INFLUENCE OF WATER SUBMERGENCE STRESS AT EARLY STAGE ON THE GROWTH PATTERN & YIELD OF SOME INBRED AND HYBRID RICE VARIETIES

BY

RAFIUN NAHAR

Registration No. : 06-1881

A Thesis

Submitted to the Department of Agricultural Botany
Sher-e-Bangla Agricultural University, Dhaka, in partial
fulfillment of the requirements
for the degree
of

MASTER OF SCIENCE
IN
AGRICULTURAL BOTANY

SEMESTER: JANUARY-JUNE/2012

Approved by:

Prof. Dr. Kamal Uddin Ahamed

Supervisor

Md. Moinul Haque
Associate Professor
Co-Supervisor

Dr. Mohammad Mahbub Islam
Associate Professor
Chairman
Examination Committee

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

PABX: +88029144270-9
Fax: +88029112649
Web site: www.sau.edu.bd

Ref: *Date: ………………*

CERTIFICATE

This is to certify that the thesis entitled, ***"INFLUENCE OF WATER SUBMERGENCE STRESS AT EARLY STAGE ON THE GROWTH PATTERN & YIELD OF SOME INBRED AND HYBRID RICE VARIETIES"*** *submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE IN AGRICULTURAL BOTANY***, *embodies the results of a piece of bona fide research work carried out by* ***RAFIUN NAHAR*** *Registration No.* **06-1881** *under my supervision and my guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Prof. Dr. Kamal Uddin Ahamed
Dept. of Agricultural Botany
SAU, Dhaka
Supervisor

Dated : December, 2013

Place: Dhaka, Bangladesh

ACKNOWLEDGEMENTS

All praises go to Almighty Allah, the Supreme Ruler of the universe who enabled the Author to complete the present piece of work.

*I would like to express my heartiest respect, my deep sense of gratitude and sincere, profound appreciation to my supervisor, **Prof. Dr. Kamal Uddin Ahamed**, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka for his sincere guidance, scholastic supervision, constructive criticism and constant inspiration throughout the course and in preparation of the manuscript of the thesis.*

*I would like to express my heartiest respect and profound appreciation to my Co-supervisor, **Md. Moinul Haque**, Associate Professor, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka for his utmost cooperation and constructive suggestions to conduct the research work as well as preparation of the thesis.*

*I express my sincere respect to the Chairman, **Dr. Mohammad Mahbub Islam,** and all the teachers of Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka for providing the facilities to conduct the experiment and for their valuable advice and sympathetic consideration in connection with the study.*

I would like to thank my all roommates and friends especially senior brother (Arif) to help me in my research work.

Mere diction is not enough to express my profound gratitude and deepest appreciation to my father, mother, brothers, sisters, and friends for their ever ending prayer, encouragement, sacrifice and dedicated efforts to educate me to this level.

December, 2013 — ***The Author***

SAU, Dhaka

INFLUENCE OF WATER SUBMERGENCE STRESS AT EARLY STAGE ON THE GROWTH PATTERN & YIELD OF SOME INBRED AND HYBRID RICE VARIETIES

ABSTRACT

The experiment was conducted during the period from June to December, 2012 in T. *aman* season to find out the influence of water submergence stress on the growth pattern & yield of some hybrid rice varieties. Four submergence duration, viz., Control (no submergence), Six days submergence, Ten days submergence and Fourteen days submergence and six varieties, viz., BRRI dhan 51, BRRI dhan 46, BRRI dhan 34. BRRI hybrid 4, Panna-1, Taj -1 were used to conduct this experiment. The experiment was laid out in Randomized Complete Block Design (RCBD) having two factors and replicated three times. All parameter were significantly affected by the interaction between submergence and variety. The tallest plant was recorded from fourteen days submergence treatment.The highest number of leaves, number of tillers hill^{-1}, number of effective tillers hill^{-1}, and number of filled grains panicle^{-1}, weight of 1000 grains were recorded from no submergence treatment. The highest grain yield was found from control (no submergence) treatments. The Panna-1 variety produced the tallest plant and highest number of leaves. The BRRI dhan 51 achieved the highest number of tillers hill^{-1}, number of effective tillers hill^{-1}, highest number of grains panicle^{-1} and 1000-grain weight. The BRRI hybrid dhan 4 produced the highest 7.18 t ha^{-1} grain yield. Significantly the highest (8.00 t ha^{-1}) grain yield was found from the treatment combination of no submergence with BRRI hybrid dhan 4 and the lowest (1.10 t ha^{-1}) from fourteen days submergence with BRRI dhan 34. Among the varieties BRRI dhan 51 is treated as submergence tolerant. In comparison to this Panna 1 and BRRI dhan 34 was found to be susceptible. BRRI dhan 46 and Taj 1 was some what tolerant and BRRI hybrid 4 provided some what good yield in submergence conditon. The tested genotypes showed wide variation in yield with BRRI dhan 51 (tolerant)> Taj-1 > BRRI dhan 46> BRRI hybrid dhan 4> Panna - 1> BRRI dhan 34(susceptible).

CONTENTS

CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APENDDIX

LIST OF ABBREVIATION AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
HRC	=	Horticulture Research Centre
BBS	=	Bangladesh Bureau of Statistics
FAO	=	Food and Agricultural Organization
N	=	Nitrogen
et al.	=	And others
TSP	=	Triple Super Phosphate
MOP	=	Muriate of Potash
DAT	=	Days after Transplanting
ha^{-1}	=	Per hectare
g	=	gram (s)
kg	=	Kilogram
SAU	=	Sher-e-Bangla Agricultural University
SRDI	=	Soil Resources and Development Institute
wt	=	Weight
LSD	=	Least Significant Difference
^0C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important staple food crops, which supplies major source of calories for about 45 per cent of world population, particularly to the people of Asian countries. Rice stands second in the world after wheat in area and production. It occupies an area of 153.76 m. ha with an annual production of 598.85 m.t., with a productivity of 3895 kg per ha in the world (Anon, 2006). Asia produces and consumes 90 per cent of world's rice. Among the rice growing countries, India ranks first in area followed 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 m.t. with average productivity of 9.84 t/ha (Anon, 2005). In Karnataka rice is cultivated in an area of 1.31 m. ha with an annual production of 2.70 m.t. with average productivity of 7.0 t/ha (Anon, 2006).

In Bangladesh total cultivable land is 90,98,460 hectare and near about 70 per cent of this land is occupied by Rice cultivation. In the year of 2011, total production of Rice is 3,35,41,099 metric ton. Hybrid rice varieties is cultivated in 6,53,000 hectare of land and total production is 28,82,000 metric ton in the year of 2010-2011. On the other hand, HYV (High Yielding Variety) is cultivated in 40,67,000 hectare land and the total production of rice is 156,32,000 metric ton. The average rice production of hybrid varieties is 4.41 metric ton and HYV varieties are 3.84 metric ton in the year of 2010 – 2011(BBS, 2011).

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

The onset of flooding (or submergence/waterlogging, for the sake of simplicity, the terms 'flooding', 'submergence' and 'waterlogging' have been interchangeably used in the present discussion) leads to the condition of anaerobiosis of oxygen deprivation (partial or complete as gas diffusion from the atmosphere to water in nearly 10^4 times slower in water as compared to diffusion in air (Armstrong, 1979). This effect is accentuated due to (i) the respiratory activities in roots and the water borne microorganisms and (ii) reduced photosynthesis of the submerged portions due to cut-off of light supply. Such a condition is lethal to most land plants. Rice is relatively a flooding tolerant crop (Perata and Alpi, 1993).

In Bangladesh rain fed lowland rice covers an area of 4.5 million hectares (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 from adjoining rivers. Such flood may continue for a week or more inflicting heavy damage to standing crop. As a result yield of rice grain is severely decreased (Zeigler and Puckridge, 1995). Dey *et al.* (1996) reported the abiotic factors submergence and drought are the two top constraints in rain fed 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 yields 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.

Flooding imposes severe selection pressure on plants, principally because excess water in the plant surroundings can deprive them of certain basic needs, notably of oxygen and of carbon dioxide and light for photosynthesis. It is a major abiotic influence on species' distribution and agricultural productivity world-wide. Strong submergence-induced elongation is a widespread escape mechanism that helps submerged plants to regain or retain contact with the aerial environment on which they depend (Arber, 1920). This mechanism enables plants to resume anaerobic metabolism and photosynthetic fixation of CO_2 by raising their shoots above water. Escape strategies based on elongation by stem or leaves are prominent characteristics of deep-water and floating rice. However, rapid elongation by leaves of young plants in response to short-term submergence flash flood (for up to 2 weeks) adversely affects tolerance by depleting carbohydrates that would otherwise support survival during and after submergence (Chaturvedi *et al.*, 1995; Setter & Laureles, 1996; Kawano *et al.*, 2002; Ram *et al.*, 2002: Jackson & Ram, 2003; Joho *et al.*, 2008). Submergence-tolerant rice varieties tend to accumulate more starch in their stem section than susceptible varieties do. They experience less carbohydrate depletion after submergence (Karin *et al.*, 1982; Emes *et al.*, 1988). To improve the circumstances of tolerant plants and to survive under flooding conditions is a major constraint for sustainable agriculture in unstable environments which is undergoing due to climate change.

Submergence stress tolerant varieties are the most desirable trait for rice farmers in our country, where flash flooding occurs frequently and unpredictably 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. 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 hybrid rice varieties.

Therefore, the specific objectives of the present study were:

i. To determine the effect of duration of submergence on the morphological attributes and yield of six hybrid and inbred rice varieties.

ii. To identify the suitable submergence tolerant ones from the varieties tested.

CHAPTER II
REVIEW OF LITERATURE

Variety and Submergence are an important factor 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. Researcher's relevant to variety and submergence effects on crop plants are done in different parts of the world are 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 yield of rice are discussed below.

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

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

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.

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.

Devaraju *et al.* (1998) in a study with two rice hybrids such as Karnataka Rice Hybrid 1 (KRH1) and Karnataka Rice Hybrid-2(KRI42) using HYV IR20 as the check variety and found that KRH2 out yielded than IR20. In IR20, the tiller number was higher than that of KRH2.

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.

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

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

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.

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 $hill^{-1}$.

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

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

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

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 $penicle^{-1}$.

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 had better morphological characters like more grains panicle^{-1} compared to their better parents which contributed to yield improvement in these hybrid lines of rice.

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.

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.

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.

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.

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.

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 yield of 5.6 t ha^{-1} that was at par with hybrid PA6201.

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

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.

Nematzadeh *et al.* (1997) reported that local high quality rice cultivars Hassan Sarai and Sang-Tarom were crossed with improved high yielding cultivars Amol 3, PND160-2-1 and RNR1446 in all possible combinations and released in 1996 under the name Nemat, it gives an average grain 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 checks Challish and Nizersail produced yields of 4.38, 3.18, 3.12, 3.12 and 2.70 5 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 than the native varieties. Liu (1995) conducted a field trial with new indica hybrid rice II-You 92 and found an average yield of 7.5 t ha^{-1} which was 10% higher than that of standard hybrid Shanyou 64.

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

Suprihatno and Sutaryo (1992) conducted an experiment with seven IRRI hybrids and 13 Indonesian hybrids using 1R64 and way-seputih. They observed that TR64 was highest yielding, significantly out yielding IR64616H, IR64618, IR64610H and IR62829A/IR54 which in turn out yielded way-seputih. Chandra *et al.* (1992) reported that hybrid IR58025A out yielded the IR62829A hybrids and the three control varieties Jaya, IR36 and hybrids IR58025A x 9761-191R and IR58025A IR58025Ax 1R35366-62-1-2-2-3R.

