30.22 a	24.42 a	10.86 b	24.06 d
V_3	120.2 c	15.22 d	18.92 d	10.18 c	27.03 c
V_4	120.3 c	16.90 c	19.22 c	9.27 d	28.56 b
V_5	116.6 d	19.67 b	20.10 b	7.91 e	30.09 a
$LSD_{(0.05)}$	3.14	0.16	0.25	0.47	0.49
CV (%)	1.78	2.61	1.92	3.17	1.29

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

Note: V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

4.15. Dry weight of leaf sheath

The dry weight of leaf sheath varied significantly due to different submergence treatment (Appendix VIII and Table 13). The highest dry weight of leaf sheath (27.96 g) was recorded from no submergence treatment whereas, the lowest (13.49 g) was obtained from 9 days submergence treatment.

The dry weight of leaf sheath varied significantly due to different rice varieties (Appendix VIII and Table 14). The highest dry weight of leaf sheath (24.42 g) was recorded from the ‘BRRI dhan 29’ whereas, the lowest (13.00 g) was obtained from the ‘BRRI dhan 28’ variety.

Interaction effect of different submergence and rice variety was significant on dry weight of leaf sheath (Appendix VIII and Table 15). The highest dry weight of leaf sheath (41.42 g) was recorded from the combination of no submergence with ‘BRRI dhan 29’ variety treatment whereas, the lowest (11.89 g) was recorded from the combination of 14 days submergence with ‘BRRI dhan 28’ variety treatment.

4.16. Dry weight of stem

Submergence significantly influenced dry weight of stem of rice (Appendix VIII and Table 13). The maximum dry weight of stem (14.01 g) was found in S_1 treatment whereas, the minimum (7.34 g) was found in S_4 treatment.

Varietal effect significantly influenced dry weight of stem of rice (Appendix VIII and Table 14). The highest dry weight of stem (13.49 g) was found in the variety ‘BRRI dhan 28’ treatment whereas, the lowest (7.91 g) was found in the ‘TIA’ treatment.

Dry weight of stem of rice significantly influenced by the interaction effect of submergence and variety (Appendix VIII and Table 15). The highest dry weight of stem (18.87 g) was recorded from S_1V_1 treatment whereas, the lowest (5.00 g) was recorded from S_4V_5 treatment.

Table 15. Interaction effect of submergence and variety on days to maturity, dry weight of leaf, dry weight of leaf sheath, dry weight of stem and dry weight of root of rice

Treatments	Days to Maturity	Dry weight of leaf (g)	Dry weight of leaf sheath (g)	Dry weight of stem (g)	Dry weight of root (g)
S_1V_1	116.0 gh	13.03 n	13.76 m	18.87 a	12.74 p
S_1V_2	120.3 de	35.56 a	41.42 a	13.41 cd	15.22 o
S_1V_3	116.0 gh	19.95 f	25.76 c	12.97 d	15.59 o
S_1V_4	116.3 gh	17.01 j	24.72 d	12.97 d	17.30 n
S_1V_5	110.0 i	26.32 c	34.16 b	11.81 e	17.67 n
S_2V_1	122.0 de	14.04 m	12.00 o	17.67 b	20.60 l
S_2V_2	127.0 c	26.25 c	18.97 h	13.89 c	20.01 m
S_2V_3	121.0 de	15.41 k	18.65 i	13.44 cd	21.17 k
S_2V_4	120.0 d-f	21.13 e	17.11 j	11.85 e	23.94 j
S_2V_5	114.3 h	17.41 i	17.39 j	8.84 f	24.60 i
S_3V_1	130.0 c	11.03 o	13.89 m	8.25 g	24.54 i
S_3V_2	136.3 b	25.75 d	15.61 k	7.27 hi	26.50 h
S_3V_3	127.0 c	10.61 p	12.35 n	6.79 i	30.61 g
S_3V_4	123.0 d	10.41 q	12.35 n	6.15 j	30.97 g
S_3V_5	119.0 e-g	17.24 i	13.70 m	5.97 j	33.03 f
S_4V_1	137.0 b	8.067 r	11.89 o	9.19 f	36.03 d
S_4V_2	149.3 a	33.33 b	21.69 f	8.89 f	34.50 e
S_4V_3	116.7 f-h	14.91 l	19.40 g	7.53 h	40.77 c
S_4V_4	122.0 de	19.03 g	22.69 e	6.11 j	42.01 b
S_4V_5	127.0 c	17.70 h	15.15 l	5.00 k	45.07 a
$LSD_{(0.05)}$	3.63	0.19	0.29	0.54	0.57
CV (%)	1.78	2.61	1.92	3.17	1.29

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence. V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

4.17. Dry weight of root

The dry weight of root of rice varied significantly due to different submergence treatment (Appendix VIII and Table 13). The maximum dry weight of root (39.68 g) was recorded from 14 days submergence treatment and the minimum (15.70 g) was obtained from no submergence treatment.

The dry weight of root varied significantly due to different rice varieties (Appendix VIII and Table 14). The maximum dry weight of root (30.09 g) was recorded from the ‘TIA’ variety treatment and the minimum (23.48 g) was recorded from the ‘BRRI dhan 28’ variety treatment.

Interaction effect of different submergence and rice variety was significant on dry weight of root of rice (Appendix VIII and Table 15). The highest dry weight of root (45.07 g) was recorded from the combination of 14 days submergence with ‘TIA’ variety (S_4V_5) treatment. On the other hand, the lowest dry weight of root (12.74 g) was recorded from the combination of no submergence with ‘BRRI dhan 28’ variety (S_1V_1) treatment.

4.18. Panicle length

Submergence significantly influenced panicle length of rice (Appendix IX and Table 16). The highest panicle length (30.44 cm) was found in 9 days submergence treatment whereas, the lowest (26.04 cm) was found in no submergence treatment.

