EFFECT OF SUBMERGENCE AT VEGETATIVE PHASE ON MORPHOLOGICAL ATTRIBUTES AND YIELD OF SOME RICE VARIETIES

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CERTIFICATE

This is to certify that the thesis entitled, "**EFFECT OF SUBMERGENCE AT VEGETATIVE PHASE ON MORPHOLOGICAL ATTRIBUTES AND YIELD OF SOME 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 result of a piece of bona fide research work carried out by* ***TANIA SULTANA*** *Registration No. 06-2126 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.

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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

The experiment was conducted during June to December, 2011 in T. *Aman* season to observe effect of submergence at vegetative phase on the morphological attributes and yield of some 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 hybrid dhan1, BRRI hybrid dhan2, ACI hybrid1 were used for this experiment. The experiment was laid out in Split Plot Design with three replications. All parameters were significantly affected by the submergence duration and variety. The tallest plant was recorded from fourteen days submergence treatment. The highest number of leaves, number of tillers hill^{-1}, and number of grains panicle^{-1}, weight of 1000 grains were recorded from no submergence. The highest grain yield was found from no submergence (control). The tallest plant was observed in BRRI hybrid dhan2. The highest number of leaves, number of tiller hill^{-1}, number grains panicle^{-1} and 1000-grain weight were achieved in BRRI dhan51. The BRRI hybrid dhan1 produced the highest (7.83 t ha^{-1}) grain yield. The highest (8.50 t ha^{-1}) grain yield was found from BRRI hybrid dhan1 with no submergence (control) and the lowest (1.20 t ha^{-1}) from BRRI dhan34 with fourteen days submergence. The test genotypes showed wide variation in yield reduction at different submergence duration. BRRI dhan51 followed by BRRI hybrid dhan1 showed lower grain yield reduction % in submerged conditions compare to control by attaining good yield contributing characters and thus proved as tolerant varieties. On the other hand, BRRI dhan34 and ACI hybrid1 were susceptible to submergence.

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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
RCBD	=	Randomized Complete Block Design
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
^{0}C	=	Degree Celsius
NS	=	Not significant
Max	=	Maximum
Min	=	Minimum
%	=	Percent
NPK	=	Nitrogen, Phosphorus and Potassium
CV%	=	Percentage of Coefficient of Variance

Chapter 1
Introduction

Chapter I

INTRODUCTION

Rice (*Oryza sativa L.*) is a cereal food crop, of the grass family *Gramineae*, extensively cultivated in warm climates, especially in East Asia. This crop has a wider adaptability and grows from sea level to a elevation of about 2600 metre (Jumla, Nepal). About 90 percent of the population of Bangladesh is rice eaters. The Food Department of the Government of Bangladesh recommends 410 gms of rice head^{-1}day^{-1}. Rice is rich in carbohydrates. The protein content is about 8.5 percent. The Thiamin and Riboflavin contents are 0.27 and 0.12 micrograms respectively. In Bangladesh total cultivable land was 90, 98,460 hectares and near about 77 percent of total cropped area is occupied by Rice cultivation. In the year of 2011, total production of Rice was 3, 35, 41,099 metric ton (BBS, 2011).

Rice is the staple food of about 140.6 million people of Bangladesh (BBS, 2006) and contributes 14.6% to the national GDP (BBS, 2004a) and supplies 71% of the total calories and 51% of the protein in a typical Bangladeshi diet (BBS, 1998). Bangladesh with its flat topography, abundant water and humid tropical climate constitutes an excellent habitat for the rice plant (BRRI, 1997a). Rice is grown in the country under diverse ecosystem like irrigated, rainfed and deep water conditions in three distinct overlapping seasons namely *Aus*, *Aman* and *Boro*.

By the year 2025, 21% increase in production over the year 2000 will be needed. The additional rice production has to come either from an expansion of the rice area or from an increase in yield, or both. The land area under rice is actually declining and expanding the area under rice cultivation is not an option for increasing rice production in many areas due to the pressure of urbanization, industrialization, crop diversification and other economic factors.

Variety itself is a genetic factor which contributes a lot in producing yield and yield components of a particular crop. Yield components are directly related to the variety and neighboring environments in which it grows. Earlier literatures indicated that there were marked differences in yield and ancillary characteristics among rice varieties. In the year 2005 among the *Aman* rice varieties modern varieties covered 67.99% and yield was 2.3 t ha^{-1} on the other hand local varieties covered 31.91% and yield was 1.37 t ha^{-1} (BBS, 2005).

In Bangladesh rainfed 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 flood 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 that the abiotic factors submergence and drought are the two top constraints in rainfed *Aman* rice. Flash flood in *Aman* season is one of the main reasons. Submergence at the vegetative stage causes deterioration in the plant 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 case of 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.

In Bangladesh, India and Thailand irrigated rice is also affected by short term submergence (Boonwite *et al.*, 1977). In 1972, the Island of Luzon in the Philippines experienced a weeklong flood, when about 0.2 million hectares of rice crop were damaged causing a loss of 74 million US dollars (Vergara and Mazaredo, 1975). During the last two decades, Bangladesh has faced a number of severe floods. The magnitude of loss due to those floods is on a steep increase. In many districts of Bangladesh in 2004, rainfed lowland rice faced a weeklong flood. Rainfed rice grown in flash flood prone areas may be partially or completely submerged. The frequency and duration of submergence depend on the topography and rainfall distribution.

Tolerance or resistance to submergence is defined as the ability of a plant to survive after complete submergence in water. It is a desirable trait in a majority of rice growing conditions. Submergence tolerance is an important requirement for both deepwater and rain fed lowland rice. Rainfed lowland rice needs the ability to survive complete submergence in areas those are occasionally inundated for a period from one day to several weeks.

Even though rice is being cultivated under flooded and irrigated condition, most of the rice varieties are susceptible to flooding if the plants are submerged under water for more than seven days (Adkins *et al.*, 1990). Hence, developing submergence tolerant rice varieties will be useful in reducing yield loss in rice.

Submergence tolerance is a metabolic adaptation in response to an anaerobiosis that enables cells to maintain their integrity to survive in hypoxia without any major damage. High starch levels prior to submergence favored tolerance by utilizing non-structural carbohydrate to supply the required energy for growth and maintenance metabolism (Jackson and Ram, 2003).

Under field condition, rapid emergence from submergence depends on the water transparency (Haque, 1975). Usually survival is more in clear water than in muddy water (Kondo and Okamura, 1934). Decreasing seedbed soil nitrogen level increases submergence tolerance (Vergara, 1985). However, information on the effect of phosphorus content of seedling on submergence tolerance is scarce. Varietal differences in terms of submergence tolerance have been shown to exist by several workers (Mackill, 1986). For the development of modern high yielding variety with submergence tolerant traits, identification of submergence tolerant varieties are very important.

Flood is the most damaging among the serious problems of agriculture. According to an estimate of national Bureau of Soil Survey and Land planning nearly 3.3 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 years. Moreover, under changing climatic scenarios, crops will be expose more frequently to episodes of drought, high temperature and flood.

Therefore, it is an urgent need of the time to increase the production of rice through increasing the yield per hectares. Among the various factors limiting rice yield, submergence is very important one. More than 18 districts of Bangladesh are more or less regularly affected by different grades of flash floods. 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 covering about 24% of the total areas.

Based on these facts, the specific objectives of the present study were

1. To observe the effect of submergence on the morphological attributes and yield of rice.
2. To find out the highest submergence period for different varieties in which rice plant can survive.
3. To identify the suitable submergence tolerant varieties for flood prone area.