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

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) also reported that 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 Factors affecting submergence tolerance

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 phenological 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 dm3 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; tillering initiation to physiological maturity; panicle 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 1,000-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 (Thiago Isquierdo Fraga *et al.*2010).

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 submerged for more than a month. Such prolonged submergence often triggers crop failures. Guinea's farmers prefer to cultivate *O. glaberrima* fields with prolonged submergence because of such advantageous traits as those explained above. Cultivars of *O. glaberrima* are 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 found in some cultivars of *O. glaberrima*. However, it is vulnerable to NaCl salinity (Awala *et al.*, 2010), grain shattering (Koffi, 1980), and lodging (Dingkuhn, 1998). It is reasonable to presume that the indigenous cultivated species of African rice can provide useful genes for improvement of tolerance to major stress in Africa.

Kawano (2009) showed that suppression of underwater elongation brought about by the mutated form of *Sub-1A* 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.

Sakagami *et al.* (2009) 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.

A strategy with shoot elongation shows two different mechanisms: rapid shoot elongation in shallow floods in a short-term submergence and internodal 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 *et al.*, 2007).

The rate of gas exchange is very slow in water because of small diffusion coefficients 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. Furthermore, 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, metabolim and survival of submergence plants, limited gas diffusion is the most crucial component, because gass 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 feature of flooding, inducing hypoxia (low O_2) or anoxia (zero O_2) around the shoot and root tissues or germinating seeds (Kennedy *et al.* 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 complicated because increase CO2 supply would increase photosunthesis, increase oxygention from potosynthesis and from aeration of solutions, and reduxe ethylene due to degassing solutions using high CO_2 pressures in air (Setter, *et al.* 1989). Measurement of the gases in floodwater during submergence is therefore relevant to undrstand 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 photsynthesis to the compensation point at 0.25m water depth (Setter, *et al.* 1987). Floodwater turbidity reduces light transmission and deposites silton the leaves of submerged plants. Irradiance in floodwater in Bangladesh was due to surface algal colonies as well as turbidity.

CHAPTER III
MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, uprooting of seedlings, intercultural operations, data collection and statistical analysis.

3.1 Experimental period

The experiment was conducted during the period from June to December, 2012 in T. *aman* season.

3.2 Site description

The experiment was conducted in the Agricultural Botany Experimental Field, Sher-e-Bangla Agricultural University farm, Dhaka, under the agro-ecological zone of Modhupur Tract, AEZ-28. For better understanding the experimental site is shown in the Map of AEZ of Bangladesh in Appendix I.

3.3 Climate

The experimental area under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the rabi season (October-March). The weather data during the study period at the experimental site are shown in Appendix II.

3.4 Soil

The farm belongs to the General soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done at Soil Resource and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix III.

3.5 Planting material

Rice variety : BRRI dhan 51, BRRI dhan 46, BRRI dhan 34. BRRI hybrid 4, Panna1, Taj1 were used as the test crop.

BRRI dhan 51 (T. Aman) is submergence tolerant for certain days. BRRI dhan 34 is susceptible to submergence and grown on Aman season. BRRI dhan 46 and BRRI hybrid 4 varieties can be grown in Aman season. The exotic hybrid varieties Taj-1 and Panna-1 are usually cultivated in Boro season in Bangladesh. These hybrid varieties have been selected to see their performance in Aman Season as well as in submergence stress. Such experiment was not carried out before in Bangladesh. So this experiment would provide important information for future use.

3.6 Seed collection and sprouting

Seeds of BRRI dhan 51, BRRI dhan 46, BRRI dhan 34. BRRI hybrid 4, Panna 1, Taj1 were collected from BRRI, Joydebpur, Gazipur. Healthy seeds were selected following standard method. Seeds were immersed in water in a bucket for 24 hrs. These were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hrs which were suitable for sowing in 72 hrs.

3.7 Raising of seedlings

A common procedure was followed in arising of seedlings in the seedbed. The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible. Irrigation was gently provided to the bed as and when needed. No fertilizer was used in the nursery bed.

3.8 Preparation of experimental land

The experimental field was first opened on 11 July, 2012 with the help of a power tiller, later the land was irrigated and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering to have a good puddled field. All kinds of weeds and residues of previous crop were removed from the field. The field layout was made on 22 July, 2012 according to design immediately after final land preparation. Individual plots were cleaned and finally leveled with the help of wooden plank.

3.9 Fertilizer management

At the time of first ploughing cowdung at the rate of 10 t ha^{-1} was applied. The experimental plots were fertilized with @ 120, 100, 50, 62.5, 10 kg ha^{-1} in the form of urea, triple superphosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate, respectively (BARC, 1989) one day before transplanting. The entire amounts of triple superphosphate (TSP), muriate of potash (MP), gypsum and zinc sulphate were applied at final land preparation as basal dose. The entire amounts of urea was applied at two times first instalment at 30 Days after transplanting and second instalment at 60 Days after transplanting.

3.10 Experimental treatments

The experiment consisted of two factors; (A) submergence duration and (B) different types of varieties. The levels of two factors were as follows:

Factor A: submergence duration, **Factor B:** different types of varieties

Factor A	Factor B
D_0= Control (no submergence)	V_1 = BRRI dhan51 (Submergence tolerant)
D_1= Six days submergence	V_2 = BRRI dhan46
D_2= Ten days submergence	V_3 = BRRI dhan34
D_3= Fourteen days submergence	V_4 = BRRI hybrid 4
	V_5 = Panna1
	V_6 = Taj1

There are reports that the rice varieties which are resistance to submergence can tolerate only 14 days of submergence. For which BRRI dhan 51 has been selected as a control variety as reference, as it can tolerate such length of submergence. Keeping fourteen days of maximum limit, lower range of 6 days and 10 days submergence have been selected as lower and medium length of period to find out the tolerance of different varieties to submergence.

3.11 Treatment combinations:

Treatment combinations are :

D_0V_1	D_1V_1	D_2V_1	D_3V_1
D_0V_2	D_1V_2	D_2V_2	D_3V_2
D_0V_3	D_1V_3	D_2V_3	D_3V_3
D_0V_4	D_1V_4	D_2V_4	D_3V_4
D_0V_5	D_1V_5	D_2V_5	D_3V_5
D_0V_6	D_1V_6	D_2V_6	D_3V_6

The experiment was laid out in a Split Plot Design with three replications. The whole field was divided into three blocks each containing 24 plots. Each block was subdivided into four sub blocks. As such there were 12 sub blocks. Each sub-block was encircled by the 50 cm high soil wall ridge, which was hundred percent water leakage proof. In total, there were 72 plots. The treatments were randomly assigned to each unit plot. The size of unit plot was 4.0m × 2.5 m. The distance between the blocks was 1 m and that between plots was 50 cm. Field Layout as per APPENDIX (IV)

3.12 Uprooting and Transplanting of seedlings

Thirty 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. Seedlings were then transplanted maintaining spacing of 25 cm × 15 cm from row to row and hill to hill, respectively.

3.13 Intercultural operations

3.13.1 Gap filling

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

3.13.2 Submergence

The plant was submerged completely in unit plot to a depth of 40 cm above the soil level. The water level was higher than the plant height. This was done to ensure that the conditions were made as similar as possible to the conditions which occur during actual flooding in nature. After 6, 10 and 14 days of submergence the water was removed from the plot. The plants were submerged 10 days after transplanting. The D_0 or controlled sub-blocks were irrigated as normal irrigation requirement as prescribed for the high yielding varieties (HYV) of rice in Boro season. The other sub-blocks D_1 (6 days submergence), D_2 (10 days submergence) and D_3 (14 days submergence) were irrigated through drain 10 days after transplanting , where the water level was raised up to 40 Cm height to submerge the rice plants. The water in submerged sub-blocks containing different varieties of rice was made turbid time to time by stirring the mud inside the sub-blocks. The water in the sub-block was receded (drained) after 6 days (D_1), 10 days (D_2) and 14 days (D_3) according to the plan made before by cutting the small part of ridge. During submergence period continuous observation was made to maintain the water level up to 40 cm in the field. The researcher was always concerned to maintain the level of water up to desired height in the submerged sub-blocks.

3.13.3 Weeding

During plant growth period two hand weedings were done, first weeding was done at 25 DAT (Days after transplanting) followed by second weeding at 40 DAT.

3.13.4 Application of irrigation

Irrigation was ensured to each plot according to the critical stage, especially at transplanting time, tillering stage, panicle initiating stage, booting stage, panicle insertion stage, anthesis stage, milk stage, dough stage and at maturing stage. Irrigation was done up to 5 cm.

3.13.5 Method of irrigation

The experimental plots were irrigated through irrigation channels. Centimeter marked sticks were installed in each plot which were used to measure depth of irrigation water.

3.13.6 Plant protection measures

Plants were infested with rice stem borer and leaf hopper to some extent which was successfully controlled by applying two times of Diazinone 60 EC on 20. Crop was protected from birds during the grain filling period.

3.13.7 General observation of the experimental field

The field was investigated 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 could be minimized. The field looked nice with normal green color plants. Incidence of stem borer, green leaf hopper, leaf roller was observed during tillering stage. But any bacterial and fungal disease was not observed. The flowering was not uniform. Lodging occurred in local variety plots during the heading stage due to heavy rainfall with gusty winds and in entire experimental plots on 15 November due to sidr.

3.14 Harvesting and post harvest operation

Maturity of crop was determined when 90% of the grains become golden yellow in color. The harvesting was done on ten pre-selected hills, from which data were collected and plants 6 middle lines from each plot was separately harvested, bundled, properly tagged and then brought to the threshing floor. Threshing was done by pedal thresher. The grains were cleaned and sun dried to moisture content of 12%. Straw was also sun dried properly. Finally grain and straw yields $plot^{-1}$ were recorded and converted to t ha^{-1}.

3.15 Experimental measurements

Experimental data collection began at 10 days after transplanting, and continued till harvest. The necessary data on agronomic characters were collected from ten selected hills from each plot in field and at harvest.

3.15.1 Plant height

Plant height was measured at 10 days interval and continued up to 60 days. 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.

3.15.2 Leaves $plant^{-1}$

Leaves per plant were counted at 10 days interval up to harvest from pre selected plants and finally averaged as their number per plant.

3.15.3 Tillers $plant^{-1}$

Tillers $plant^{-1}$ was counted from pre selected plant and finally averaged as their number per plant. Only those tillers having three or more leaves were considered for counting.

3.15.4 Effective tillers $hill^{-1}$

The panicles which had at least one grain was considered as effective tiller.

3.15.5 SPAD reading of flage leaf

SPAD reading of flage leaf was measured by SPAD meter at 30, 40 and 50 days after transplanting. The average value was used in Table 5 to calculate combined effect of submergence and varieties on yield contributing characters of rice

3.15.6 Filled grains panicle^{-1}

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

3.15.7 Sterile grains panicle^{-1}

Sterile grain means the absence of any kernel inside in and such spikelets present on each panicle were counted.

3.15.8 Weight of 1000-grain

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained 12% moisture and the mean weight were expressed in gram.

3.15.9 Grain yield

Grain yield was determined from the central 1 m^2 of all rows of the plot and expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

3.16 Statistical analysis

The recorded data on various parameters were statistically analyzed by using MSTAT statistical package programmed. The mean for all the treatments was calculated and analysis of variance for all the characters was performed by F-test. Difference between treatment means were determined by Duncan's new Multiple Range Test (DMRT) according to Gomez and Gomes, (1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to investigate influence of water submergence stress at early stage on the growth pattern & yield of some inbred and hybrid rice varieties. Data on different parameters were analyzed statistically. The result of the present study have been presented and discussed in this chapter under the following headings.