Varietal effect significantly influenced panicle length of rice (Appendix IX and Table 17). The maximum panicle length (36.29 cm) was found in the variety ‘TIA’ treatment whereas, the minimum (26.48 cm) was found in the ‘BRRI hybrid dhan 2’ which was statistically identical to ‘BRRI dhan 29’ (26.50 cm), ‘BRRI dhan 28’ (26.92 cm) and ‘BRRI hybrid dhan 3’(27.37 cm).

Panicle length of rice significantly influenced by the interaction effect of submergence and variety (Appendix IX and Table 18). The highest panicle length (40.33 cm) was recorded from S_4V_5 treatment whereas, the lowest (22.47 cm) was recorded from S_1V_1 treatment.

4.19. Number of fertile panicles plant^{-1}

Number of fertile panicles plant^{-1} of rice were significantly affected by the submergence (Appendix IX and Table 16). Number of fertile panicles plant^{-1} increased with the decrease of the submergence days (Table 16). The highest number of fertile panicles plant^{-1} (30.00) was recorded from S_1 treatment and the lowest (14.27) was recorded from S_4 treatment.

Number of fertile panicles of rice were significantly affected by varieties (Appendix IX and Table 17). The highest number of fertile panicles plant^{-1} (32.92) was recorded from 'TIA' variety whereas, the lowest (14.42) was recorded from the variety 'BRRI dhan 28'variety treatment.

Interaction effect of different submergence and variety in terms of number of fertile panicles plant^{-1} also showed significant variation (Appendix IX and Table 18). The highest number of fertile panicles plant^{-1} (42.00) was recorded from the combination of no submergence and 'TIA' (S_1V_5) treatment whereas, the lowest (10.00) was recorded from the combination of 14 days submergence and 'BRRI dhan 29' (S_4V_1) treatment.

Table 16. Effect of submergence on panicle length, number of panicle and number of seed plant^{-1} of rice

Treatments	Panicle length (cm)	Number of panicles plant^{-1}		Number of seeds palnt^{-1}	
		Fertile	Infertile	Fertile	Infertile
S_1	26.04 c	30.00 a	5.70 d	4765.00 a	1339.00 d
S_2	29.18 b	26.00 b	6.95 c	2014.00 b	2900.00 c
S_3	30.44 a	18.47 c	9.85 b	1927.00 b	3578.00 b
S_4	29.19 b	14.27 d	13.09 a	946.70 c	4142.00 a
$LSD_{(0.05)}$	0.99	0.90	0.54	116.60	5.87
CV (%)	2.69	2.99	4.27	3.77	4.85

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence.

Table 17. Effect of variety on panicle length, number of panicles plant^{-1} and number of seeds plant^{-1} of rice

Treatments	Panicle length (cm)	Number of panicles plant^{-1}		Number of seeds palnt^{-1}	
		Fertile	Infertile	Fertile	Infertile
V_1	26.92 b	14.42 e	10.10 a	2092.00 c	3696.00 a
V_2	26.50 b	16.75 d	9.45 b	2484.00 b	3144.00 b
V_3	26.48 b	21.75 c	9.35 b	2205.00 c	3046.00 c
V_4	27.37 b	25.08 b	8.23 c	2488.00 b	2843.00 d
V_5	36.29 a	32.92 a	6.60 d	2796.00 a	2222.00 e
$LSD_{(0.05)}$	1.11	0.01	0.61	130.30	6.56
CV (%)	2.69	2.99	4.27	3.77	4.85

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

Note: V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

4.20. Number of unfertile panicles plant^{-1}

Number of unfertile panicles of rice were significantly affected by the submergence (Appendix IX and Table 16). Number of unfertile panicles plant^{-1} increased with the increasing the submergence days (Table 16). The maximum number of unfertile panicles plant^{-1} (13.09) was recorded from S_4 treatment and the minimum (5.70) was recorded from S_1 treatment.

Number of unfertile panicles of rice were significantly affected by varieties (Appendix IX and Table 17). The maximum number of unfertile panicles plant^{-1} (10.10) was recorded from 'BRRI dhan 28' whereas, the minimum (6.60) was recorded from the variety 'TIA' variety treatment.

Interaction effect of different submergence and variety in terms of number of unfertile panicles plant^{-1} also exposed significant variation (Appendix IX and Table 18). The maximum number of unfertile panicles plant^{-1} (15.13) was recorded from the combination of 14 days submergence and 'BRRI dhan 28'

(S_4V_1) treatment and the minimum (2.00) was recorded from the combination of no submergence with 'TIA' variety (S_1V_5) treatment.

4.21. Number of fertile seeds plant^{-1}

The number of fertile seeds plant^{-1} varied significantly due to different submergence treatment (Appendix IX and Table 16). Number of fertile seeds plant^{-1} increased with the decrease of the submergence days (Table 16). The highest number of fertile seeds plant^{-1} (4765.00) was recorded from no submergence treatment whereas, the lowest (946.70) was obtained from 14 days submergence treatment.

The number of fertile seeds plant^{-1} varied significantly due to different rice varieties (Appendix IX and Table 17). The highest number of fertile seeds plant^{-1} (2796.00) was recorded from the 'TIA' whereas, the lowest (2092.00) was obtained from the 'BRRI dhan 28' variety which, was statistically identical to (2205.00) 'BRRI hybrid dhan 2'variety treatment.

Interaction effect of different submergence and rice variety was significant on number of fertile seeds plant^{-1} (Appendix IX and Table 18). The highest number of fertile seeds plant^{-1} (5704.00) was recorded from the combination of no submergence with 'TIA' variety treatment whereas, the lowest (297.00) was recorded from the combination of 14 days submergence with 'BRRI dhan 28' variety treatment.