Chapter 2
Review of literature

Chapter II

REVIEW OF LITERATURE

2.1 Effect of variety

Variety itself is the genetical factor which contributes a lot for producing yield and yield components. Different researchers 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 have been discussed below -

Julfiquar *et al*. (1998) reported that BRRI evaluated twenty three hybrid rice varieties along with three standard check varieties during *Boro* season of 1994-95 as preliminary yield trial at Gazipur and it was reported that five hybrids (IR 58025A/IR 54056, IR 54883, PMS 8A/IR 46R) out yielded the check varieties (BR 14 and BR 16) with significant yield difference. Julfiquar *et al.* (1998) also reported that thirteen rice hybrids were evaluated in three locations of BADC farm during the *Boro* season of 1995-96. Two hybrids out yielded the check variety of same duration by more than 1 t ha^{-1}.

Rajendra *et al.* (1998) carried out an experiment with hybrid rice cv. Pusa 834 and Pusa HR 3 and observed that mean grain yields of Pusa 834 and Pusa HR 3 were 3.3 t ha^{-1} and 5.6 t ha^{-1}, respectively.

Devaraju *et al.* (1998) in a study with two rice hybrids such as Karnataka Rice Hybrid 1 (KRH 1) and Karnataka Rice Hybrid 2(KRI 42) using HYV IR 20 as the

check variety and found that KRH 2 out yielded than IR 20. In IR 20, the tiller number was higher than that of KRH 2.

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 three seedlings $hill^{-1}$, wide-narrow row spacing and one seedling $hill^{-1}$, and wide-narrow row spacing and three 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%.

Swain *et al.* (2006) also reported that the control cultivar IR 64, 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 PA 6201.

Molla (2001) reported that Pro-Agro 6201 (hybrid) had a significant higher yield than IET 4786 (HYV), due to more mature panicles m^{-2}, higher number of filled grains $panicle^{-1}$ and greater seed weight.

BRRI (1997) reported that three modern upland rice varieties namely, BR 20, BR 21, BR 24 was suitable for high rainfall belts of Bangladesh. Under proper management, the grain yield was 3.5 ton for BR 20, 3.0 ton for BR 21 and 3.5 ton for BR 24 ha^{-1}.

Pruneddu and Spanu (2001) conducted an experiment with 18 varieties to know the varietal performance of rice. They classified them into groups according to grain properties (round, medium, long A, long B and aromatic) and the highest yield was obtained from the long-grained varieties (9.1 t ha^{-1}), while the lowest was recorded in aromatic rice (3.15 t ha^{-1}).

Mondal *et al.* (2005) conducted an experiment with 17 modern varieties of rice in the northern region of Bangladesh and reported that BRRI dhan36 produced the highest grain yield (5.30 t ha^{-1}) due to superior yield components. Further, Kamal *et al.* (1998) conducted an experiment to assess the yield of nine modern varieties and six local improved varieties and observed that modern varieties gave greater yield (4.98 t ha^{-1}) than the local cultivars (3.36 t ha^{-1}) due to production of greater number of effective tillers $hill^{-1}$, number of grains $panicle^{-1}$.

Rahman (2002) studied seven fine grain rice (Ukunimadhu, Bullet, Hetkumra, Ghunshi, Bojromuri, Hoglapata and Binashail) to assess their yield and yield related traits and reported that Binashail produced the highest grain yield (5.36 t ha^{-1}) due to the production of higher number of effective tillers m^{-2}, filled grains $panicle^{-1}$, and better partitioning (HI) while Hetkumra, a aromatic rice, produced the lowest (2.70 t ha^{-1}).

2.2 Effect of Submergence

Some phyisological indices, growth development indices and yield components were investigated comparatively under complete plant submergence stress at booting and milk stages of rice. It had been shown that net photosynthetic rate of the treated leaves was decreased, chlorophyll content was decreased at booting stage, but little affected at milk stage, electric conductivity increased markedly due to efflux of electrolyte from injured cells, proline content increased obviously.The bleeding sap of root system was reduced, but contents of its major amino acids e.g., Ala, Pro, Phe were increased.Soluble sugar of leaf sheath dropped. Plant height raised slightly, but the fourth internode elongated significantly. As time of submergence stress was prolonged, the number of green leaves on a stem were lowered, necrotic rate of tillers was increased, tiller rate on high nodes was raised distinctly, duration of growth was delayed.The reduction of grain yield was resulted from decrease of effective tillers per hill, increase of empty grain ratio, decline of thousand grain weight (Yangsheng and Shaoqing, 2000).

Rice crop in lowland areas is invariably subjected to flooding stress continuously for various periods. Nearly half of the ecosystem is prone to submergence damages caused by flash flooding. Although the rice plant is well adapted to aquatic environments, it is unable to survive if it is completely submerged in water for an extended period (Ito *et al*,.1999). Flooding is widespread in southeast Asia, Bangladesh, and northeast India and about 15 million ha comes under potential flash flood in rainfed low land areas and 5 million ha of deepwater rice (Khush, 1984). Flooding is a serious constraint to rice plant growth and survival in rainfed lowland and deepwater areas because it results in partial or complete submergence of the plant. Flooding imposes a severe selection pressure on plants principally because excess water in their surroundings can deprive them of certain basic needs, notably of oxygen and of carbon dioxide and light for photosynthesis. It is one of the major abiotic influences on species distribution and agricultural productivity world-wide (Jackson *et al*., 2009).

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 surfaces 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 (hypoxia) or no O_2 at all (anoxia) around the plant tissues such as seeds or root apices and atele. Though floodwater O_2 concentration during flash floods is generally high, floodwater may become anoxic in some environments, especially during the night when the O_2 produced in the daytime had been consumed for respiration. O_2 concentration in stagnant air- saturated water of 0.25 mol m^{-3} was considered a reasonable threshold value required for respiration in germinating rice seeds, coleoptiles, and embryos (Taylor, 1942).

Light is another important factor to consider during submergence. When floodwater is turbid, solar radiation under water becomes very low and limits the capacity of plants to photosynthesize. Palada and Vergara (1972), observed a decrease in survival of rice seedling after complete submergence in turbid water because of lower light transmission (40% of that in ar). There was a reduction in solar radiation to <1% that in air at only 40cm depth in one flood-affected location in eastern India (Setter *et al.,* 1995). Flood turbidity reduces light transmission and deposits silt on the submerged plant. Low irradiance in surface water is occurring to surface algal colony and turbidity.

Temperature is a further factor affecting the survival of plants during submergence. High temperature (30^0C) accelerates plant mortality; where as low temperature (20^0C) improves survival. High temperature decreases O_2 and CO_2 solubility in floodwater and accelerates anaerobic respiration leading to faster starvation and faster death of the plant (Ram *et al*., 2002). 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 couduness during the wet season. This could be caused by reduction in light penetration, the subsequent chlorophyll degradation and under water photosynthesis.

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.

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.

Rice has adapted to submergence-prone environments through the use of two strategies: submergence tolerance to flash floods where a rapid increase in water level causes partial to complete submergence for up to 2 weeks, and shoot elongation too short to long term submergence. *Sub1A* gene in *O. sativa* reportedly confers submergence tolerance to flash floods through a quiescence strategy in which cell elongation and carbohydrate metabolism in young seedlings is repressed during submergence (Fukao *et al*., 2006). This strategy is a predominant tolerance mechanism that is driven by adjustment of metabolism.

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).