4.1 Plant height

Plant height in normal treatments and submergence treatments expected to be different, for which height was recorded to find out the differences among the treatments.

Plant height of rice showed statistically significant differences at 10, 20, 30, 40, 50 and 60 days after transplanting and at harvest. The tallest plant (20.33, 22.97, 38.14, 40.65, 59.72 and 86.23 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively) was recorded from D_3 (Fourteen days submergence) treatment, while the shortest plant (18.99, 21.37, 32.96, 33.9, 59.72 and 81.35 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively) was observed from D_0 (no submergence) (Figure 1).

Plant height of the cultivars was measured at 10, 20, 30, 40, 50 and 60 days after transplanting and at harvest. It was evident from Figure 2 that the height of the plant was significantly influenced by variety at all the sampling dates. Figure 2 showed that irrespective of varieties, the height of rice plants increased rapidly at the early stages of growth and rate of progress in height was slow at the later stages. The V_5 (Panna1) variety produced the tallest plant (21.81, 23.15, 36.04, 38.62, 61.81 and 89.27 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively) and V_1 (BRRI dhan 51) produced shortest (18.06, 20.59, 30.09, 32.53, 53.85 and 81.1 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively). Probably the genetic makeup of varieties was responsible for the variation in plant height. This confirms the reports of BINA (1992), BRRI (1991) and Shamsuddin *et al.* (1988) that plant height differed due to varietal variation.

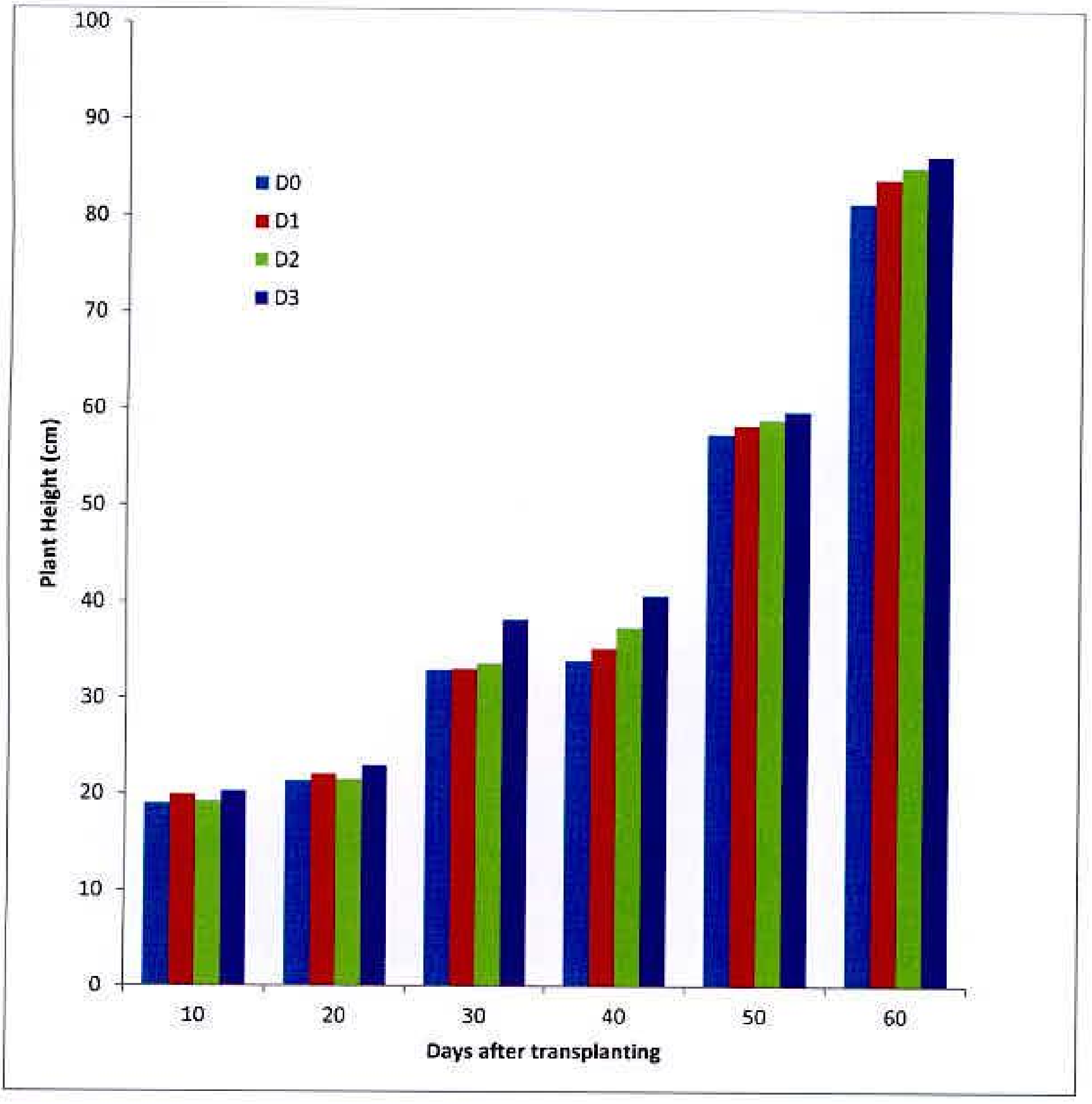


Figure 1. Effect of duration submergence on plant height of rice at different days after transplanting

D_0= Control (no submergence)

D_1= Six days submergence

D_2 = Ten days submergence

D_3 = Fourteen days submergence

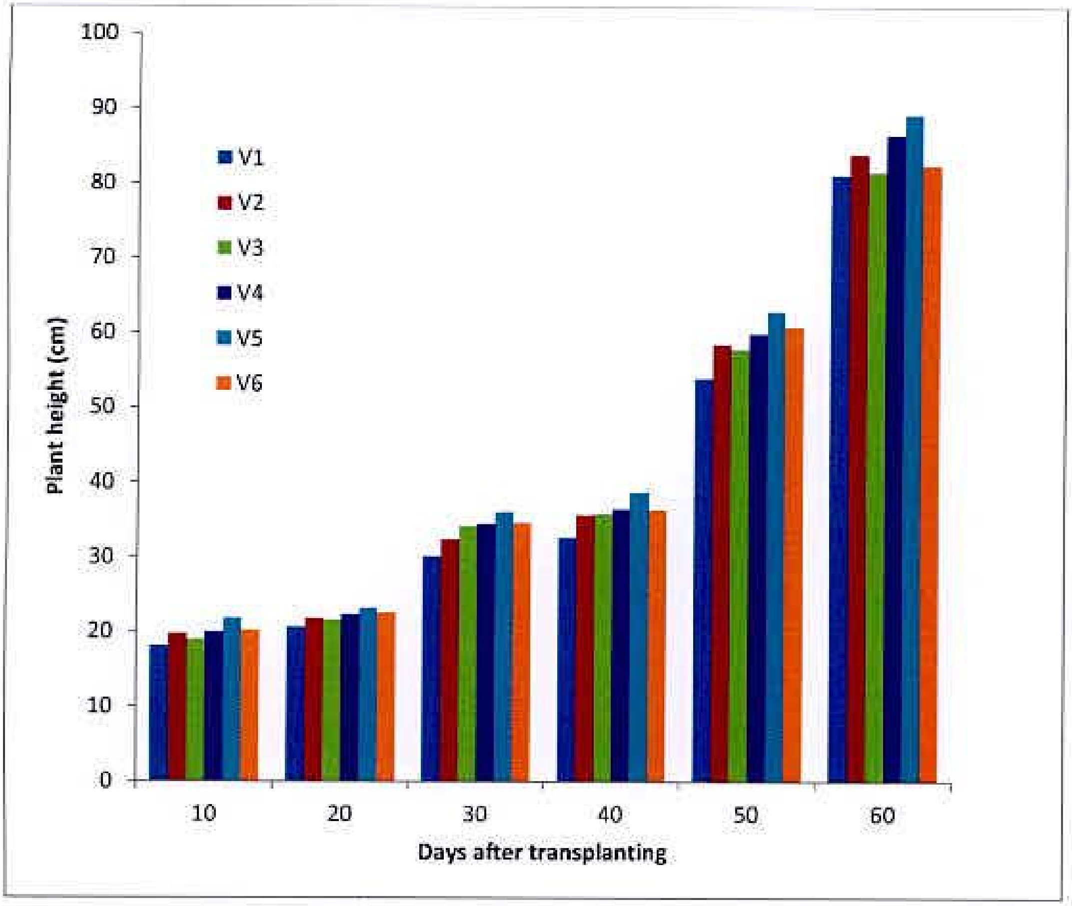


Figure 2. Plant height of six varieties at different days after transplanting

V_1 = BRRI dhan51 (Submergence tolerant)

V_2 = BRRI dhan46

V_3 = BRRI dhan34

V_4 = BRRI hybrid 4

V_5 = Panna1

V_6 = Taj1

Plant height at different day after transplanting was significantly affected by the interaction between submergence and variety (Table 1). The tallest plant (21.97, 24.73, 39.42, 42.42, and 64.2 at 10, 20, 30, 40, 50 and 60 DAT, respectively) was found from D_3V_5 (Fourteen days submergence with Panna - 1) and shortest plant (16.93, 19.23, 29.33, 31.87, 44.39 and 72.27cm at 10, 20, 30, 40, 50 and 60 DAT, respectively) from D_0V_1 (no submergence with BRRI dhan 51).

4.2 Leaves per plant

Number of leaves was significantly influenced by submergence at 10, 20, 30, 40, 50 and 60 days after transplanting and at harvest. The highest number of leaves (4.46, 9.92, 17.4, 28.02, 40.65, 59.72 and 69.92 at 10, 20, 30, 40, 50 and 60 DAT, respectively) was recorded from D_0 (no submergence) treatment, while the lowest number of leaves (3.30, 8.22, 16.62, 25.22, 48.08 and 65.02 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively) was observed from D_3 (Fourteen days submergence) (Figure 3).

Number of leaves was significantly influenced by variety at all the sampling dates (fig.4). The V_5 (Panna1) variety produced the highest number of leaves (4.49, 9.48, 16.19, 28.08, 50.63and 69.13 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively) and V_1 (BRRI dhan 51) produced shortest (18.06, 20.59, 30.09, 32.53, 53.85 and 81.1 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively). Probably the genetic makeup of varieties was responsible for the variation in plant height. This confirms the reports of BINA (1992), BRRI (1991) and Shamsuddin *et al.* (1988) that plant height differed due to varietal variation.

Number of leaves per plant at different days after transplanting was significantly affected by the interaction between submergence and variety (Table 2). The maximum number of leaves per plant (3.57, 9.63, 16.03, 29.10, 51.03 and 69.13 at 10, 20, 30, 40, 50 and 60 DAT, respectively) was found from D_0V_5 (no submergence with Panna1) and lowest number of leaves per plant (3.23, 7.67, 14.27, 23.17, 46.37 and 61.50 at 10, 20, 30, 40, 50 and 60 DAT, respectively) from D_3V_3 (Fourteen day submergence with BRRI dhan 34).