Table 18. Interaction effect of submergence and variety on panicle length, number of panicles plant^{-1} and number of seeds plant^{-1} of rice

Treatments	Panicle length (cm)	Number of panicles plant^{-1}		Number of seeds palnt^{-1}	
		Fertile	Infertile	Fertile	Infertile
S_1V_1	22.47 k	20.33 g	6.33 g	4475.00 d	2145.00 p
S_1V_2	25.00 j	21.67 f	5.00 h	5324.00 b	1463.00 q
S_1V_3	25.55 ij	32.00 c	5.00 h	3531.00 e	1240.00 s
S_1V_4	27.30 f-h	34.00 b	4.67 i	4790.00 c	1359.00 r
S_1V_5	29.89 e	42.00 a	2.00 i	5704.00 a	489.70 t
S_2V_1	25.78 ij	18.00 h	9.50 ef	2593.00 f	2583.00 k
S_2V_2	28.01 fg	21.00 fg	7.00 g	2137.00 gh	3148.00 h
S_2V_3	27.30 f-h	26.00 e	6.67 g	2187.00 g	2335.00 o
S_2V_4	28.48 f	30.33 d	6.67 g	1996.00 h	2528.00 l
S_2V_5	36.35 c	34.67 b	6.60 g	2005.00 h	3904.00 f
S_3V_1	34.00 d	12.00 k	9.95 e	2081.00 gh	2670.00 j
S_3V_2	26.37 hi	14.33 j	9.85 e	2128.00 gh	2494.00 m
S_3V_3	26.63 hi	16.00 i	8.92 f	1287.00 i	2817.00 i
S_3V_4	26.59 hi	20.00 g	6.602 g	1040.00 j	2390.00 n
S_3V_5	38.59 b	30.00 d	10.75 d	2569.00 f	3464.00 g
S_4V_1	25.45 ij	7.330 m	15.13 a	297.30 l	5408.00 a
S_4V_2	26.63 hi	10.00 l	12.25 c	655.70 k	5045.00 c
S_4V_3	26.43 hi	13.00 k	13.00 b	721.70 k	4764.00 d
S_4V_4	27.11 gh	16.00 i	13.00 b	1022.00 j	5095.00 b
S_4V_5	40.33 a	25.00 e	12.25 c	1287.00 i	4457.00 e
$LSD_{(0.05)}$	1.28	1.16	0.70	150.50	7.57
CV (%)	2.69	2.99	4.27	3.77	4.85

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence. V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

4.22. Number of infertile seeds plant^{-1}

The number of infertile seeds plant^{-1} varied significantly due to different submergence treatment (Appendix IX and Table 16). Number of infertile panicles plant^{-1} increased with the increasing the submergence days (Table 16). The highest number of unfertile seeds plant^{-1} (4142.00) was recorded from 14 days submergence treatment and the lowest (1339.00) was obtained from no submergence treatment.

The number of infertile seeds plant^{-1} varied significantly due to different rice varieties (Appendix IX and Table 17). The highest number of infertile seeds plant^{-1} (3696.00) was recorded from the 'BRRI dhan 28' variety and the lowest (2222.00) was obtained from the 'TIA' variety treatment.

Interaction effect of different submergence and rice variety was significant on number of unfertile seeds plant^{-1} (Appendix IX and Table 18). The highest number of unfertile seeds plant^{-1} (5408.00) was recorded from the combination of 14 days submergence with 'BRRI dhan 28' variety (S_4V_1) treatment and the lowest (489.70) was recorded from the combination of no submergence with 'TIA' variety (S_1V_5) treatment.

4.23. Number of fertile grains tiller^{-1}

Submergence significantly influenced number of fertile grains tiller^{-1} of rice (Appendix X and Table 19). Number of fertile grains tiller^{-1} increased with the decrease of the submergence days (Table 19). The maximum number of fertile grains tiller^{-1} (151.90) was found in no submergence (S_1) treatment whereas, the minimum (70.14) was found in 14 days submergence (S_4) treatment.

Varietal effect significantly influenced number of fertile grains tiller^{-1} of rice (Appendix X and Table 20). The maximum number of fertile grains tiller^{-1} (109.80) was found in the variety 'TIA' (V_5) treatment whereas, the minimum (92.09) was found in the 'BRRI dhan 28' (V_1) treatment.

Number of fertile grains tiller^{-1} of rice significantly influenced by the interaction effect of submergence and variety (Appendix X and Table 21). The maximum number of fertile grains tiller^{-1} (187.60) was recorded from S_1V_5 treatment whereas, the minimum (58.83) was recorded from S_4V_1 treatment.

Table 19. Effect of submergence on number of grains tiller^{-1}, 1000 grains weight and weight of grains plant^{-1} of rice

Treatments	Number of grains tiller^{-1}		1000 grains weight (g)	Weight of grains plant^{-1} (g)	
	Fertile	Infertile		Fertile	Infertile
S_1	151.90 a	50.42 d	25.75 a	65.15 a	6.05 d
S_2	93.98 b	81.71 c	17.84 b	29.38 b	7.45 c
S_3	90.78 c	94.74 b	15.90 c	20.47 c	9.03 b
S_4	70.14 d	97.51 a	15.12 d	17.81 d	10.58 a
$LSD_{(0.05)}$	1.16	2.16	0.29	0.08	0.08
CV (%)	1.66	2.08	1.21	2.20	2.40

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence.