Rapid shoot elongation for young seedlings is usually disadvantageous in conditions of short-term submergence with deep water conditions because lodging usually occurs once floodwaters recede. This water regime adapts well, using submergence tolerance with a quiescence strategy. By tolerance, cell elongation and carbohydrate metabolism are repressed. Furthermore, fast shoot elongation can restore contact between the leaves and air, but it can also result in death if carbohydrate reserves are depleted before emergence in leaves above the water surface. Leaf elongation during submergence is controlled by the interaction of at least three plant hormones: ethylene, GA, and ABA (Kende *et al.*, 1998). Accumulated ethylene is probably the primary signal which triggers the plant to start a cascade of reactions leading to enhanced cell elongation (Voesenek *et al.*, 2006) because ethylene is accumulated in rice plants during submergence because of the fact that gas diffusion is 104-fold slower in solution than in air (Armstrong, 1979). The cascade model was proposed from the study of stem elongation in deepwater rice (Kende *et al.*, 1998).

Rapid elongation of the leaves and leaf sheath is advantageous for rainfed lowland varieties because it enables them to avoid submergence stress when moderate flooding occurs during the early vegetative stage. Deepwater rice is often characterized as floating rice. Nevertheless, the differences in characteristics of floating rice and deepwater rice remain unclear. In fact, the physiological mechanisms of growth differ between the two. Some rice plants can survive and stand without floating in water at 1 m water depth. In this chapter, such rice plants that stand without floating in water are designated as deepwater rice to distinguish them from floating rice. In general, the plant height of deepwater rice reaches 140–180 cm in the absence of submergence (Catling, 1992), but the abilities of deepwater rice shoots to extend are varied. Deepwater rice can maintain an aerobic metabolism during submergence via development of its canopy above water because of the elongation of its internodes and because of its long leaves. Deepwater rice's ability to elongate in a single day is less than that of floating rice. However, deepwater rice can adapt to submergence under conditions in which the water level increases 5 cm per day (Catling, 1992). However, this type of tall plant architecture often causes lodging after the water recedes.

Setter *et al.* (1988) demonstrated that the adverse effects are caused mainly by reduced photosynthesis capacity because of CO2 starvation in the shoot organs during submergence. Furthermore, they suggested a relation between ethylene concentration, leaf chlorosis and leaf elongation. Partial submergence treatment to deep water rice never affects carbohydrate and sugar contents in newly developed leaves under the water compared to the control (Setter *et al.,* 1987). Elongation with floating ability is the most important morphological feature of deepwater rice. In particular, internode elongation is a more important mechanism for increasing shoot length. Internode elongation is related closely to plant hormones. Submergence lowers the O2 level in rice internodes. Then low O2 levels simulate ethylene synthesis. Ethylene accumulation occurs in the submerged internodes. Then high internodal ethylene concentration increases the sensitivity of tissues to gibberelic acid or increases the concentration of physiologically active gibberellins, thereby leading to commonly observed growth responses (Rose-John & Kende, 1985). Deepwater rice differs in its ability to accumulate carbohydrate contents within the cultivar's carbohydrate content, which does not correlate with the total internode length or plant length (Vergara *et al.*, 1975).

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 (Fraga *et al.*2010).

Submergence is one of the major limiting factors for successful cultivation of rainfed lowland T. Aman rice. Many studies were made by the scientists in different countries have identified many factors responsible for the tolerance of plants to complete submergence. A number of physical or environmental and plant factors are associated with the damage due to submergence (Ram et al. 1999; Greenway and Setter, 1996)

Submergence tolerance in rice is a genetical character. But there are some physical factors which obscure the tolerance to submergence. Palada and Vergara (1972) reported that several environmental factors affected the tolerance of rice plant to submergence which is water depth, water temperature, duration of submergence, degree of water turbidity, nitrogen level in the soil and light intensity. Greenway and Setter (1996) reported that a number of environmental factors are associated with damage due to flooding namely low light, siltation on the leaves, mechanical damage etc. these factors are reviewed separately in the following paragraphs.

Depth of water affects the tolerance of the rice plant during submergence due to change in the oxygen tension, light intensity and temperature of water with increasing depth. With the increasing water depth (50 to 70 cm above the leaves) percent survival reduced (Palada, 1970). Increasing water depth reduced the yield of deepwater rice (Datta nd Benerji, 1973; Kupkanchanakul et al. 1983). Pande et al (1979) reported that deeper submergence suppressed tiller formation at the early growth phase which adversely affect yield. Sen (1937) and Ghosh (1945) observed that increase in water level resulted in diminished meristematic activity as evidenced by the low production of tillers. This was resulted due to the accumulation of sugar in the leaves. Higher sugar content was noticed at the highest level of water where tillering was much suppressed. Tsunoda and Matsushima (1962) reported that the adverse effect of submergence were severe in any depth of water. If plants were treated at the booting stage the adverse effect increased progressively with water depth due to immersion of young panicle.

The survival of rice seedlings after complete submergence in water decreased with increased water temperature (Palada and Vergara, 1972). Kondo and Okamura (1932) reported that the the reduction in grain yield depend on the temperature of the inundation water. Plants survived longer period in cool water than warm water. The leaves of the plants under low temperature were dark green, while at high temperature (40°C), the leaves were scaled and decayed. They also reported that in clear water, plants died within 8 days at 30° C, 6 days at 35°C and 4 days at 40°C, Gomosta (1985) reported that elongation of different plant parts in deepwater rice increased with the increases in water temperature from 15°C to 30°C and then decreased at 35°C. Palada (1970) found that the survival of plant increased with lower temperature, high light intensity, clear water and lower nitrogen level in the soil.

Submergence tolerance of a variety deceased with the increase in duration of submergence (Palada and Vergara, 1992). Pande et al. (1979) reported that crop damage increased as the duration of complete submergence increased from 4 to 8 and 12 days. Adak and Gupta (2000) reported that duration of submergence decreased the photosynthetic rate, stomatal conductance, intercellular CO_2 concentration, hill activity etc. irrespective of varieties as compared to those under normal condition. Reddy and Mittra (1985) reported that with increasing duration of submergence, tiller number, green leaves and dry weight of all varieties tested devreased. The decrease was less in the flood tolerant variety FR13A than in other varieties. Contents of reducing sugars and amylase activity also decreased with increasing duration of submergence. The N contents increased and P and K contents decreased with duration of submergence.

The floodwater is usually turbid because it carries some soil and other particles. Gomosta (1985) reported that internodes, leaf sheath and leaf blade elongation in 4-week old seedling of Habiganj Aman VIII was not affected but elongation of leaf sheath and leaf blades of RD19 were severely inhibited by water turbidity. Water turbidity however inhibited by water turbidity. Water turbidity however inhibited internodes elongation of 3 week old seedling of Habiganj Aman VIII, which had smaller amount of pre-submergemce carbohydrate content and shorter plant height than 4-week old seedling. Dry matter accumulation was found to be negatively related with degree of water turbidity. Komdo and Okamura (1934) reported that growth in height was stimulated by clear water and inhibited by turbid water. All plants submerged under turbid water for 10 days died after flooding but plants submerged under clear water recovered well and continued to grow normally. Damage due to turbid water attributed to the plants being covered by mud. Flooding with clear water resulted in less damage than with muddy water (Oka and Kibota, 1961). Similar results were also reported by Vamadevan et al. (1971) and Pande et al. (1979). Mud deposition on the leaf surface hindered both respiration and photosynthesis and aggregated mortality (Kondo and Okamura, 1934, Palada and Vergara, 1972).

Palada and Vergara (1972) reported that low light transmission through turbid water might be the main reason for the lower percentage of survival among submerged plants in turbid water. The percentage of survival was significantly higher (45% and 83%) at high light intensity that in low light intensity in both short and tall peta variety respectively.

Nitrogen level in the soil was found to affect the resistance of rice plants to submergence. Plants from soil with a low nitrogen level had a significantly higher percentage of survival than that from high nitrogen level. A high level of nitrogen in plants, as a result of more nitrogen in the soil, would result in more susceptibility to damage caused by submergence (Palada, 1970). Yamada (1959) reported that top dressing of nitrogen before flooding caused a remarkable decrease in resistance against submergence because of its diminishing effect on the starch content of the plant.