Table 1. Combined effect of submergence and varieties on plant height of rice

Treatment	Plant height (cm)											
	10 DAT		20 DAT		30 DAT		40 DAT		50 DAT		60 DAT	
D_0V_1	16.93	b	19.23	e	29.33	e	31.87	f	44.39	d	72.27	d
D_0V_2	18.60	ab	21.97	b-e	34.07	a-e	34.72	a-f	62.02	ab	82.74	abcd
D_0V_3	18.00	ab	21.40	b-e	35.81	a-e	35.73	a-f	61.05	ab	80.75	a-d
D_0V_4	19.83	ab	22.93	abc	31.90	de	34.57	a-f	57.73	abc	82.98	a-d
D_0V_5	20.60	ab	23.40	ab	33.14	b-e	32.83	def	61.34	ab	88.84	abc
D_0V_6	19.97	ab	21.90	b-e	31.52	e	33.66	b-f	59.65	abc	80.53	a-d
D_1V_1	19.27	ab	20.43	de	32.84	cde	33.69	b-f	57.88	abc	81.49	a-d
D_1V_2	20.23	ab	21.03	cde	33.79	b-e	34.46	a-f	57.23	bc	85.16	abc
D_1V_3	19.17	ab	20.90	cde	34.79	a-e	33.40	c-f	58.79	abc	79.31	bcd
D_1V_4	20.53	ab	22.03	b-e	34.13	a-e	32.09	ef	58.99	abc	85.59	abc
D_1V_5	21.00	ab	22.70	a-d	31.00	e	37.02	a-f	58.98	abc	87.27	abc
D_1V_6	19.53	ab	21.10	b-e	31.87	de	34.91	a-f	58.24	abc	84.55	abc
D_2V_1	17.53	ab	21.07	cde	38.59	ab	38.02	a-e	56.59	bc	84.98	abc
D_2V_2	19.97	ab	21.63	b-e	37.68	abc	37.92	a-e	56.19	bc	80.82	a-d
D_2V_3	19.32	ab	21.70	b-e	37.89	abc	38.64	a-d	57.66	abc	79.85	bcd
D_2V_4	18.81	ab	21.27	b-e	37.26	a-d	39.63	ab	61.51	ab	90.22	ab
D_2V_5	19.65	ab	21.77	b-e	38.00	abc	37.27	a-f	60.48	ab	88.04	abc
D_2V_6	20.10	ab	22.53	a-e	34.47	a-e	38.17	a-d	60.97	ab	86.85	abc
D_3V_1	18.50	ab	20.63	cde	33.59	b-e	37.08	a-f	56.54	bc	77.41	cd
D_3V_2	20.30	ab	22.67	a-d	31.70	e	35.03	a-f	58.36	abc	86.95	abc
D_3V_3	19.35	ab	22.20	b-e	31.68	e	35.29	a-f	53.58	c	86.46	abc
D_3V_4	20.68	ab	22.90	abc	34.52	a-e	39.50	ab	61.09	ab	87.56	abc
D_3V_5	21.97	a	24.73	a	39.42	a	42.42	a	64.20	a	92.93	a
D_3V_6	21.20	ab	24.67	a	35.63	a-e	39.27	abc	62.45	ab	86.11	abc
$LSD_{(0.05)}$	3.98		1.92		4.60		4.92		5.45		10.20	
CV (%)	12.33		10.22		20.72		14.82		16.28		10.38	

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

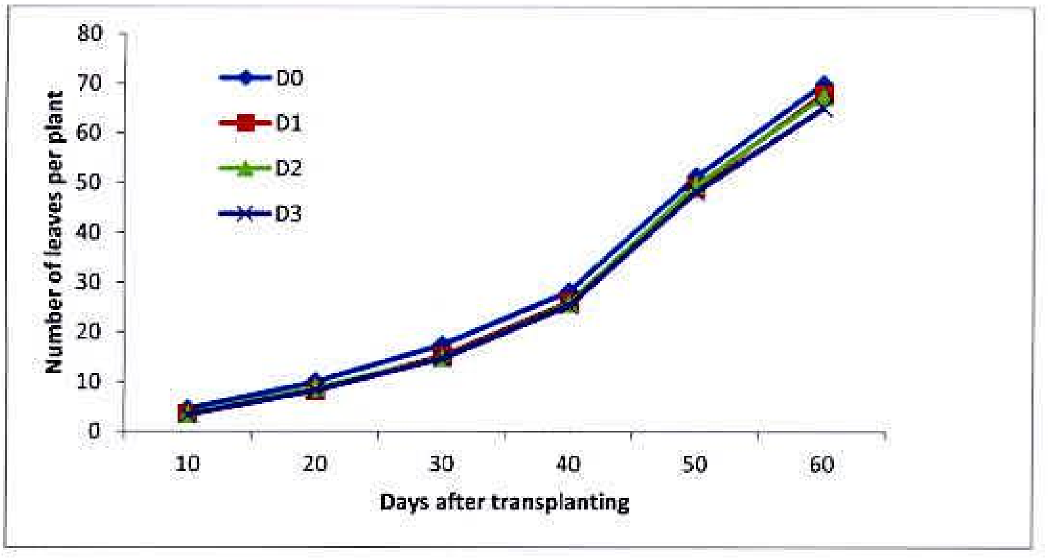


Figure 3. Effect of submergence on number of leaves per plant of rice at different days after transplanting

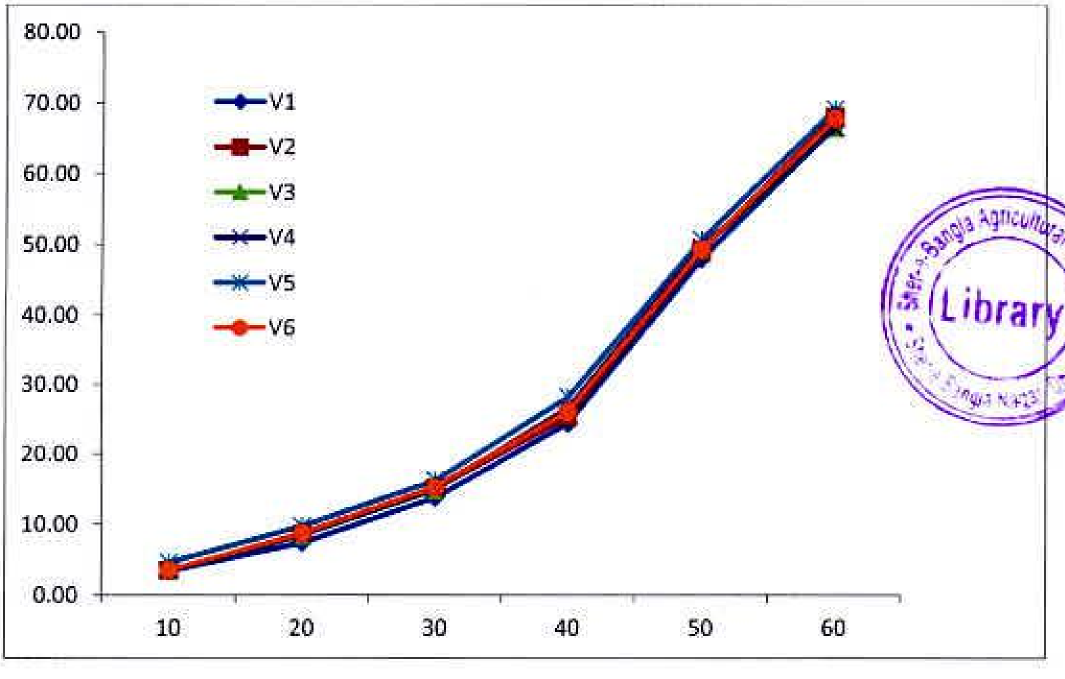


Figure 4. Effect of variety on number of leaves per plant of rice at different days after transplanting

Table 2. Combined effect of submergence and varieties on number of leaves per plant of rice

Treatment	Number of leaves per plant					
	10 DAT	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT
D_0V_1	3.23 b	8.40 abc	15.17 abc	24.70 cde	49.60 a-e	69.33 a
D_0V_2	3.50 ab	8.73 abc	14.93 abc	26.57 a-e	50.20 abc	68.70 a
D_0V_3	3.37 ab	8.37 abc	14.60 bc	26.00 a-e	50.63 ab	69.10 a
D_0V_4	3.57 a	8.60 abc	15.07 abc	28.87 ab	49.83 a-d	68.30 ab
D_0V_5	3.57 a	9.63 a	16.03 a	29.10 a	51.03 a	69.13 a
D_0V_6	3.53 ab	8.90 abc	15.20 abc	26.90 a-d	49.33 a-e	68.97 a
D_1V_1	3.33 ab	8.70 abc	15.10 abc	25.53 b-e	47.73 def	66.83 a-d
D_1V_2	3.43 ab	7.87 bc	14.23 c	24.70 cde	48.50 b-f	68.53 a
D_1V_3	3.47 ab	8.20 abc	14.33 bc	26.37 a-e	49.13 a-e	67.97 ab
D_1V_4	3.40 ab	8.43 abc	14.73 abc	27.67 abc	50.10 a-d	62.23 cd
D_1V_5	3.57 a	8.07 bc	14.47 bc	25.00 cde	49.27 a-e	67.93 ab
D_1V_6	3.37 ab	8.30 abc	14.87 abc	25.93 a-e	48.97 a-e	62.87 bcd
D_2V_1	3.40 ab	8.67 abc	15.47 abc	23.97 de	47.93 c-f	67.07 a-d
D_2V_2	3.40 ab	8.93 abc	15.37 abc	24.53 cde	49.37 a-e	68.70 a
D_2V_3	3.40 ab	8.53 abc	15.07 abc	26.33 a-e	49.37 a-e	67.50 abc
D_2V_4	3.27 ab	9.17 ab	15.40 abc	26.93 abcd	50.47 ab	68.33 ab
D_2V_5	3.37 ab	8.97 abc	15.47 abc	26.50 a-e	49.77 a-d	68.00 ab
D_2V_6	3.43 ab	8.57 abc	15.07 abc	25.37 b-e	49.70 a-d	67.90 ab
D_3V_1	3.50 ab	8.37 abc	15.17 abc	26.63 a-e	49.40 a-e	67.93 ab
D_3V_2	3.47 ab	7.80 bc	14.37 bc	25.37 cde	48.23 b-f	66.53 a-d
D_3V_3	3.23 b	7.67 c	14.27 c	23.17 e	46.37 f	61.50 b
D_3V_4	3.57 a	7.80 bc	14.53 bc	24.60 cde	47.97 c-f	66.97 a-d
D_3V_5	3.47 ab	8.73 abc	14.77 abc	25.53 b-e	47.27 ef	66.80 a-d
D_3V_6	3.50 ab	8.93 abc	15.63 ab	26.03 a-e	49.23 a-e	68.37 ab
$LSD_{(0.05)}$	0.27	1.20	1.10	2.90	1.99	4.69
CV (%)	4.82	11.78	8.27	11.15	6.93	7.29

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

4.3 Total tiller hill^{-1}

Statistically variation was recorded for number of tillers hill^{-1} due to the duration of submergence. The maximum number of tillers hill^{-1} (17.84) was obtained from D_0 (no submergence) while the minimum number of tillers hill^{-1} was recorded from D_3 (Fourteen days submergence) (Table 3).