Table 20. Effect of variety on number of grains tiller^{-1}, 1000 grains weight and weight of grains plant^{-1} of rice

Treatments	Number of grains tiller^{-1}		1000 grains weight (g)	Weight of grains plant^{-1} (g)	
	Fertile	Infertile		Fertile	Infertile
V_1	92.09 d	100.20 a	15.88 d	31.70 e	10.38 a
V_2	100.5 c	83.79 b	17.20 c	31.89 d	9.45 b
V_3	100.7 c	75.98 c	18.74 b	32.30 c	7.52 d
V_4	105.4 b	74.61 c	18.83 b	34.61 b	8.47 c
V_5	109.8 a	70.91 d	22.60 a	35.51 a	6.57 e
$LSD_{(0.05)}$	2.41	2.41	0.33	0.09	0.09
CV (%)	1.66	2.08	1.21	2.20	2.40

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

Note: V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

4.24. Number of infertile grains tiller^{-1}

Submergence significantly influenced number of infertile grains tiller^{-1} of rice (Appendix X and Table 19). Number of infertile grains tiller^{-1} increased with the increase of the submergence days (Table 19). The minimum number of unfertile grains tiller^{-1} (50.42) was found in no submergence (S_1) treatment and the maximum (97.51) was found in 14 days submergence (S_4) treatment.

Varietal effect significantly influenced number of infertile grains tiller^{-1} of rice (Appendix X and Table 20). The minimum number of infertile grains tiller^{-1} (70.91) was found in the variety 'TIA' (V_5) treatment and the maximum (100.20) was found in the 'BRRI dhan 28' (V_1) treatment.

Number of infertile grains tiller^{-1} of rice was significantly influenced by the interaction effect of submergence and variety (Appendix X and Table 21). The minimum number of infertile grains tiller^{-1} (42.05) was recorded from S_1V_5 treatment whereas, the maximum (147.70) was recorded from S_4V_1 treatment.

4.25. 1000 grains weight

Submergence significantly influenced 1000 grains weight of rice (Appendix X and Table 19). The maximum 1000 grains weight (25.75 g) was found in no submergence treatment. On the other hand, the minimum 1000 grains weight (15.12 g) was found in 14 days submergence treatment.

Varietal effect significantly influenced 1000 grains weight of rice (Appendix X and Table 20). The maximum 1000 grains weight (22.60 g) was found in the variety 'TIA' treatment. On the other hand, the minimum 1000 grains weight (15.88 g) was found in the 'BRRI dhan 28' treatment.

1000 grains weight of rice was significantly influenced by the interaction effect of submergence and variety (Appendix X and Table 21). The maximum 1000 grains weight (29.53 g) was recorded from the combination of no submergence with ‘BRRI hybrid dhan 3’ (S_1V_4) treatment. On the other hand, the minimum 1000 grains weight (10.67 g) was recorded from the combination of 9 days submergence with ‘BRRI dhan 28’ (S_3V_1) treatment.

4.26. Weight of fertile grains plant^{-1}

Submergence significantly influenced weight of fertile grains plant^{-1} of rice (Appendix X and Table 19). Weight of fertile grains plant^{-1} increased with the decrease of the submergence days (Table 19). The highest weight of fertile grains plant^{-1} (65.15 g) was found in no submergence (S_1) treatment whereas, the lowest (17.81 g) was found in 14 days submergence (S_4) treatment.

Varietal effect significantly influenced weight of fertile grains plant^{-1} of rice (Appendix X and Table 20). The highest weight of fertile grains plant^{-1} (35.51 g) was found in the variety ‘TIA’ (V_5) treatment whereas, the lowest (31.70 g) was found in the ‘BRRI dhan 28’ (V_1) treatment.

Weight of fertile grains plant^{-1} of rice was significantly influenced by the interaction effect of submergence and variety (Appendix X and Table 21). The highest weight of fertile grains plant^{-1} (73.00 g) was recorded from the combination of no submergence with ‘TIA’ (S_1V_5) treatment whereas, the lowest (8.82 g) was recorded from the combination of 14 days submergence with ‘BRRI hybrid dhan 2’ (S_4V_3) treatment.

4.27. Weight of infertile grains plant^{-1}

Submergence significantly influenced weight of infertile grains plant^{-1} of rice (Appendix X and Table 19). Weight of infertile grains plant^{-1} increased with the increase of the submergence days (Table 19). The maximum weight of unfertile grains plant^{-1} (10.58 g) was found in 14 days submergence (S_4) treatment and the minimum (6.05 g) was found in no submergence (S_1) treatment.

Varietal effect significantly influenced weight of infertile grains plant^{-1} of rice (Appendix X and Table 20). The maximum weight of infertile grains plant^{-1} (10.38 g) was found in the variety 'BRRI dhan 28' (V_1) treatment whereas, the minimum (6.57 g) was found in the 'TIA' (V_5) treatment.

Weight of infertile grains plant^{-1} of rice significantly influenced by the interaction effect of submergence and variety (Appendix X and Table 21). The maximum weight of infertile grains plant^{-1} (12.07 g) was recorded from the combination of 14 days submergence with 'BRRI hybrid dhan 2' (S_4V_3) treatment whereas, the minimum (2.83 g) was recorded from the combination of no submergence with 'TIA' (S_1V_5) treatment.

Table 21. Interaction effect of submergence and variety on number of grains tiller^{-1}, 1000 grains weight and weight of grains plant^{-1} of rice