The re-entry of air after de-submergence introduces higher oxygen concentration relative to the very low concentration under water. Injury of the submerged plant generally develops after desubmergence (Gutteridge and Halliwell, 1990) and is possibly caused by active oxygen species

(Hunter *et al.,* 1983; Crawford, 1992). Oxygen is one possible source of oxygen species. When oxygen get reduced, one electron leaks out from the electron transfer system, converting it into suoeroxide anion (O^{-2}). Superoxide anion, in return, produces more active O_2 species; hydrogen peroxide (H_2O_2) and hydroxyl radical (OH^-). The active O_2 Species are cytotoxic because these are highly reactive. It oxidizes unsaturated fatty acids of the lipid layers in cellular membrane or in intercellular organelles, known as lipid peroxidation. Lipid peroxidation is at its peak soon after de-submergence. The level of lipid peroxidation in anoxia-intolerant *Iris germanica* increased by 157-fold relative to the non-submerged control, where in case anoxia-tolerant *I. pseudacorus* increased by only 1.2-fold (Hunter *et al*., 1983). Lipid peroxidation and associated harmful effects of anoxia and submergence can be reduced by substances like alfa-tocopherol and carotenoids. The level alfa-tocopherol was three times higher in submerged rice seedling than that of aerobically grown controls and remained higher for 24h after transfer of seedlings to air (Ushimaru *et al*., 1994).

Age of seedlings at the time of submergence or flooding determines the degree of submergence tolerance. Seedlings are generally susceptible at the lower ages (10-20 days) than at the higher ages (30-40 days) (BRRI, 1982). Another experiment revealed that due to submergence grain yield was more affected in 60 day old seedlings than 30 day old seedlings both in BR22 and BR23 (BRRI, 1991). Several other workers also reported that resistance to submergence was increased with the age of seedlings (Chowdhury and Zaman, 1970). Pande *et al*. (1979) reported the increase of grain yield with the increase of seedling age in intermittent flooded area. Richharia and Parasuram (1963) indicated that in case of any flood resistant variety there should be an interval of at least six to seven weeks between the time of sowing or planting and the advent of the flood, to enable the plants to withstand submergence. This indicated that the ability to withstand this condition increased with the age of plants. Adkins et al. (1988) reported that submergence sensitivity of plants varied with age, with younger ones more sensitive than older ones.

Anaerobic response of plant tissues is the adaptive metabolic mechanism of increasing rate of alcoholic fermentation (AF) which involves alcohol dehydrogenase (ADH) and pyruvate dehydroxylase (PDC) as the two key enzymes. Submergence can shift aerobic respiration to the less efficient anaerobic fementation 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 activitiesALDH with concomitant increase in submergence tolerance (Sarkar *et al.*, 2006). The beneficial effect of alcoholic fermentation in growth and survival of rice under anoxia due to several points of view: (1) enzymes of alcoholic fermentation often increase (Drew *et al.*, 1994), (2) hypoxic pretreatment increased anoxia tolerance in submergence in submerged rice seedling (Ellis and Setter, 1999), (3) higher sugar supply improves survival. Schwartz (1969), observed that in maize, *Arabidopsis* ADH-null mutants, and rice ADH-reduced mutants showed lower tolerance to anaerobic conditions.

Submergence or anoxia-tolerant and intolerant species may differ in the number and the level of production of anaerobic proteins due to repression of most of the anaerobic proteins, however, are enzymes involved in carbohydrate metabolism and alcoholic fermentation. Six of the inducible proteins have been identified as cytosolic enzymes; alcohol dehydrogenase, aldolase, glucose phosphate isomerase, sucrose synthase, pyruvate decarboxylase, and glyceraldehydes phosphate dehydrogenase in many crops including rice (Walker *et al.*, 1987). In rice, Reggiani *et al.*, (1990) observed that repression was greater in membrane proteins than in soluble proteins. In maize, a set of 20 anaerobic polypeptides is selectively expressed in primary roots (Sachs *et al.*, 1980). A similar pattern of altered gene expression was observed in barley (Hoffman *et al.*, 1986), in cottonwood (Kimmerer, 1987), in tomato (Tanksley and Jones, 1981).

Chapter 3

Materials and Methods

Chapter III

MATERIALS AND METHODS

A brief description about experimental period, site, climatic condition, planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, uprooting of seedlings, intercultural operations, data collection and statistical analysis have been presented in this chapter.

3.1 Experimental period

The experiment was conducted during the period from July to December, 2011 in T. *Aman* season.

3.2 Site description

The experiment was conducted in the Sher-e-Bangla Agricultural University farm, Dhaka, under the agro-ecological zone of Modhupur Tract, AEZ-28. For better understanding, the experimental site has been 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 have been 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 have been presented in Appendix III.

3.5 Planting materials

Rice variety BRRI dhan51, BRRI dhan46, BRRI dhan34, BRRI hybrid dhan1, BRRI hybrid dhan2 and ACI hybrid1 were used as the test crop.

3.6 Seed collection and sprouting

Seeds of BRRI dhan51, BRRI dhan46, BRRI dhan34, BRRI hybrid dhan1, BRRI hybrid dhan2 were collected from Bangladesh Rice Research Institute (BRRI), Joydebpur and Gazipur. ACI hybrid1 was collected from ACI centre, Tejgaon, Dhaka. 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 raising 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 20 July, 2011 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 4 August, 2011 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 3t ha^{-1} was applied. The experimental plots were fertilized with @ 109, 134, 59, 8 kg ha^{-1} in the form of Urea, Triple Superphosphate (TSP), Muriate of Potash (MoP), Gypsum and Zinc Sulphate, respectively one day before transplanting. Urea was top dressed @ 89 kg N ha^{-1} in three equal splits at 10, 30 and 50 DAT. The entire amounts of Triple Superphosphate (TSP), Muriate of Potash (MoP), Gypsum and Zinc Sulphate were applied at final land preparation as basal dose.

3.10 Experimental treatments

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

A. Submergence – 4 different duration:

D_0= control (no submergence)

D_1= Six days submergence

D_2= Ten days submergence

D_3 = Fourteen days submergence

B. Variety – Six different inbreed & hybrid rice varieties:

V_1= BRRI dhan51

V_2= BRRI dhan46

V_3= BRRI dhan34

V_4= BRRI hybrid dhan1

V_5= BRRI hybrid dhan2

V_6= ACI hybrid dhan1

3.11 Experimental design

The experiment was laid out in a split plot design with three replications. The whole field was divided into three equal blocks each containing 24 plots. Each block was subdivided into four sub blocks. As such there were 12 sub blocks. Each sub blocks was encircled by the 50 cm high soil wall ridge, which was hundred percent water leakage proof. In total, there were 72 plots. The treatment was randomly assigned to each unit plot. The size of each unit plot was 3m × 2m. The distance between two blocks and two plots were kept 1m and 0.80 m respectively.

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. Dated on 11 August 2011 the rice seedlings were transplanted in lines each having a line to line distance of 25 cm and plant to plant distance 15 cm in the well prepared plots.

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 Weeding

During plant growth period two hand weeding were done, the first weeding was done at 23 DAT (Days after transplanting) followed by the second weeding at 38 DAT.

3.13.3 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. The D_0 or controlled sub-blocks were irrigated as optimum irrigation requirement as prescribed for the high yielding varieties of rice. The other sub-blocks D_1 (6 days submergence), D_2(10 days submergence) and D_3 (14 days submergence) were irrigated through drain 6 days after transplanting, where the water level was raised up to 40 cm height to submerge the rice plants. The water in submersed 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 (D3) 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.