The number of total tillers hill^{-1} was significantly influenced by variety (Table 4). Varietal effects on the formation of total number of tillers are shown in Table 4. The V_1 variety (BRRI dhan 51) was achieved the highest number of tiller hill^{-1} (18.20); where as in the case of V_3 minimum tiller (16.88) production was observed. The value decreased because some of the last emerged tillers died due to their failure in competing for light and nutrients. This revealed that during the reproductive and ripening phases the rate of tiller mortality exceeded the tiller production rate (Roy and Satter, 1992). Variable effect of variety on. number of total tillers hill^{-1} was also reported by Hussain *et al.* (1989) who noticed that number of total tillers hill^{-1} differed among the varieties

The effect of submergence and variety were statistically significant on total number of tillers hill^{-1} (Table 5). The highest total number of tillers hill^{-1} (18.76) was found from D_0V_1 (no submergence with BRRI dhan 51) and the lowest total number of tillers hill^{-1} (15.18) from D_3V_3 (Fourteen days submergence with BRRI dhan 34).

Table 3. Effect of submergence on yield contributing characters of rice

Treatment	No. of tiller		No of effective tiller		SPAD reading of leaf		No. of grain/panicle		No. unfilled grains/panicle	
D_0	17.84	a	15.45	a	36.9	a	127.3	a	17.84	c
D_1	17.69	a	14.19	a	36.54	a	117.1	b	18.95	bc
D_2	17.23	a	13.9	b	35.87	ab	107.3	c	21.53	ab
D_3	16.98	b	13.54	b	34.99	b	98.77	d	22.84	a
$LSD_{(0.05)}$	1.421		1.16		1.39		0.6625		3.44	

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

Table 4. Effect of varieties on yield contributing characters of rice

Treatment	No. of tiller		No. of effective tiller		SPAD reading of leaf		No. of grain/panicle		No. unfilled grains/panicle	
V_1	18.2	a	14.69	a	38.69	a	164.9	a	17.95	c
V_2	16.92	b	13.8	b	35.36	bc	101.3	c	12.31	d
V_3	16.88	b	13.08	b	34.06	c	80.78	e	27.79	a
V_4	17.87	b	14.37	a	35.72	bc	133.2	b	24.26	b
V_5	17.65	b	14.26	a	36.33	b	100.9	c	24.38	b
V_6	17.1	b	13.62	b	36.31	b	94.51	d	15.03	d
$LSD_{(0.05)}$	1.994		1.183		1.863		0.535		2.779	

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

Table 5. Combined effect of submergence and varieties on yield contributing characters of rice

Treatment	No. of tiller		No of effective tiller		SPAD reading of leaf		No. of grain/panicle		No. unfilled grains/panicle	
D_0V_1	18.76	a	15.96	a	40.75	a	187.7	a	11.05	m
D_0V_2	18.27	ab	14.93	abc	34.37	abcde	118.2	i	11.6	m
D_0V_3	17.12	ab	13.25	def	38.93	abc	94.23	n	18.72	ij
D_0V_4	16.94	ab	13.40	def	32.50	cde	148.00	d	11.41	m
D_0V_5	16.65	ab	15.23	a	34.67	abcde	112.8	j	24.09	ef
D_0V_6	15.74	ab	15.04	abc	40.20	a	102.6	l	12.82	lm
D_1V_1	17.68	ab	14.18	abcde	36.93	abcde	172.4	b	15.08	kl
D_1V_2	16.41	ab	13.58	cdef	33.07	bcde	102.6	l	11.6	m
D_1V_3	16.43	ab	12.93	ef	35.57	abcde	87.63	r	20.44	hi
D_1V_4	18.56	ab	15.06	abc	35.97	abcde	137.6	f	24.89	de
D_1V_5	17.68	ab	14.51	abcd	37.50	abcd	104.6	k	20.2	hi
D_1V_6	16.63	ab	13.13	def	36.20	abcde	97.8	m	21.48	gh
D_2V_1	17.19	ab	13.69	bcdef	33.27	bcde	152.4	c	15.75	k
D_2V_2	18.54	ab	15.08	ab	31.80	de	94.63	n	16.47	jk
D_2V_3	18.04	ab	14.54	abcd	33.20	bcde	78.63	t	21.23	gh
D_2V_4	18.73	a	13.62	bcdef	38.63	abc	127.6	g	22.98	efg
D_2V_5	17.74	ab	14.24	abcde	34.3	abcde	97.6	m	27.05	cd
D_2V_6	18.58	ab	15.08	ab	38.77	abc	92.8	o	18.14	ij
D_3V_1	17.86	ab	14.36	abcde	37.53	abcd	147.4	e	31.24	b
D_3V_2	17.83	ab	14.33	abcde	37.00	abcde	89.63	p	14.99	kl
D_3V_3	15.18	b	12.01	f	30.50	e	62.63	u	35.09	a
D_3V_4	18.58	ab	12.41	f	35.77	abcde	119.6	h	22.14	fgh
D_3V_5	15.91	ab	12.34	f	38.83	abc	88.6	q	30.92	b
D_3V_6	17.44	ab	13.94	abcde	39.60	ab	84.8	s	27.52	c
$LSD_{(0.05)}$	2.87		1.24		5.64		0.58		3.23	
CV (%)	14.43		17.17		5.5		11.28		11.50	

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

4.4 Effective tiller hill^{-1}

Statistically variation was recorded for number of effective tillers hill^{-1} due to the duration of submergence. The maximum number of effective tillers hill^{-1} (15.45) was obtained from D_0 (no submergence) while the minimum number of tillers hill^{-1} (13.54) was recorded from D_3 (Fourteen days submergence) (Table 3).

The number of effective tillers hill^{-1} was significantly influenced by variety (Table 4). The V_1 variety (BRRI dhan 51) was achieved the highest number of effective tiller hill^{-1} (14.49); where as in the case of V_3 (BRRI dhan 34) minimum tiller (13.08) production was observed. The value decreased because some of the last emerged tillers died due to their failure in competing for light and nutrients. This revealed that during the reproductive and ripening phases the rate of tiller mortality exceeded the tiller production rate (Roy and Satter, 1992). Variable effect of variety on number of total tillers hill^{-1} was also reported by Hussain *et al.* (1989) who noticed that number of total tillers hill^{-1} differed among the varieties

The effect of submergence and variety were statistically significant on number of effective tillers hill^{-1} (Table 5). The highest number of tillers hill^{-1} (15.66) was found from D_0V_1 (no submergence with BRRI dhan 51), which was statistically similar with D_0V_5 and the lowest number of effective tillers hill^{-1} (12.01) from D_3V_3 (Fourteen days submergence with BRRI dhan 34).

4.5 SPAD reading of leaf

Statistically significant variation was recorded for SPAD reading of leaf showed differences due to the duration of submergence. The highest SPAD reading of leaf (36.9) was obtained from D_0 treatment and the lowest number of filled grains panicle^{-1} (34.99) was attained from D_3 treatment (Table 3).

The cultivars affected significantly in SPAD reading of leaf. The V_1 (BRRI dhan 51) gave significantly highest SPAD reading of leaf (38.69). The lowest SPAD reading of leaf(34.06) was found in V_3 treatment (Table 4).

Interaction effect of submergence and variety was found significant on SPAD reading of leaf (Table 5). The highest (40.75) SPAD reading of leaf was found from the combination of D_0V_1. The lowest SPAD reading of leaf (30.05) was found from the combination of D_3V_3 treatment.

4.6 Filled grains panicle^{-1}

Statistically significant variation was recorded for number of filled grains panicle^{-1} showed differences due to the duration of submergence. The highest number of filled grains panicle^{-1} (127.30) was obtained from D_0 treatment and the lowest number of filled grains panicle^{-1} (98.77) was attained from D_3 treatment (Table 3). Table 4 showed that cultivars affected significantly in number of filled grains panicle^{-1}. The V_1 (BRRI dhan 51) gave significantly highest number (164.90) grains panicle^{-1}. The lowest number of filled grains panicle^{-1} (80.78) was found in V_3 treatment. BRRI (1994) found that number of filled grains panicle^{-1} significantly differed.

Interaction effect of submergence and variety was found significant on filled grains panicle^{-1} (Table 5). From the results of Table 5 it was observed that the highest (187.7) number of filled grains panicle^{-1} was found from the combination of D_0V_1. The lowest filled grains panicle^{-1} (62.63) was found from the combination of D_3V_3 treatment.

4.7 Unfilled grains panicle^{-1}

Number of unfilled grains panicle^{-1} varied significantly for duration of submergence. The lowest number of unfilled grains panicle^{-1} was found from D_0

(17.84) treatment and the highest number was recorded from D_3 (22.84) treatment (Table 3).

Among the traits made, number of unfilled grains panicle^{-1} plays a vital role in yield reduction. Results showed that variety had significant effect in respect of the number of unfilled grains panicle^{-1} (Table 4). The V_1 variety (BRRI dhan 51) produced the lowest number (17.95) of unfilled grains panicle^{-1} and V_3 produced highest number (27.89) of unfilled grains panicle^{-1} and this variation might be due to genetic characteristics. BINA (1993) and Chowdury *et al.* (1993) also reported differences in number of unfilled grains panicle^{-1} due to varietal differences.

Interaction effect of duration of submergence and showed significantly response on unfilled grains panicle^{-1} (Table 5). It observed that lowest (11.00) number of unfilled grains panicle^{-1} was observed from D_0V_1, and the highest (34.03) number of unfilled grains panicle^{-1} from D_3V_3.

4.8 1000-grain weight

Statistically significant difference was recorded for weight of 1000 grains for duration of submergence. The highest weight of 1000 grains (25.04 g) was observed from D_0 treatment, while the lowest weight was recorded from D_3 (23.03 g) treatment (table 6).

Variety had significant effect on 1000-grain weight (Table 7). The maximum 1000-grain weight (27.05 g) was found in V_1 treatment. The lowest thousand seed weight (20.72 g) was found in V_3 treatment.

Interaction effect of submergence and variety showed significant effect on 1000-grain (Table 8). From the table 8 it was observed that the lowest (17.49 g) thousand seed weight was observed from D_3V_3 treatment, and the highest (29.68 g) thousand seed weight from D_0V_1.

4.9 Yield m^{-2}

Grain yield m^{-2} of rice varied significantly for different submergence. The highest grain yield m^{-2} was found from D_0 (0.54 kg) whereas the lowest yield was recorded from D_3 (0.40 kg) treatment (Table 6).

Grain yield per plot is a function of interplay of various yield components such as number of productive tillers, grains panicle^{-1} and 1000-grain weight. In present experiment variety had significant effect on grain yield (Table 7). It was evident from Table 7 that V_4 (BRRI hybrid dhan 4) produced the highest (0.72 kg) grain yield m^{-2} and the lowest grain weight m^{-2} (0.23 kg) was found V_3 (BRRI dhan 34). Grain yield differences due to varieties were reported by Suprithatno and Sutaryo (1992), Alam (1988) and IRRI (1978) who recorded variable grain yield among tested varieties.

Interaction of submergence and variety significantly affected the grain yield m^{-2} (Table 8). Significantly the highest (0.80 kg) grain yield was found from the combination of D_0V_4 (no submergence with BRRI hybrid dhan 4) and the lowest (0.11 kg) from D_3V_3 (Fourteen days submergence with BRRI dhan 34).