Treatments	Number of grains tiller^{-1}		1000 grains weight (g)	Weight of grains plant^{-1} (g)	
	Fertile	Infertile		Fertile	Infertile
S_1V_1	152.9 b	45.37 l	21.60 e	40.54 f	4.98 n
S_1V_2	136.0 d	55.43 k	25.33 d	35.39 h	8.98 g
S_1V_3	136.4 d	47.05 l	26.33 b	17.56 q	4.51 o
S_1V_4	146.5 c	60.22 j	29.53 a	22.07 k	8.94 g
S_1V_5	187.6 a	42.05 m	25.94 c	73.00 a	2.83 p
S_2V_1	107.6 g	59.00 j	16.53 i	19.20 n	10.74 d
S_2V_2	123.6 e	74.09 h	13.20 n	21.03 l	6.52 l
S_2V_3	104.9 g	75.00 h	18.40 h	17.95 p	7.55 j
S_2V_4	99.80 h	73.53 h	21.48 e	20.88 m	11.81 c
S_2V_5	115.0 f	53.67 k	19.57 g	24.54 i	10.74 d
S_3V_1	92.60 i	70.27 i	10.67 o	16.03 r	8.37 h
S_3V_2	93.09 i	86.22 e	15.75 j	22.72 j	6.73 k
S_3V_3	94.60 i	78.87 g	15.82 j	18.21 o	7.72 i
S_3V_4	70.73 j	88.20 e	18.41 h	62.00 d	6.13 m
S_3V_5	61.67 k	82.73 f	14.97 k	65.00 c	8.31 h
S_4V_1	58.83 l	147.7 a	14.73 k-m	66.29 b	11.95 b
S_4V_2	68.60 j	126.90 c	14.52 lm	59.31 e	10.03 f
S_4V_3	60.80 k	125.10 c	14.40 m	8.82 s	12.07 a
S_4V_4	63.27 k	129.80 b	21.00 f	37.47 g	10.62 e
S_4V_5	99.42 h	98.60 d	14.84 kl	15.95 r	6.04 m
$LSD_{(0.05)}$	1.78	2.79	0.37	0.10	0.10
CV (%)	1.66	2.08	1.21	2.20	2.40

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence. V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

Table 22. Effect of dough stage emergence on the yield of rice

Treatments	Weight of grains per plant (g)	Weight of grains per hectare (kg)	Reduction % of grain weight due to submergence	Remarks
S_1V_1	40.54 f	10,810.67 b	-	-
S_1V_2	35.39 h	9,437.33 c	-	-
S_1V_3	17.95 q	4, 786.66 l	-	-
S_1V_4	22.07 k	5,885.33 f	-	-
S_1V_5	73.00 a	19,466.67 a	-	-
S_2V_1	19.20 n	5,120.00 j	52.64	Highly susceptible
S_2V_2	21.03 l	5,607.90 g	40.58	Susceptible
S_2V_3	17.56 p	4,682.66 m	2.17	Highly tolerant
S_2V_4	20.88 m	5,568.00 h	5.39	Highly tolerant
S_2V_5	24.54 i	6,544.00 d	66.38	Highly susceptible
S_3V_1	16.03 r	4,274.66 p	60.46	Highly susceptible
S_3V_2	22.72 j	6,058.66 e	35.80	Susceptible
S_3V_3	16.21 q	4,456.00 o	9.69	Highly tolerant
S_3V_4	19.00 p	5,066.33 k	13.91	Highly tolerant
S_3V_5	17.00 p	4,533.33 n	76.71	Highly susceptible
S_4V_1	16.29 q	4,343.99 q	59.82	Highly susceptible
S_4V_2	19.31 f	5,149.32 i	45.44	Susceptible
S_4V_3	8.82 s	2,352.00 r	50.86	Highly susceptible
S_4V_4	17.47 r	4,658.66 m	20.84	Medium tolerant
S_4V_5	15.95 r	4,253.33 p	78.15	Highly susceptible
$LSD_{(0.05)}$	0.10	35.35	-	-
CV (%)	2.20	3.28	-	-

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

Note: S_1 – No submergence, S_2 – 4 days submergence, S_3 -9 days submergence and S_4 -14 days submergence. V_1 – BRRI dhan 28, V_2 - BRRI dhan 29, V_3 - BRRI hybrid dhan 2, V_4 - BRRI hybrid dhan 3 and V_5 – TIA.

Percentage yield was calculated on the basis of plant population. Reduction percentage was calculated by comparing the submergence treatments with the control treatments. Weight of grains have been given in the Table 22 again to have a clear idea about the yield and its reduction in comparison to control treatment.

4.28. Weight of grains per hectare

Weight of grains per hectare of rice significantly influenced by the interaction effect of submergence and variety (Table 22). The maximum weight of grains per hectare (19466.67 kg) was recorded from the combination of no submergence with 'TIA' (S_1V_5) treatment whereas, the minimum (2352.00 kg) was recorded from the combination of 14 days submergence with 'BRRI dhan-2' (S_4V_3) treatment.

4.29. Reduction percentage of grain weight due to submergence

Reduction percentage of grain weight of rice due to submergence and variety was numerically significant (Table 22). The highest reduction (66.38%) was recorded from the combination of 4 days submergence with 'TIA' (S_2V_5) treatment whereas, the lowest (2.17%) was recorded from the combination of 4 days submergence with 'BRRI hybrid dhan-2' (S_2V_3) treatment. Comparatively less reduction of yield were observed in case of variety BRRI hybrid dhan-2, which reveals that this variety is the higher tolerant to submergence at dough stage.

The variety BRRI hybrid dhan-2 showed tolerance in case of 4 days and 9 days submergence period but it was highly susceptible in case of 14 days submergence period. In this case further investigation can confirm the situation.

Chapter V

Summary and Conclusion

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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 December, 2013 to April, 2014 to find out the effect of dough stage submergence on the yield of high yielding rice varieties. Treatments included in the two factors experiment were as follows: factor A: Submergence period- S_1 – Control/No submergence, S_2 – Submergence for 4 days, S_3 - Submergence for 9 days, S_4 - Submergence for 14 days and factor B: varieties- V_1 – BRRI dhan 28, V_2 – BRRI dhan 29, V_3 – BRRI hybrid dhan 2, V_4 – BRRI hybrid dhan 3, V_5 – TIA. The experiment was laid out in Randomized Complete Block Design (RCBD) with five replications.