3.13.4 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.

3.13.5 Plant protection measures

Plants were infested with rice stem borer and leaf hopper to some extent which were successfully controlled by applying one time of Furadan 2,4D on 11 September, 2011. Crop was protected from birds during the grain filling period.

3.14 Harvesting and post harvest operation

The rice was harvested depending upon the maturity of plant and harvesting was done manually from each plot on 15^{th} November, 2011. The harvested plants of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during harvesting, threshing and cleaning of rice seed. Fresh weight of grain was recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 12%. The yields of grain $plot^{-1}$ were recorded and converted to t ha^{-1}.

3.15 Recording of data

The following data were recorded at different stage:

A. Crop growth characters

Plant height

Leaves $plant^{-1}$

Tillers $plant^{-1}$

SPAD values

Survival percent after submergence

Plant with dead leaf percent

Plant with fresh leaf percent

Plant with partially damage leaf percent

Days to 50 % booting

Days to 100% booting

Days to 50% panicle emergence

Days to 100% panicle emergence

B. Yield contributing characters

Effective tillers $plant^{-1}$

Panicle length

Filled spikelets $panicle^{-1}$

Sterile spikelets $panicle^{-1}$

Days to maturity

Weight of 1000- grain

Yield kgm^{-2}

Yield (t ha^{-1})

3.16 Experimental measurements

The necessary data on different characters were collected from ten selected hills of each plot at different stages.

Plant height

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

Leaves plant^{-1}

Numbers of leaves per plant was counted at 10 days interval up to 60 days from pre selected plant and finally averaged as their number per plant.

Tillers plant^{-1}

Numbers of tillers plant^{-1} were counted at 10 days interval starting 30 DAT and continued up to 80 DAT from pre selected plant and finally averaged as their number plant^{-1}. Only those tillers having three or more leaves were considered for counting.

SPAD values of flag leaf

SPAD values of flag leaf were measured by SPAD meter at 30, 40 and 50 DAT.

Percent survival after submergence:

Percent survival was measured after removing water. The percent survival, of each variety was calculated as follows:

$$\text{Percent survival} = \frac{\text{Number of live seedling after termination of submergence}}{\text{Number of live seedlings before submergence}} \times 100$$

Plant with dead leaf percent

Numbers of plant with 100% dead leaves after termination of submergence were counted from pre selected plant and finally averaged as their number of plant with100% dead leaves.

Plant with fresh leaf percent

Numbers of plant with 100% live leaves after termination of submergence were counted from pre selected plant and finally averaged as their number of plant with 100% live leaves.

Plant with partially damage leaf percent

Numbers of partially damage leaves after termination of submergence were counted from pre selected plant and finally converted into percent.

Days to 50% booting

Days to 50% booting were recorded from transplanting date to the date of 50% booting of every entry.

Days to 100% booting

The data were recorded from the date of transplanting to the date of 100% booting of each entry.

Days to 50% panicle emergence

Days to 50% panicle emergence were recorded from transplanting date to the date of 50% panicle initiation of every entry.

Days to 100% panicle emergence

The data were recorded from the date of transplanting to days of 100% panicle emergence of each entry.

Panicle length

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

Effective tillers hill^{-1}

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

Filled spikelets panicle^{-1}

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

Sterile spikelets panicle^{-1}

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

Days to maturity:

The data were recorded from the date of transplanting to the date of 100% maturity of each entry.

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.

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 or meter.

3.17 Statistical analysis

The recorded data on various parameters were statistically analyzed by using MSTAT statistical package programme. Difference between treatment means were determined by Duncan`s new Multiple Range Test (DMRT) according to Gomez and Gomeg, (1984).

Chapter 4
Results and Discussion

CHAPTER IV

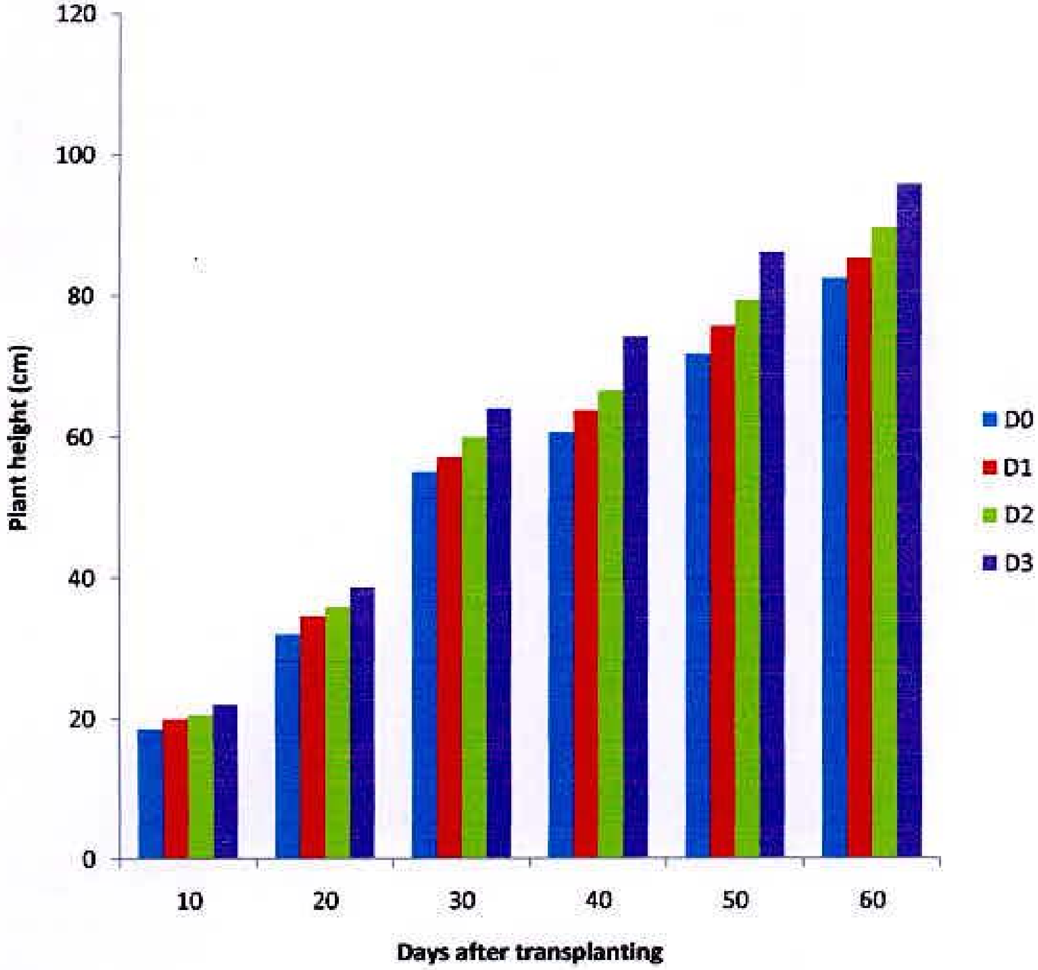
RESULTS AND DISCUSSION

The experiment was conducted to find study the effect of submergence stress at vegetative phase on the morphological attributes and yield of some rice varieties. Data on different parameters were analyzed statistically. The results of the present study have been presented and discussed in this chapter under the following headings.