Table 6. Effect of submergence on yield of rice

Treatment	1000 grain wt.	Yield m-^{2}	yield t ha^{-1}	Reduction of yield (%)
D_0	25.4 a	0.54 a	5.43 a	0.00 d
D_1	24.6 ab	0.52 ab	5.20 ab	4.62 c
D_2	23.73 ab	0.45 bc	4.47 bc	20.32 b
D_3	23.03 b	0.40 c	3.95 c	29.59 a
LSD $_{(0.05)}$	25.4	0.08	0.96	0.37

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

Table 7. Effect of varieties on yield of rice

Treatment	1000 grain wt.	Yield m-^{2}	yield t ha^{-1}	Reduction of yield (%)
V_1	27.05 a	0.44 c	4.35 bc	5.43 f
V_2	22.55 ab	0.40 c	3.98 bc	9.66 d
V_3	20.72 b	0.23 d	2.33 c	35.42 a
V_4	26.43 a	0.72 a	7.18 a	10.31 c
V_5	22.36 ab	0.51 b	5.08 ab	12.50 b
V_6	26.04 ab	0.57 b	5.68 ab	8.47 e
LSD $_{(0.05)}$	5.402	0.07	2.60	0.30

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

Yield of V_4 (BRRI hybrid 4)> V_6 (Taj-1)> V_5 (Panna 1)> V_1 (BRRI dhan 51)> V_2 (BRRI dhan 46)> V_3 (BRRI dhan 34)

Table 8a. Combined effect of submergence and varieties on yield of rice

Treatment	1000 grain wt.		Yield m-^{2}		yield t ha^{-1}	
D_0V_1	29.68	a	0.46	cdefg	4.6	cdefg
D_0V_2	27.81	a	0.44	defg	4.4	defg
D_0V_3	22.30	cdef	0.36	efg	3.6	efgh
D_0V_4	27.83	a	0.8	a	8.0	a
D_0V_5	25.63	abcde	0.58	abcdef	5.8	abcdef
D_0V_6	27.49	a	0.62	abcd	6.2	abcd
D_1V_1	22.45	bcdef	0.45	defg	4.5	cdefg
D_1V_2	21.31	def	0.43	defg	4.3	defg
D_1V_3	21.63	def	0.32	ghi	3.2	ghi
D_1V_4	28.86	a	0.77	ab	7.7	ab
D_1V_5	25.45	abcde	0.55	bcdefg	5.5	bcdefg
D_1V_6	28.86	a	0.6	abcde	6.0	abcde
D_2V_1	27.26	ab	0.43	defg	4.3	defg
D_2V_2	21.67	def	0.38	defg	3.8	defg
D_2V_3	20.96	ef	0.14	hi	1.4	hi
D_2V_4	25.34	abcde	0.69	abc	6.9	abc
D_2V_5	26.16	abcd	0.48	cdefg	4.8	cdefg
D_2V_6	25.52	abcde	0.56	bcdefg	5.6	bcdefg
D_3V_1	26.82	abc	0.4	defg	4.0	defg
D_3V_2	20.92	ef	0.34	fgh	3.4	fgh
D_3V_3	17.49	f	0.11	i	1.1	i
D_3V_4	18.98	f	0.61	abcd	6.1	abcd
D_3V_5	20.35	f	0.42	defg	4.2	defg
D_3V_6	19.81	f	0.49	cdefg	4.9	cdefg
LSD $_{(0.05)}$	4.23		0.2013		2.037	
CV (%)	25.02		53.98		53.98	

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

Here, V_1 = BRRI dhan 51 (Submergence tolerant, T. Aman)
V_2 = BRRI dhan 46 (T. Aman)
V_3 = BRRI dhan 34 (T.Aman Susceptible)
V_4 = BRRI hybrid 4 (T. Aman)
V_5 = Panna 1 (Exotic Hybrid Rice)
V_6 = Taj-1 (Exotic Hybrid Rice)

Tolerance of $V_1 > V_6 > V_2 > V_4 > V5 > V_3$

Table 8b. Tolerance and susceptibility of different varieties in different duration of submergence.

Combination	Yield Position	Yield t ha^{-1}	% of Yield reduction	Tolerant/ Susceptible to submergence	Position of Tolerance
D_0V_4	1st	8.0	0.0	Medium Tolerant 13.75% Yield Loss	4th
D_1V_4	2nd	7.7	3.75		
D_2V_4	3rd	6.9	13.75		
D_3V_4	5th	6.1	23.75		
D_0V_6	4th	6.2	0.0	More Tolerant 11.29% Yield Loss	2nd
D_1V_6	6th	6.0	3.23		
D_2V_6	8th	5.6	9.68		
D_3V_6	10th	4.9	20.97		
D_0V_5	7th	5.8	0.0	Less Tolerant (Susceptible) 16.57% Yield Loss	5th
D_1V_5	9th	5.5	5.17		
D_2V_5	11th	4.8	17.24		
D_3V_5	17th	4.2	27.59		
D_0V_1	12th	4.6	0.0	Most Tolerant 7.24% Yield Loss	1st
D_1V_1	13th	4.5	2.17		
D_2V_1	15th	4.3	6.52		
D_3V_1	18th	4.0	13.04		
D_0V_2	14th	4.4	0.0	Medium Tolerant 12.88% Yield Loss	3rd
D_1V_2	16th	4.3	2.27		
D_2V_2	19th	3.8	13.64		
D_3V_2	21st	3.4	22.73		
D_0V_3	20th	3.6	0.0	Most susceptible 47.22% Yield Loss	6th
D_1V_3	22nd	3.2	11.11		
D_2V_3	23rd	1.4	61.11		
D_3V_3	24th	1.1	69.44		

4.10 Grain yield

Grain yield per hectare of rice varied significantly for submergence. The highest grain yield was found from D_0 (5.43 t/ha) whereas the lowest yield was recorded from D_3 (3.95 t/ha) treatment (Table 6).

Grain yield is a function of interplay of various yield components such as number of productive tillers, grains panicle^{-1} and 1000-grain weight. In present experiment variety had significant effect on grain yield (Table 7). It was evident from Table 7 that V_4 (BRRI hybrid dhan 51) produced the highest (7.18 t ha^{-1}) grain yield. Grain yield differences due to varieties were reported by Suprithatno and Sutaryo (1992), Alam (1988) and IRRI (1978) who recorded variable grain yield among tested varieties.

From the table 8a and table 8b it was evident that interaction of submergence and variety significantly affected the grain yield. Significantly the highest (8.00 t ha^{-1}) grain yield was found from the combination of D_0V_4 (no submergence with BRRI hybrid dhan 4) and the lowest (1.10 t ha^{-1}) from D_3V_3 (fourteen days submergence with BRRI dhan 34).

4.11 Percent reduction of yield

Percent reduction of yield of rice varied significantly for submergence. The highest percent reduction over control (29.59) was found from D_3 whereas the lowest percent reduction over control (4.62) was recorded from D_1 (six days submergence) treatment (Table 6).

Percent reduction of yield over was evident from Table 7 that V_3 (BRRI dhan 34) produced the highest (35.42 t ha^{-1}) percent reduction. The lowest percent reduction of yield (5.43) was found in V_1 (BRRI dhan 51).

From the table 9 it was evident that the highest percent reduction of yield (69.44) was found from the combination of D_3V_3 (fourteen days submergence with BRRI dhan 34) and the lowest (2.17) from D_1V_1 (six days submergence with BRRI dhan 51).

The response of 6 rice genotypes under duration of submergence levels is present in experiment. Susceptible genotypes could not be distinguished from submergence although seedling growth of the test genotypes declines somewhat due to reduce SPAD reading of leaf. Differentiation of tolerant and moderate tolerant genotypes was clear even at 10 days and 14 days submergence. This result indicated that rice is moderately sensitive to submergence. The discriminating level for selection was observed at 10-14 days submergence as distinct differentiation of genotypes into tolerant, moderately tolerant and susceptible was observed at this level. The tested genotypes showed wide variation in yield with BRRI dhan 51 (tolerant)> Taj-1 > BRRI dhan 46> BRRI hybrid dhan 4> Panna - 1> BRRI dhan 34(susceptible).

Table 9. Percentage of yield reduction in different submergence duration shown by different varieties of rice

Varieties	No Submergence (D_0)	6 days Submergence (D_1)	10 days Submergence (D_2)	14 days Submergence (D_4)	Remarks
BRRI dhan51 (V_1)	0	2.17	6.52	13.04	Best tolerant
BRRI dhan46(V_2)	0	2.27	13.64	22.73	Better
BRRI dhan34(V_3)	0	11.11	61.11	69.44	Susceptable
BRRI hybrid 4(V_4)	0	3.75	13.75	23.75	good
Panna1(V_5)	0	5.17	17.24	27.59	Susceptable
Taj1(V_6)		3.23	9.68	20.97	Better

Tolerence of V_1 (BRRI dhan 51)> V_6 (Taj-1)> V_2 (BRRI dhan 46)> V_4 (BRRI hybrid 4)> V_5 (Panna 1)> V_3 (BRRI dhan 34).

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from June to December, 2012 in T. *aman* season to find out the influence of water submergence stress on the growth pattern & yield of some hybrid rice varieties. Four submergence duration, viz., Control (no submergence), Six days submergence, Ten days submergence and Fourteen days submergence and six varieties, viz., BRRI dhan51, BRRI dhan46, BRRI dhan34. BRRI hybrid4, Panna1, Taj1 were used to conduct this experiment. The experiment was laid out in Randomized complete Block Design (RCBD) having two factors and replicated three times. Data were taken on growth, yield contributing characters, yield and the collected data were statistically analyzed for evaluation of the treatment effects. The summary of the results has been described in this chapter.

Plant height of rice showed statistically significant differences at 10, 20, 30, 40, 50 and 60 days after transplanting and at harvest. The tallest plant (20.33, 22.97, 38.14, 40.65, 59.72 and 86.23 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively) was recorded from D_3 (Fourteen days submergence) treatment. The highest number of leaves (4.46, 9.92, 17.4, 28.02, 40.65, 59.72 and 69.92 at 10, 20, 30, 40, 50 and 60 DAT, respectively) was recorded from D_0 (no submergence) treatment.The maximum number of tillers hill^{-1} (17.84) was obtained from D_0 (no submergence). The maximum number of effective tillers hill^{-1} (15.45) was obtained from D_0. The highest SPAD reading of leaf (36.9) was obtained from D_0 treatment. The highest number of filled grains panicle^{-1} (127.30) was obtained from D_0 treatment. The lowest number of unfilled grains panicle^{-1} was found from D_0 (17.84) treatment. The highest weight of 1000 grains (25.04 g) was observed from D_0 treatment. The highest grain yield m^{-2} was found from D_0 (0.54 kg). The highest grain yield was found from D_0 (5.43 t/ha) whereas the lowest yield was recorded from D_3 (3.95 t/ha) treatment. The highest percent reduction over control (29.59) was found from

D_3 whereas the lowest percent reduction over control (4.62) was recorded from D_1 (six days submergence) treatment.

Plant height of the cultivars was measured at 10, 20, 30, 40, 50 and 60 days after transplanting and at harvest. The V_5 (Panna-1) variety produced the tallest plant (21.81, 23.15, 36.04, 38.62, 61.81 and 89.27 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively). The highest number of leaves (4.49, 9.48, 16.19, 28.08, 50.63and 69.13 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively) was produced in V_5 (Panna-1). The V_1 variety (BRRI dhan 51) was achieved the highest number of tiller hill^{-1} (18.20). The V_1 variety (BRRI dhan 51) was achieved the highest number of effective tiller hill^{-1} (14.49). The V_1 (BRRI dhan 51) gave significantly highest SPAD reading of leaf (38.69). The V_1 (BRRI dhan 51) gave significantly highest number (164.90) grains panicle^{-1}. The V_1 variety (BRRI dhan 51) produced the lowest number (17.95) of unfilled grains panicle^{-1}. The maximum 1000-grain weight (27.05 g) was foun in V_1 treatment. The V_4 (BRRI hybrid dhan 4) produced the highest (0.72 kg) grain yield m^{-2}. V_4 (BRRI hybrid dhan 51) produced the highest (7.18 t ha^{-1}) grain yield. V_3 (BRRI dhan 34) produced the highest (35.42) percent reduction. The lowest percent reduction of yield (5.43) was found in V_1 (BRRI dhan 51).