Results showed that plant height, number of tiller plant^{-1}, number of fresh leaves plant^{-1}, number of rotten leaves plant^{-1}, 1%, 50%, 100% booting stage, 1%, 50% panicle insertion stage, 1%, 50%, 100% milking stage, days to maturity, dry weight of leaf, dry weight of leaf sheath, dry weight of root, dry weight of stem, panicle length, number of fertile panicles plant^{-1}, number of unfertile panicles plant^{-1}, number of fertile seeds plant^{-1}, number of unfertile seeds plant^{-1}, number of fertile grains tiller^{-1}, number of unfertile grains tiller^{-1}, 1000 grains weight, weight of fertile grains plant^{-1}, weight of unfertile grains plant^{-1} were significantly influenced by rice varieties. The highest plant height (84.50 cm), number of tillers plant^{-1} (61.42) and number of fresh leaves plant^{-1} (255.8) was found in V_5 (LAL TEER TIA variety) treatment. The maximum 1% booting stage (84.47 days), 50% booting stage (106.7 days), 100% booting stage (114.30 days), 1% panicle insertion stage (96.33 days), 50% panicle insertion stage (119.30 days), 1% milking stage (91.33 days), 50% milking stage (116.30 days), 100% milking stage

(127.80 days), days to maturity (133.20 days) was counted from V_2 (BRRI dhan 29 variety) treatment. The highest dry weight of leaf (30.22 g), dry weight of leaf sheath (24.42 g), dry weight of stem (13.47 g), dry weight of root (30.09 g), panicle length (36.29 cm), number of fertile panicles plant^{-1} (32.92), number of fertile seeds plant^{-1} (2796.00), number of fertile grains tiller^{-1} (109.80), 1000 grains weight (22.60 g), weight of fertile grains plant^{-1} (65.15 g) were obtained from V_5 (LAL TEER TIA variety) treatment.

Significant Interaction effects of submergence and rice varieties on plant height, number of tillers plant^{-1}, number of fresh leaves plant^{-1}, number of rotten leaves plant^{-1}, 1%, 50%, 100% booting stage, 1%, 50% panicle insertion stage, 1%, 50%, 100% milking stage, days to maturity, dry weight of leaf, dry weight of leaf sheet, dry weight of root, dry weight of stem, panicle length, number of fertile panicles plant^{-1}, number of unfertile panicles plant^{-1}, number of fertile seeds plant^{-1}, number of unfertile seeds plant^{-1}, number of fertile grains tiller^{-1}, number of unfertile grains tiller^{-1}, 1000 grains weight, weight of fertile grains plant^{-1}, weight of unfertile grains plant^{-1} were observed. The highest plant height (105.00 cm), number of tiller plant^{-1} (83.33) and number of fresh leaves plant^{-1} (340.00) were found in S_1V_5 treatment. The maximum 1% booting stage (86.00 days), 50% booting stage (108.00 days), 100% booting stage (120.00 days), 1% panicle initiation stage (103.70 days), 50% panicle initiation stage (126.70 days), 1% milking stage (98.00 days), 50% milking stage (123.00 days), 100% milking stage (134.30 days), days to maturity (149.30 days) were counted from S_2V_2 treatment. The highest dry weight of leaf (35.56 g), dry weight of leaf sheath (41.42 g), dry weight of stem (18.87 g), dry weight of root (45.07 g), panicle length (40.33 cm) were observed from S_1V_2 treatment. The maximum number of fertile panicles plant^{-1} (42.00), number of fertile seeds plant^{-1} (5704.00), number of fertile grains tiller^{-1} (187.60), 1000 grains weight (29.53 g), weight of fertile grains plant^{-1} (73.00 g) were observed from S_1V_5 treatment.

Maximum reduction of yield (66.38%) was found in S_2V_5 treatment which was highly susceptible and minimum reduction of yield (2.17%) was obtained from the treatment S_2V_3 in case of 4 and 9 days submergence. Comparatively less reduction of yield were observed in case of variety BRRI hybrid dhan-2, which reveals that this variety has the higher tolerance to submergence at dough stage. Variety V_2 (BRRI dhan-29) was highly susceptible to submergence.

Based on the experimental results, it may be concluded that:

i) The effect of submergence had negative effect on morphological characters, yield and yield attributes of rice. The varieties BRRI dhan-28 and TIA were highly susceptible to submergence.

ii) TIA variety provided the highest yield in normal condition i.e., without submergence. BRRI dhan 29 was susceptible variety for submergence at dough stage. In case of submergence the variety BRRI hybrid dhan 2 was highly tolerant up to 9 days of submergence which was highly susceptible at 14 days of submergence. BRRI hybrid dhan 3 was highly tolerant up to 9 days of submergence and medium tolerant up to 14 days of submergence.

iii) Cultivation of BRRI hybrid dhan 2 can be suggested for possible submergence condition of up to 9 days and BRRI hybrid dhan 3 can be suggested for possible submergence condition of up to 14 days.

Recommendation

Considering the above observations of the present study further investigation in the following areas may be suggested:

1. Further study may be needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.
2. More number of treatments with different periods of submergence duration and other rice varieties may be selected to study such effect.