4.1 Plant height

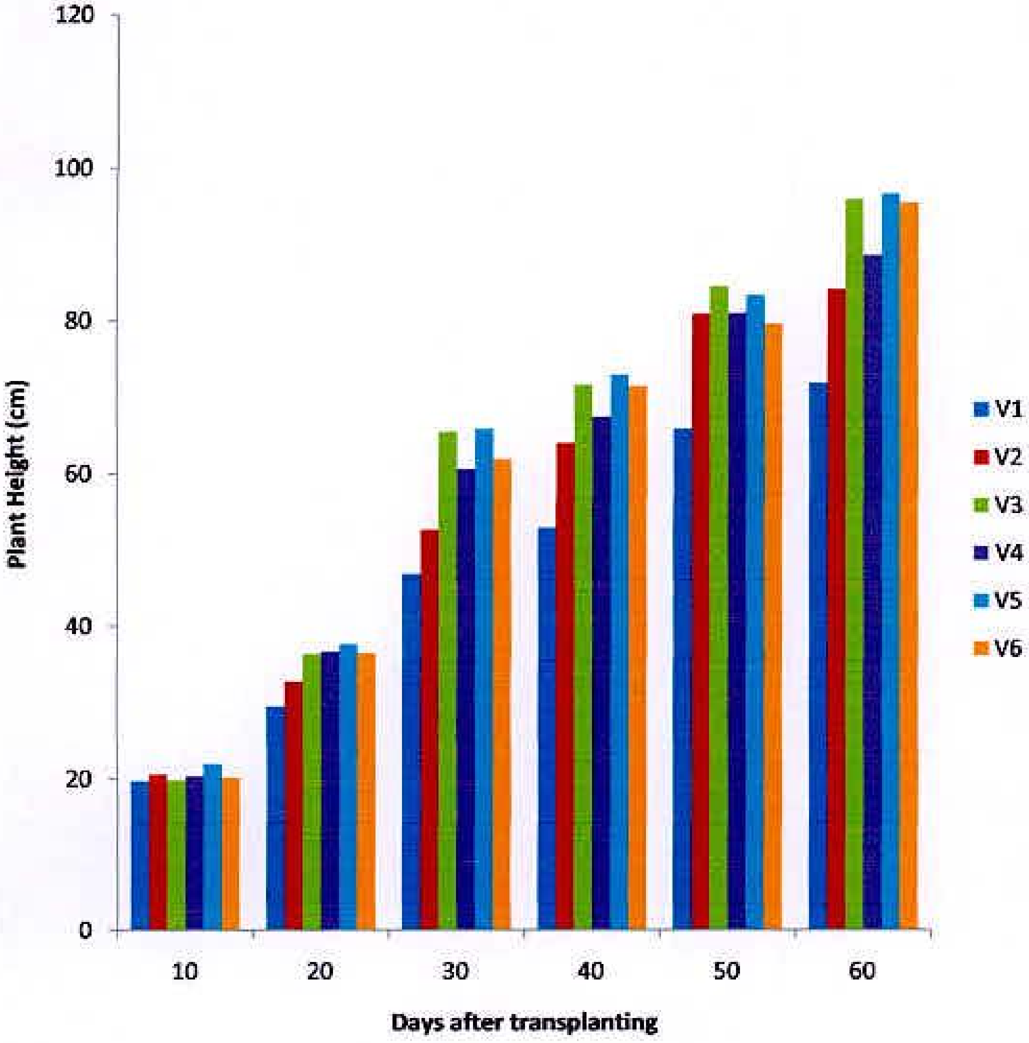
Statistically significant variation was observed in case of plant height of rice at 10, 20, 30, 40, 50 and 60 days after transplanting and at harvest under the treatment of different submergence duration (appendix IV). The tallest plant (21.93, 38.57, 63.91, 74.00, 86.04, and 85.65 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively) was recorded from D_3 (fourteen days submergence) treatment, while the shortest plant (18.46, 31.89, 54.94, 60.48, 71.54 and 82.26 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively) was observed from D_0 (no submergence) (Figure 1). Increased submergence duration increased plant height.

Plant height of the cultivars was measured at 10, 20, 30, 40, 50 and 60 days after transplanting and at harvest (Fig. 2 & appendix IV). The height of the plant was significantly influenced by variety at all the sampling dates. The V_5 (BRRI hybrid2) variety produced the tallest plant (21.94, 37.58, 65.72, 72.81, 83.19 and 96.50 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively) and V_1 (BRRI dhan51) produced shortest (19.75, 29.45, 46.83, 52.85, 65.81 and 71.72 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively).



D_0 = No submergence; D_1 = Six days submergence; D_2 =Ten days submergence; D_3 = Fourteen days submergence

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



V_1 = BRRI dhan51; V_2 = BRRI dhan46; V_3 = BRRI dhan34 V_4= BRRI hybrid dhan1; V_5 = BRRI hybrid dhan2; V_6 = ACI hybrid1

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

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.

Plant height at different day after transplanting was significantly affected by the interaction between submergence and variety (Table 1 & appendix IV). The tallest plant (23.33, 40.56, 71.33, 81.78, 97.67 and 104.90 at 10, 20, 30, 40, 50 and 60 DAT, respectively) was found from D_3V_5 (Fourteen days submergence with BRRI hybrid 2) and shortest plant (16.93, 19.23, 29.33, 31.87, 44.39 and 66.56 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively) from D_0V_1 (no submergence with BRRI dhan51)..

4.2 Leaves plant^{-1}

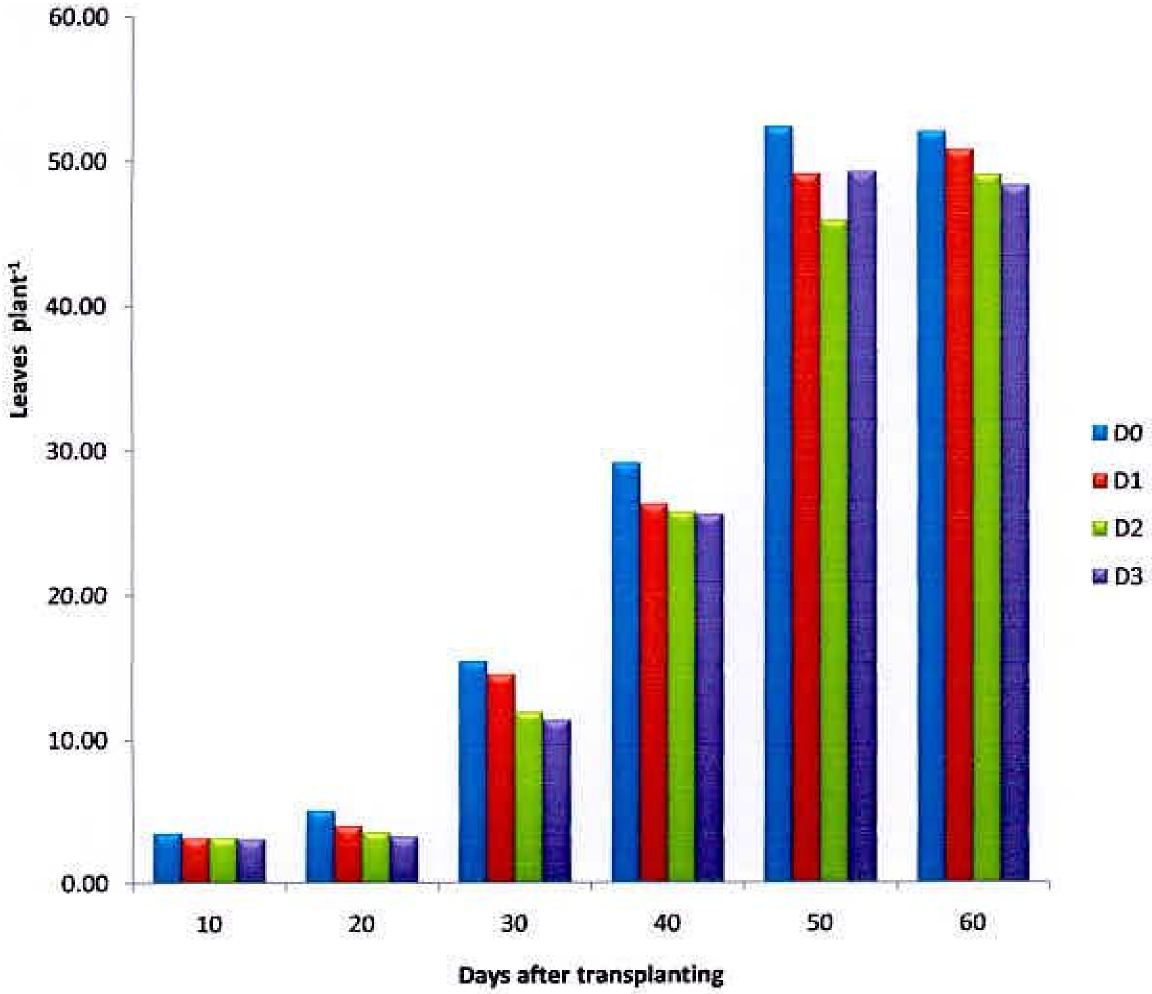
Number of leaves was significantly influenced by submergence. The number was counted at 10, 20, 30, 40, 50 and 60 days after transplanting and at harvest (appendix V). The highest number of leaves (3.49, 5.07, 15.39, 29.10, 52.33 and 52.0 at 10, 20, 30, 40, 50 and 60 DAT, respectively) was recorded from D_0 (no submergence) treatment, while the lowest number of leaves (3.04, 3.24, 11.33, 25.51, 49.22 and 48.25 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 & appendix V). The V_1 (BRRI dhan51) variety produced the highest number of leaves (3.31, 4.42, 14.60, 30.46, 53.00 and 54.46 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively) and V_1 (BRRI dhan51) produced shortest (3.15, 3.58, 12.27, 22.23, 44.71 and 44.42 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively).