All parameter was significantly affected by the interaction between submergence and variety. The tallest plant (21.97, 24.73, 39.42, 42.42, and 64.2 at 10, 20, 30, 40, 50 and 60 DAT, respectively) was found from D_3V_5 (Fourteen days submergence with Panna - 1). The maximum number of leaves per plant (3.57, 9.63, 16.03, 29.10, 51.03 and 69.13 at 10, 20, 30, 40, 50 and 60 DAT, respectively) was found from D_0V_5 (no submergence with Panna - 1). The highest total number of tillers hill^{-1} (18.76) was found from D_0V_1. The highest number of tillers hill^{-1} (15.66) was found from D_0V_0 (no submergence with BRRI dhan 51). The highest (40.75) SPAD reading of leaf was found from the combination of D_0V_1 . The highest (187.7) number of filled grains panicle^{-1} was found from the combination of D_0V_1. The lowest (11.05) number of unfilled grains panicle^{-1} was observed from D_0V_1. The highest (29.68 g) thousand seed weight from D_0V_1. Significantly the highest (0.80 kg) grain yield was found from the combination of D_0V_4 (no submergence with BRRI hybrid dhan 4). Significantly the highest (8.00 t ha^{-1}) grain yield was found from the combination of D_0V_4 (no submergence with BRRI hybrid dhan 4) and the lowest (1.10 t ha^{-1}) from D_3V_3 (fourteen days submergence with BRRI dhan 34). The highest percent reduction of yield (69.44) was found from the combination of D_3V_3 (fourteen days submergence with BRRI dhan 34) and the lowest (2.17) from D_1V_1 (six days submergence with BRRI dhan 51).

The response of 6 rice genotypes under duration of submergence levels is present in experiment. Susceptible genotypes could not be distinguished from submergence although seedling growth of the test genotypes declines somewhat due to reduce SPAD reading of leaf. Differentiation of tolerant and moderate tolerant genotypes was clear even at 10 days and 14 days submergence. This result indicated that rice is moderately sensitive to submergence. The discriminating level for selection was observed at 10-14 days submergence as distinct differentiation of genotypes into tolerant, moderately tolerant and susceptible was observed at this level. The tested genotypes showed wide variation in yield with BRRI dhan 51 (tolerant)> Taj-1 > BRRI dhan 46> BRRI hybrid dhan 4> Panna - 1> BRRI dhan 34 (susceptible).

Submerged rice is in an anaerobic environment because of the 10^4-fold slower gas diffusion under water than in air. Furthermore, levels of oxygen, and carbon dioxide and light for photosynthesis drastically differ according to the floodwater period, depth, temperature and turbidity. Varieties of rice, can lodge readily under aerobic conditions after desubmergence because of weakening of the shoot base, which causes rapid leaf elongation and which increases plant mortality through photosynthetic products accumulated before submergence is exhausted under short-term submergence with the rapid increase of water level.

Conclusion

BRRI dhan 51 adapt to long-term (14 days) complete submergence apparently because of their greater photosynthetic capacity developed by leaves that have newly emerged above floodwaters through rapid shoot elongation. However, other varieties, Taj-1, BRRI dhan 46 and BRRI hybrid dhan 4 can also be cultivated in the submergence risk areas. These varieties can be improved through crossing with BRRI dhan 51.

Recommendation

- The tolerant varieties are suggested to grow under actual submerged condition in the farmer's field. Promising varieties can either be used in flood-prone area or be used for genetic improvement.
- More experiments should be conducted to find out the submergence tolerance in different stages of rice plant life cycle using different varieties of rice.

REFERENCES

Ahmed, M. R., Rashid, M. A., Alam, M. S., Billah, K. A. and Jameel, F. (1997). Performance of Eight Transplant *Aman* Rice Varieties under Irrigated Conditions. *Bangladesh Rice J.* **8**(1 &2): 43-44.

Ali, M. G., Mannan, M. A., Halder, K. P. and Siddique, S. B (1993). Effect of planting dates on the growth and yield of modern transplanted *Aman* rice. Annals of Bangladesh Agriculture. **3**(2): 103-108.

Amin, M. R., Hamid, A., Choudhury, R. U., Raquibullah, S. M. and Asaduzz Aman M. (2006). Nitrogen Fertilizer Effect on Tillering, Dry Matter Production and Yield of Traditional Varieties of Rice. *Int. J. Sustain. Crop Prod.* **1**(1): 17-20.

Anonymous, (2006). Rice in India, A Hand Book of Statistics, Director of Rice Development, Government of India, Hyderabad (A.P.).

Anonymuos (2005). Statistical Database, Food and Agricultural Organisation (FAO) of United Natinos, Rome, www.fao.org.

Arber, A. (1920) *Water Plants: a study of aquatic angiosperms.* Cambridge University Press. Cambridge UK.

Armstrong, W. (1979). Aeration in higher plants. In *Advances in Botanical Research* Vol.7, Woolhouse, H.W.W. (Ed.), pp. 225–332, Academic Press, London, UK

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

BBS (Bangladesh Bureau of Statistics). (2011). Statistical Year Book of Bangladesh Bureau of Statistics. Bangladesh Rice Knowledge Bank (BRKB). Available at the following web site: http://www.knowledgebank-brri.org.

BINA (Bangladesh Institute of Nuclear Agriculture). (1993). Annual Report (1992-93). Bangladesh Inst. Nucl. Agric. P. O. Box No. 4. Mymensingh.

BINA (Bangladesh Institute of Nuclear Agriculture). (1993). Annual Report (1992-93). Bangladesh Inst. Nucl. Agric. P. O. Box No. 4. Mymensingh.

BRRI (Bangladesh Rice Research Institue). (1995). Adhunik Dhaner Chash (in bengali). Pub no.5. Bangladesh Rice Res. Inst., Joydebpur, Gazipur. pp. 12-23.

BRRI (Bangladesh Rice Research Institute). (1979). Annual report for 1975-76. Bangladesh Rice Res. Inst., Jodebpur, Gazipur, Bangladesh. pp. 3-5.

BRRI (Bangladesh Rice Research Institute). (1985). Annual report for 1982. Bangladesh Rice Res. Inst., Joydebpur, Gazipur, Bangladesh. BRRI pub. No. 79. pp. 236-238.

BRRI (Bangladesh Rice Research Institute). (1991). Annual Report for 1988. Bangladesh Rice Res. Inst., Joydebpur, Gazipur. pp. 8-15.

BRRI (Bangladesh Rice Research Institute). (1994). Annual Report for 1993. Bangladesh Rice Res. Inst., Jodebpur, Gazipur. pp. 8-9.

Chaturvedi, G.S., Mishra, C.H., Singh, O.N., Pandey, C.B., Yadav, V.P., Singh, A.K., Dwivedi, J.L.;, Singh, B.B. & Singh, R.K. (1995). Physiological basis and screening for tolerance for flash flooding. In: *Rainfed lowland rice: agricultural research for high-risk environments*, Ingram K.T., (Ed.) pp. 79–96, International Rice Research Institute, Los Banos, Philippines

Chowdhury, M. T. U., Sarker, A. U., Sarker, M. A. R. and Kashem, M. A.

(1993). Effect of variety and number of seedlings $hill^{-1}$ on the yield and its components on late transplanted *Aman* rice. *Bangladesh J. Agril. Sci.* **20**(2): 311-316.

Chowdhury, S. A., Majid, M. A., Huque, K. S., Islam, M. and Rahman, M. M. (1995). Effect of variety on yield and nutritive value of rice straw. *Asian-Australasian J. Ani. Sci.* **8**(4): 329-335.

Collis, G.N. and Melville, M.D. (1974). Model of oxygen diffusion in respiring seeds. J. Exp. Bot. 25, 1053-1069.

Costa, D. J. and Hoque, M. N. (1986). Superimposed variety trial on T. *Aman* [Transplanted rice in Bangladesh]. Proc. Central Review Workshop, On-Farm Research Div. Jul. 5-10. BARI., Joydebpur, Bangladesh. pp. 25-26.

Devaraju, K. M., Gowda, H. and Raju, B. M. (1998). Nitrogen response of Karnataka Rice Hybrid 2. *Int.Rice Res. Notes.* **23**(2): 43.

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

Dey, M.M., Miah, M. N. I. Miah, Mustsfi, B.A.A. and Hossain, M. (1996). Rice production constrains in Bangladesh: Implications for further research priorities. In: Rice Research in Asia; Progress and priorities, CAB International Wallingford, U.K. pp. 179-192.

Dingkuhn, M., Jones, M.P., Johnson, D.E. and Sow, A. (1998). Growth and yield potential of *Oryza sativa* and *O. glaberrima* upland rice cultivars and their interspecific progenies. *Field Crops Research.* **57** (1): pp. 57–69.

Guilani, A. A., Siadat, S. A. and Fathi, G. (2003). Effect of plant density and seedling age on yield and yield components in 3 rice cultivars in Khusestan growth conditions. *Iranian J. Agric. Sci.* **34**(2): 427-438.

Haque, M.Z. (1980). Photoperiod-sensitive transplant *Aman* rice-based cropping systems of Bangladesh. In proceedings of the international seminar on photoperiod sensitive transplant rice. Bangladesh Rice Research Institute, Joydebpur, Bangladesh. Pp. 243-257.

Hossain, S. M. A and Alam, A. B. M. N. (1991). Productivity of cropping pattern of participating farmers. ***In***: Fact searching and Intervention in two FSRDP Sites, Activities. 1980-1990. Farming system Research and Development Programme, BAU, Mymensingh, Bangladesh. pp. 41-44.

Idris, M. and Matin, M. A. (1990). Response of four exotic strains of *Aman* rice to urea. *Bangladesh J. Agric. Assoc. China.* **118**: 48-61.

Inouye, J., Hakoda, H. and Ng, N.Q. (1989). Preliminary studies on some ecological characteristics of African deep water rice (*Oryza glaberrima* Steud.). *Japanese Journal of Tropical Agriculture* 33(3): pp. 158–163,.

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

Islam, S. (1995). Effect of variety and fertilization on yield and nutrient uptake in transplant *Aman* rice. M.S. thesis. Dep. Agron. Bangladesh Agril. Univ. Mymensingh. pp. 26, 29.

Jackson, M.B. & Ram, P.C. (2003). Physiological and molecular basis of susceptibility and tolerance of rice plants to complete submergence. *Annals of Botany* **91**(2) pp. 227–241.

Joho, Y., Omsasa, K., Kawano, N. and Sakagami, J.I. (2008). Growth responses of seedlings in *Oryza glaberrima* Steud. to short-term submergence in Guinea, West Africa. *Japan Agricultural Research Quarterly* **42**(3):157–162, Kamal, A. M. A., Azam, M. A. and Islam, M. A. (1998). Effect of cultivar and NPK combinations on the yield contributing characters of rice. *Bangladesh J. Agril. Sci.* **15**(1): 105-110.

Karin, S.; Vergara, B.S. and Mazaredo, A.M. (1982). Anatomical and morphological studies of rice varieties tolerant of and susceptible to complete submergence at seedling stage. *Proceedings of the 1981 International Deepwater Rice Workshop,* pp. 287–291,.