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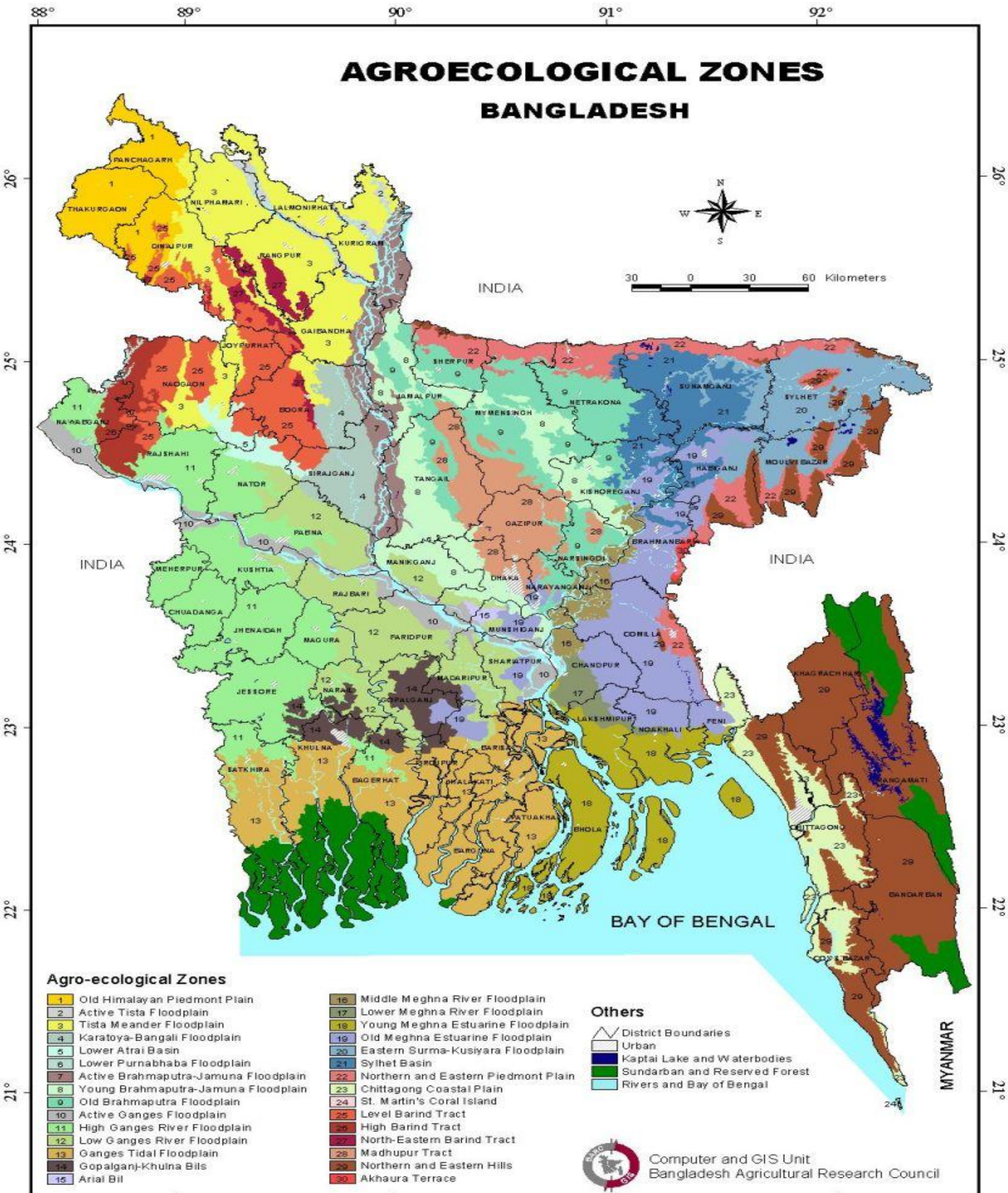
Appendices

APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh



Appendix II. Characteristics of Agricultural Botany Farm soil as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agricultural Botany Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Fallow- Rice

B. Physical and chemical properties of the initial soil

Characteristics	Value
%Sand	27
%Silt	43
%clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel 1 00 g soil)	0.10
Available S (ppm)	45

Source : SRDI, 2013

Appendix III. Monthly record of air temperature, rainfall, relative humidity and Sunshine of the experimental site during the period from November 2013 to April 2014

Month	Average air temperature (°C)			Average relative humidity (%)	Total rainfall (mm)	Total Sunshine per day (hrs)
	Maximum	Minimum	Mean			
November, 2013	29.7	20.1	24.9	65	5	6.4
December, 2013	26.9	15.8	21.35	68	0	7.0
January, 2014	24.6	12.5	18.7	66	0	5.5
February, 2014	25.6	16.1	20.9	65	2	6.0
March, 2014	30.5	20.3	25.4	67	57	6.7
April, 2014	33.7	23.8	28.81	69	185	7.8

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

Appendix IV: Error mean square values for plant height of rice at different days after sowing (DAS)

Source of variation	Degrees of freedom	Plant height						
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	120 DAS	Harvest
Replication	2	0.512	6.929	6.929	70.355	146.980	146.980	6.929
Submergence (A)	3	61.214*	258.021*	258.021*	262.010*	150.568*	111.634*	79.470*
Variety (B)	4	5.027*	121.587*	55.037**	79.470*	84.468*	84.468**	5.685**
A × B	12	0.716**	6.669**	6.669*	3.795*	5.685**	5.685*	6.669*
Error	38	1.949	15.077	15.077	36.725	11.934	11.934	19.573

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix V: Error mean square values for number of tillers plant^{-1} of rice at different days after sowing (DAS)

Source of variation	Degrees of freedom	Number of tillers plant^{-1}						
		20 DAS	40 DAS	60 DAS	80 DAS	100 DAS	120 DAS	Harvest
Replication	2	0.008	0.612	0.401	0.737	0.136	0.138	70.355
Submergence (A)	3	3.909**	8.810*	12.801*	6.418**	8.048**	3.923**	262.010*
Variety (B)	4	0.268*	13.934**	9.808*	7.435*	10.310*	0.328**	79.470*
A × B	12	0.087*	0.679*	0.368**	0.081*	0.252**	1.247*	3.795*
Error	38	0.185	0.350	0.481	0.522	0.591	0.245	36.725

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix VI: Error mean square values for number of leaves and booting stage of rice

Source of variation	Degrees of freedom	Number of leaves		Booting stage		
		Fresh	Rotten	1%	50%	100%
Replication	2	0.020	0.433	0.001	0.001	0.07
Submergence (A)	3	0.305*	0.135*	0.082*	0.041*	0.012*
Variety (B)	4	0.081*	0.395*	0.034*	0.026*	0.33*
A × B	12	0.003*	0.641*	0.008*	0.007*	0.103*
Error	38	0.006	2.839	0.003	0.002	6.720