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

	Plant height (cm)											
Treatment	10 DAT		20 DAT		30 DAT		40 DAT		50 DAT		60 DAT	
D_0V_1	18.00	d	28.00	j	42.00	i	49.00	g	60.33	f	66.56	k
D_0V_2	18.11	cd	34.44	efg	49.22	ghi	63.80	def	74.44	cde	81.78	hi
D_0V_3	18.33	cd	37.33	a-e	58.66	c-g	63.89	def	76.89	cd	89.11	fg
D_0V_4	19.33	bcd	34.96	efg	49.22	ghi	61.11	f	74.78	cde	88.22	fg
D_0V_5	21.78	a-d	39.33	ab	66.00	a-d	67.00	c-f	80.56	bc	86.11	gh
D_0V_6	20.00	a-d	34.51	efg	62.00	a-d	68.56	b-f	74.67	cde	91.22	efg
D_1V_1	18.56	bcd	30.33	ij	46.89	hi	49.05	g	66.22	def	67.45	k
D_1V_2	20.00	a-d	31.11	hij	50.00	f-i	62.00	f	76.00	cd	81.67	hi
D_1V_3	18.44	bcd	35.78	c-f	60.66	b-e	67.50	c-f	80.11	bc	91.22	efg
D_1V_4	20.89	a-d	35.22	def	59.44	b-f	66.22	c-f	80.44	bc	74.11	j
D_1V_5	22.00	abc	35.82	c-f	66.45	a-d	73.00	a-d	81.67	abc	93.45	def
D_1V_6	20.44	a-d	35.07	ef	59.67	b-f	64.11	def	80.44	bc	97.67	bcd
D_2V_1	19.33	bcd	28.36	j	49.22	ghi	50.56	g	61.89	ef	74.33	j
D_2V_2	18.78	bcd	33.78	fgh	51.22	e-i	62.56	ef	78.56	cd	78.00	ij
D_2V_3	19.33	bcd	34.67	efg	63.44	a-d	73.89	a-d	85.78	abc	97.89	bcd
D_2V_4	20.55	a-d	36.33	b-f	56.56	d-h	66.67	c-f	83.89	abc	93.00	def
D_2V_5	22.00	abc	36.89	b-f	67.45	abc	73.89	a-d	85.11	abc	99.11	bc
D_2V_6	19.78	a-d	36.89	b-f	62.66	a-d	72.56	a-e	79.78	bc	102.30	ab
D_3V_1	20.33	a-d	31.78	ghi	56.55	d-h	62.78	ef	74.78	cde	78.56	ij
D_3V_2	23.33	a	38.56	a-d	59.89	b-e	67.33	c-f	87.89	abc	94.56	cde
D_3V_3	23.22	a	37.78	a-e	66.45	a-d	77.78	ab	92.78	ab	102.80	ab
D_3V_4	20.67	a-d	37.78	a-e	69.55	ab	75.44	abc	83.11	abc	98.33	bcd
D_3V_5	23.33	a	40.56	a	71.33	a	81.78	a	94.67	a	104.90	a
D_3V_6	21.67	a-d	39.00	abc	67.00	abc	78.89	a	83.00	abc	94.78	cde
CV (%)	14.56		8.55		8.82		7.78		8.79		9.34	

D0 = No submergence; D1 = Six days submergence; D2 =Ten days submergence; D3 = Fourteen days submergence; V1 = BRRI dhan51; V2 = BRRI dhan46; V3 = BRRI dhan34; V4 = BRRI hybrid dhan1; V5 = BRRI hybrid dhan2; V6 = ACI hybrid 1



D_0 = No submergence; D_1 = Six days submergence; D_2 =Ten days submergence; D_3 = Fourteen days submergence

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

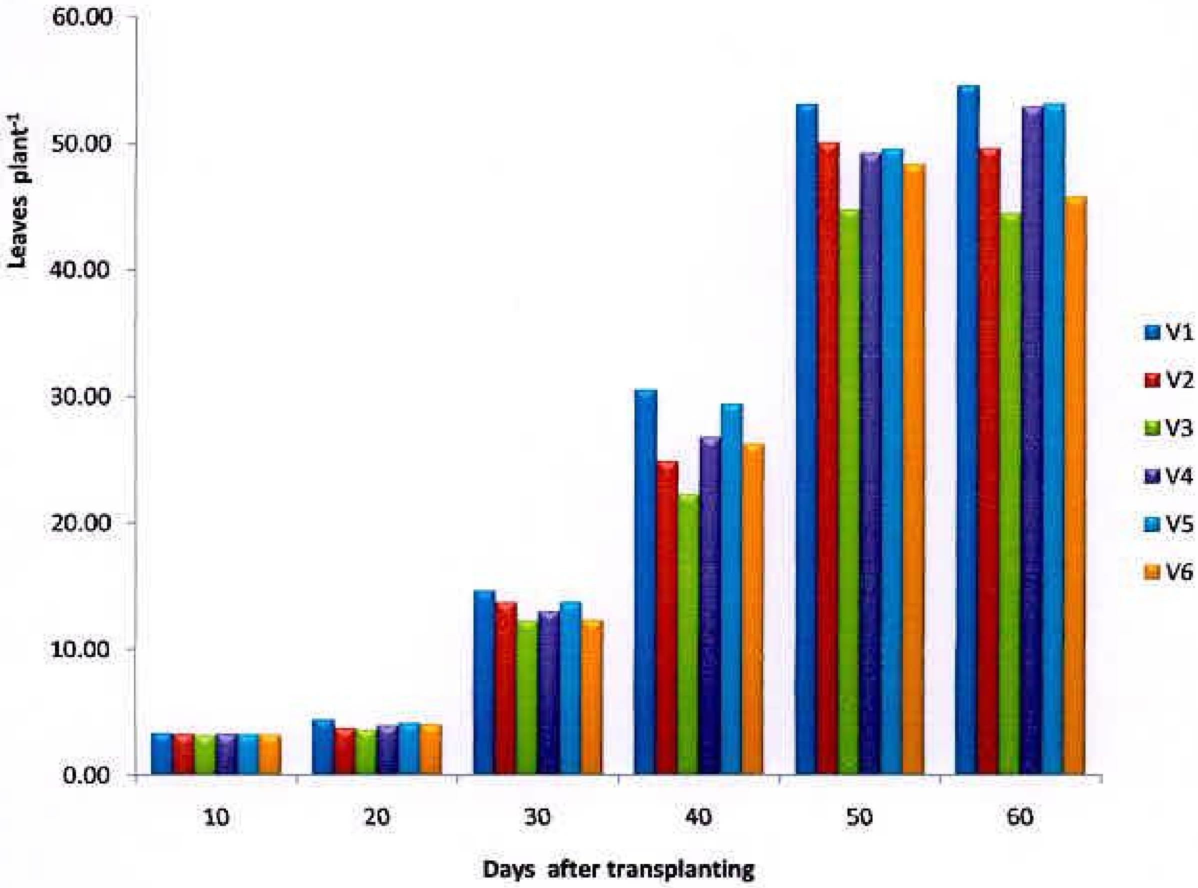
Interaction between submergence and variety was significantly affected on number of leaves per plant at different day after transplanting (Table 2 & appendix V). The maximum number of leaves per plant (3.83, 5.67, 19.08, 35.50, 59.58 and 64.25 at 10, 20, 30, 40, 50 and 60 DAT, respectively) was found from D_0V_1 (no submergence with BRRI dhan51) and lowest number of leaves per plant (3.00, 2.50, 9.17, 16.50, 38.75 and 39.17 at 10, 20, 30, 40, 50 and 60 DAT, respectively) from D_3V_3 (Fourteen day submergence with BRRI dhan34).