Kawano, N., Ella, E.; Ito, O., Yamauchi, Y. & Tanaka, K. (2002). Comparison of adaptability to flash flood between rice cultivars differing in flash flood tolerance. *Soil Science and Plant Nutrition.* **48**(5). pp. 659–66,

Kennedy, R.A. and Rumpho, M.E. (1992). Anaerobic metabolism in plants. Plants physiol. 100. 1-6.

Khush, G.S. (1984). Terminology for Rice-growing Environments. International Rice Research Institute, Manila, Philippines, 35 pp.

Koffi, G., 1980. Collection and conservation of existing rice species and varieties in Africa. *Agronomie Tropicale* **34**: pp. 228-237

Liu, X. (1995). II-you 92: a new hybrid rice for late season. *Chinese Rice Res. Newsl.* **3**(2): 12.

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

Miah, M. H., Karim, M. A., Rahman, M. S. and Islam, M. S. (1990). Performance of Nizersail mutants under different row spacing. *Bangladesh J. Train. Dev.* **3**(2): 31-34.

Molla, M. A. H. (2001). Influence of seedling age and number of seedlings on yield attributes and yield of hybrid rice in the wet season. *Int. Rice. Res. Notes.* **26**(2): 73-74.

Nematzadeh, G. A., Arefi, H. A., *Amani*, R and Mani (1997). Release of a new variety of rice, namely "Nemat" with superiority in yield and quality. *Iranian J. Agric. Sci.* **28**(4): 79-86.

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

Om, H., Dhiman, S. D., Nandal, D. P. and Verma, S. L. (1998). Effect of method nursery raising and nitrogen on growth and yield of hybrid rice (*Oryza sativa*). *Indian J. Agron.* **43**(1): 68-70.

Patel J. R. (2000). Effect of water regime, variety and blue green algae on rice (*Oryza sativa*). *Indian J. Agron.* **45**(1): 103-106.

Perata, P. and Alpi, A. 1993. Plant responses to anaerobiosis. Pl. Sci. **93**: 1-17.

Ram, P.C. Singh, A. K. sing, B.B. singh, V.K. Singh, H.P. Setter, T.L., Sing, V.P. Singh, R.K. (1999). Environmental characterization of floodwater in eastern India: relevance to submergence tolerance of lowland rice. Exp. Agric. **35**: 141-152.

Ram, P.C., Singh, B.B., Singh, A.K., Ram, P., Singh, P.N., Singh, H.P., Boamfa, I., Harren, F., Santosa, E., Jackson, M.B., Setter, T.L., Reuss, J., Wade, L.J., Pal Singh, L. and Singh, R.K. (2002). Submergence tolerance in rainfed lowland rice: physiological basis and prospects for cultivar improvement through marker-aided breeding. *FieldCrops Research* **76**(2-3) pp. 131–152.

Reddy, M. D. and Sharma, A. R. (1992). Agro-techniques for rice grown on rainfed flooded lands of eastern India. Indian Farming. January. pp. 22-23.

Sakagami, J-I.; Isoda, A.; Nojima, H. & Takasaki, Y. (1999). Growth and survival rate after maturity in *Oryza sativa* L. and *O. glaberrima* Steud. *Japanese Journal of Crop Science*, **68** (2) pp. 257–265.

Sawant, A. C., Throat, S. T., Khadse, R. R. and Bhosalef, R. J. (1986). Response of early rice varieties to nitrogen levels and spacing in coastal Maharashtra. *J. Maharashtrta Agril. Univ.* **11**(2): 182-184.

Setter, T.L. & Laureles, E.V. (1996). The beneficial effect of reduced elongation growth on submergence tolerance of rice. *Journal of Experimental Botany* **47** (10): pp. 1551–1559.

Setter, T.L., Kupkanchanakul, K., Bhekasut, P., Weingweera, A., Greenway, H. (1987). Concentration of CO_2 and O_2 in floodwater and in internodal lacunae of floating rice growing at 1-2 m wate depth. Plant cell environ. **10**:767-776.

Setter, T.L., Waters, I., Wallace, I., Bhekasut, P. and Greenway, H. (1989). Submergence of rice. II. Growth and photosynthetic response to CO_2 enrichment of floodwater. *Aust. J. Plant physiol.* **16**:251.263.

Shamsuddin, A. M., Islam, M. A. and Hossain, A. (1988). Comparative study on the yield and agronomic characters of nine cultivars of *aus* rice. *Bangladesh J. Agril. Sci.* **15**(1): 121-124.

Singh, S. and Gangwer, B. (1989). Comparative studies on production potentials in traditional tall and improved rice cultivars. *J. AndAman Sci. Assoc.* **5**(1): 81-82.

Son, Y., Park, S. T., Kim, S. Y., Lee, H. W. and Kim, S. C. (1998). Effects plant density on the yield and yield components of low-tillering large panicle type rice. *RDA J.Crop Sci. I.* **40**: 2.

Suprithatno, B. and Sutaryo, B. (1992). Yield performance of some new rice hybrids varieties in Indonesia. *Int. Rice Res. Newsl.* **17**(3): 12.

Swain, P., Annie, P. and Rao, K. S. (2006). Evaluation of rice (*Oryza sativa*) hybrids in terms of growth and physiological parameters and their relationship with yield under transplanted condition. *Indian J. Agric. Sci.* **76**(8): 496-499.

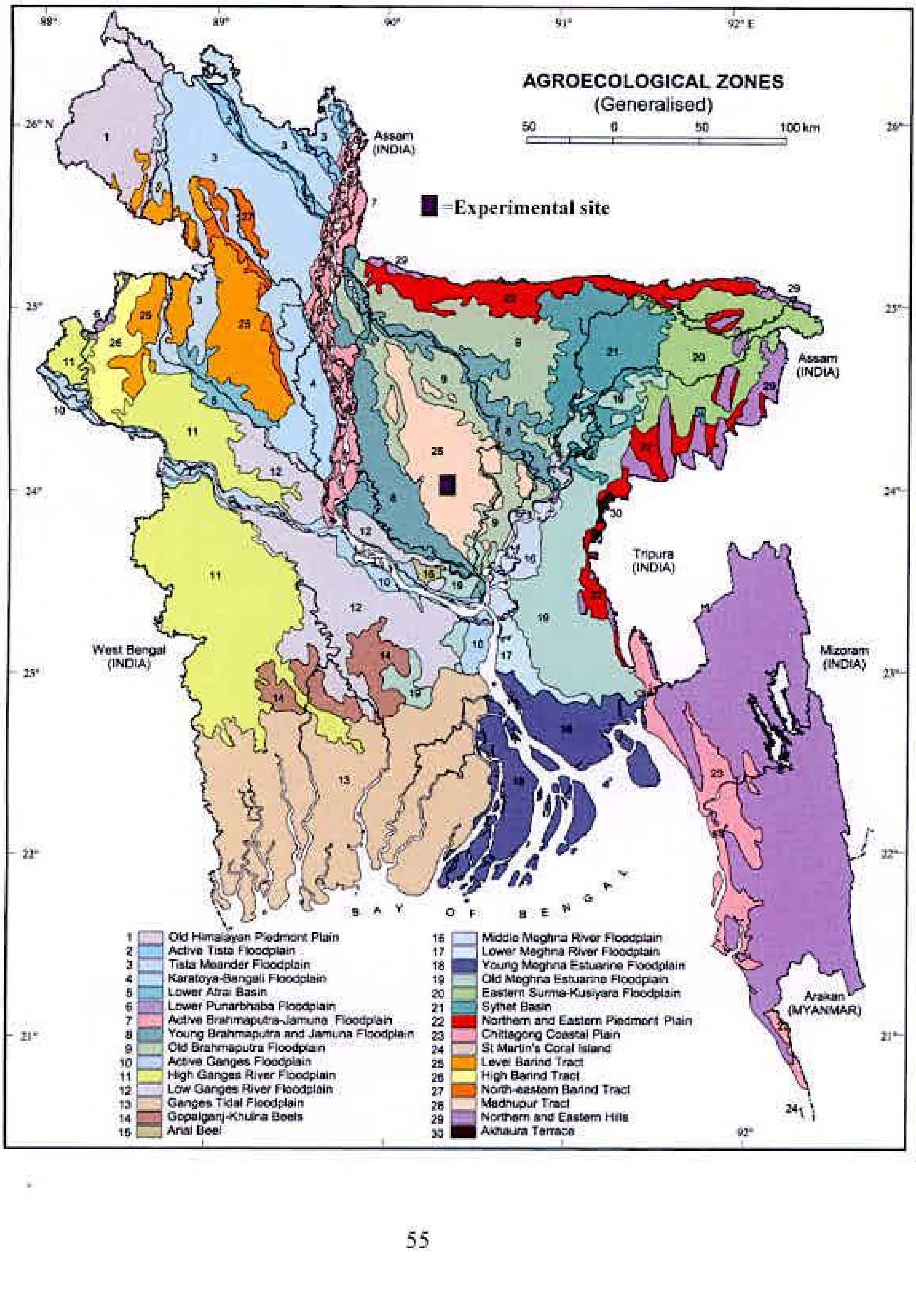
Thiemele, D.; Boisnard, A.; Ndjiondjop, M.N.; Cheron, S.; Sere, Y.; Ake, S.; Ghesquiere, A. & Albar, L. (2010). Identification of a second major resistance gene to Rice yellow mottle virus, RYMV2, in the African cultivated rice species, *O. Glaberrima. Theoretical and Applied Genetics* **121**(1). pp.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

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

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

APPENDICES

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



Appendix II. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from July to Dec 2012

Month	Air temperature (^0C)			RH (%)	Total rainfall (mm)
	Maximum	Minimum	Mean		
July 2012	33.00	27.40	30.20	77.00	167
August, 2012	33.10	27.00	30.05	78.00	340
September, 2012	32.50	26.60	29.55	79.00	169
October, 2012	32.40	25.00	28.70	74.00	174
November, 2012	30.00	20.90	25.45	68.00	0
December, 2012	26.0027	15.40	20.70	66.00	81

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

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

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

Chemical composition:

Soil characters	Value
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.07
Phosphorus	22.08 µg/g soil
Sulphur	25.98 µg/g soil
Magnesium	1.00 meq/100 g soil
Boron	0.48 µg/g soil
Copper	3.54 µg/g soil
Zinc	3.32 µg/g soil
Potassium	0.30 µg/g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka

Appendix IV: Field Layout of the Experiment

Rep – 1

V_1	V_5	V_2	V_2
V_6	V_3	V_4	V_6
V_2	V_6	V_5	V_4
V_5	V_1	V_6	V_5
V_4	V_2	V_3	V_1
V_3	V_4	V_1	V_3
D_3	D_1	D_0	D_2

Rep - 2

V_1	V_5	V_2	V_4
V_4	V_2	V_1	V_3
V_6	V_3	V_5	V_2
V_3	V_4	V_3	V_1
V_5	V_1	V_6	V_6
V_2	V_6	V_4	V_5
D_0	D_3	D_1	D_2

Rep - 3

V_3	V_4	V_1	V_3
V_6	V_3	V_5	V_2
V_1	V_6	V_2	V_5
V_4	V_2	V_3	V_1
V_2	V_5	V_4	V_6
V_5	V_1	V_6	V_4
D_2	D_1	D_3	D_0

D_0= Control (no submergence)
D_1= Six days submergence
D_2= Ten days submergence
D_3= Fourteen days submergence

V_1 = BRRI dhan51 (Submergence tolerant)
V_2 = BRRI dhan46
V_3 = BRRI dhan34
V_4 = BRRI hybrid 4
V_5 = Panna1
V_6 = Taj1