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix VII: Error mean square values for panicle insertion and milking stage of rice

Source of variation	Degrees of freedom	Panicle insertion stage		Milking stage		
		1%	50%	1%	50%	100%
Replication	2	1.863	2.164	4.224	0.302	0.264
Submergence (A)	3	3.346*	6.761**	5.643**	5.362*	2.794*
Variety (B)	4	4.086**	1.107**	8.127**	1.901*	3.655*
A × B	12	3.407**	1.26**	5.03**	1.60*	3.660*
Error	38	0.452	1.61	3.35	4.23	2.752

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix VIII: Error mean square values for days to maturity and dry weight of leaf, leaf sheath, stem and root of rice

Source of variation	Degrees of freedom	Days to maturity	Dry weight of leaf	Dry weight of leaf sheath	Dry weight of stem	Dry weight of room
Replication	2	0.934	0.042	0.147	0.0001	0.000
Submergence (A)	3	0.883**	0.491*	0.952*	0.017**	0.054*
Variety (B)	4	0.933*	0.832*	0.892*	0.001*	0.880*
A × B	12	0.518**	0.981*	0.50**	0.001*	0.515*
Error	38	8.306	5.173	5.38	0.001	3.412

*Significant at 5% level of probability
** Significant at 1% level of probability

Appendix IX: Error mean square values for panicle parameter of rice

Source of variation	Degrees of freedom	Panicle length	Number of panicles palnt^{-1}		Number of seeds plant^{-1}	
			Fertile	Unfertile	Fertile	Unfertile
Replication	2	4.000	0.096	0.001	0.132	0.186
Submergence (A)	3	31.750*	43.002**	95.807**	132.281**	10.131**
Variety (B)	4	107.889*	10.131**	24.101*	82.548*	36.101*
A × B	12	7.306**	0.024*	0.697**	31.750*	3.323*
Error	38	1.364	0.059	0.001	1.343	3.000

*Significant at 5% level of probability
** Significant at 1% level of probability

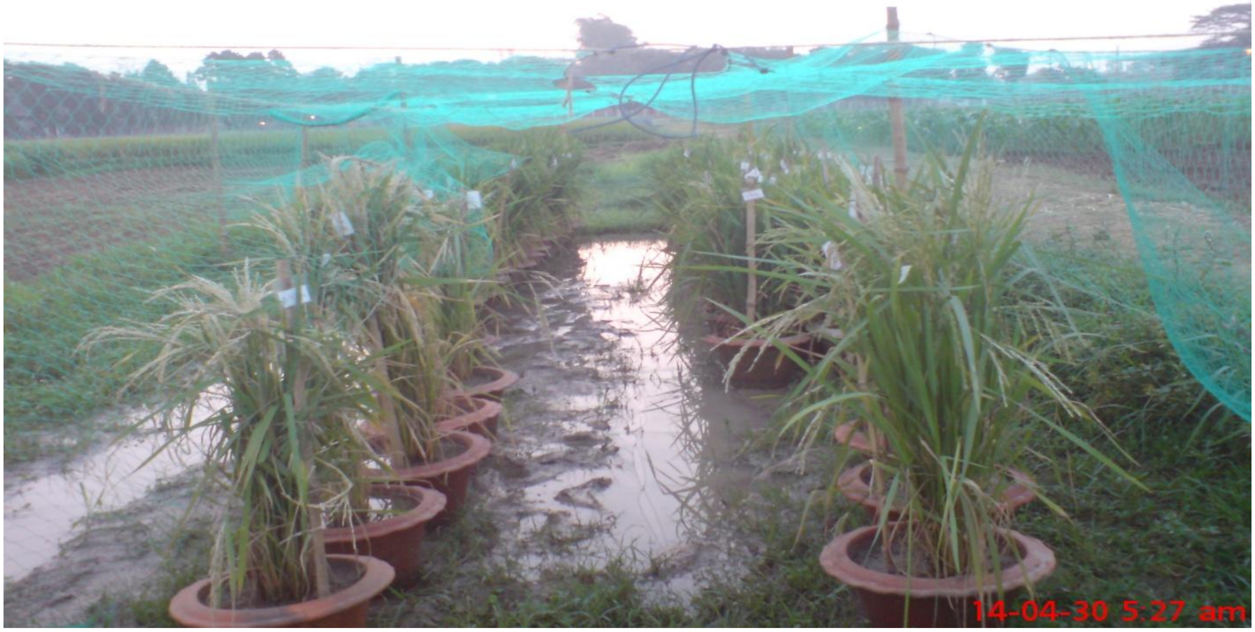
Appendix X: Error mean square values for grain yield parameter of rice

Source of variation	Degrees of freedom	Number of grains tiller^{-1}		1000 grains weight	Weight of grains palnts^{-1}	
		Fertile	Unfertile		Fertile	Unfertile
Replication	2	0.009	0.068	0.058	29.538	0.147
Submergence (A)	3	0.833*	1.577**	0.147*	1242.871*	0.952*
Variety (B)	4	0.494**	1.040*	0.134*	723.641*	0.892*
A × B	12	0.017*	0.018*	0.017*	18.225**	0.50**
Error	38	0.004	0.024	0.017	11.292	5.38

*Significant at 5% level of probability

** Significant at 1% level of probability

PLATES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Implemented under the Project : "Development of Plant Physiology Laboratory of Agricultural Botany Department for the Enhancement of Quality Education" (CP-532).
Department : Agricultural Botany. SAU.
Sub Project Manager : Prof. Dr. Kamal Uddin Ahamed
Dept. of Agricultural Botany. SAU.
Funded by : Higher Education Quality Enhancement Project (HEQEP), UGCB, Ministry of Education, People's Republic of Bangladesh.

Plate. The Experiment of different duration of submergence with five rice varieties