4.3 Plant with dead leaf (%)

Statistically variation was recorded for plant with dead leaves percent due to the duration of submergence (appendix VI). The maximum percent of dead leaves (11.89) was obtained from D_3 (Fourteen days submergence), which was statistically similar with D_2 treatment. The minimum percent of dead leaves (5.10) was recorded from D_0 (no submergence) (Table 3).

The percent of dead leaves was significantly influenced by variety (Table 4 & appendix VI). The V_1 variety (BRRI dhan51) achieved the minimum percent of dead leaves (5.83) and the higher production was observed. The maximum percent of dead leaves (9.83) was found in V_3 treatment.

The effect of submergence and variety were statistically significant on percent of dead leaves (Table 5 & appendix VI). The highest percent of dead leaves (16.67) was found from D_3V_3 (fourteen submergence with BRRI dhan34) and the lowest percent of dead leaves (2.00) from D_0V_1 (No submergence with BRRI dhan51).



V_1 = BRRI dhan51; V_2 = BRRI dhan46;; V_3 = BRRI dhan34 V_4= BRRI hybrid dhan1; V_5 = BRRI hybrid dhan2; V_6 = ACI hybrid1

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 leaves Plant^{-1} of rice

Treatment	Leaves plant^{-1} 10 DAT		20 DAT		30 DAT		40 DAT		50 DAT		60 DAT	
D_0V_1	3.83	a	5.67	a	19.08	a	35.50	a	59.58	a	64.25	a
D_0V_2	3.17	abc	5.33	abc	16.42	ab	31.08	ab	48.75	a-d	54.42	a-d
D_0V_3	3.17	abc	4.00	a-f	14.42	a-d	27.75	abc	46.33	bcd	53.08	a-d
D_0V_4	3.25	abc	5.08	a-d	14.67	a-d	30.17	ab	52.42	abc	54.50	a-d
D_0V_5	3.17	abc	4.67	a-e	15.92	abc	31.50	ab	51.67	abc	58.83	ab
D_0V_6	3.17	abc	4.25	a-f	14.92	a-d	31.17	ab	51.08	abc	55.42	a-d
D_1V_1	3.75	ab	3.33	c-f	12.83	a-d	28.58	abc	52.33	abc	49.92	a-d
D_1V_2	3.25	abc	5.08	a-d	15.42	abcd	22.75	bcd	51.58	abc	54.25	a-d
D_1V_3	3.33	abc	4.08	a-f	10.17	bcd	22.42	bcd	53.83	abc	50.58	a-d
D_1V_4	3.08	bc	3.42	b-f	14.00	a-d	28.33	abc	52.08	abc	52.67	a-d
D_1V_5	3.25	abc	5.08	a-d	13.58	a-d	28.67	abc	49.67	a-d	44.25	bcd
D_1V_6	3.50	abc	3.67	a-f	11.50	bcd	23.33	bcd	47.25	bcd	46.00	bcd
D_2V_1	3.17	abc	3.67	a-f	11.75	bcd	30.33	ab	42.58	cd	57.58	abc
D_2V_2	3.25	abc	3.00	def	11.17	bcd	25.58	a-d	51.33	abc	48.25	a-d
D_2V_3	3.08	bc	2.67	ef	10.17	bcd	23.75	bcd	55.42	ab	41.83	cd
D_2V_4	3.17	abc	3.58	a-f	12.75	a-d	27.83	abc	48.67	a-d	50.58	a-d
D_2V_5	3.17	abc	3.67	a-f	12.50	bcd	29.92	ab	46.58	bcd	53.25	a-d
D_2V_6	3.08	bc	2.83	ef	13.33	a-d	24.50	bcd	49.67	a-d	51.50	a-d
D_3V_1	3.17	abc	3.83	a-f	16.00	abc	26.08	a-d	49.83	a-d	49.17	abcd
D_3V_2	3.08	bc	3.00	def	15.50	a-d	24.92	bcd	46.33	bcd	39.50	d
D_3V_3	3.00	c	2.50	f	9.17	d	16.50	d	38.75	d	39.17	d
D_3V_4	3.00	c	3.00	def	10.50	bcd	19.33	cd	43.50	bcd	44.00	bcd
D_3V_5	3.17	abc	3.58	a-f	9.67	cd	25.83	a-d	45.58	bcd	46.33	bcd
D_3V_6	3.00	c	2.92	ef	13.00	a-d	23.42	bcd	43.83	bcd	40.67	d
CV (%)	11.48		7.33		8.56		8.92		12.46		9.82	

D0 = No submergence; D1 = Six days submergence; D2 =Ten days submergence; D3 = Fourteen days submergence; V1 = BRRI dhan51; V2 = BRRI dhan46; V3 = BRRI dhan34 V4 = BRRI hybrid dhan1; V5 = BRRI hybrid dhan2; V6 = ACI hybrid

Table. 3. Effect of submergence on plant with percent of dead leaf and fresh leaf and partially damaged leaves of rice

Treatment	Plant with dead leaf (%)	Plant with fresh leaf (%)	Partially damaged leaves (%)
D_0	5.10 b	84.90 a	10.00 b
D_1	5.44 b	84.56 a	10.00 b
D_2	9.00 a	67.43 b	23.57 a
D_3	11.89 a	64.56 b	23.67 a
CV (%)	5.21	13.55	5.29

D_0 = No submergence; D_1 = Six days submergence; D_2 =Ten days submergence; D_3 = Fourteen days submergence

Table. 4. Effect of varieties on plant with percent of dead leaf and fresh leaf and partially damaged leaves of rice

Treatment	Plant with dead leaf (%)	Plant with fresh leaf (%)	Partially damaged leaves (%)
V_1	5.83 c	84.67 a	9.50 c
V_2	9.67 ab	68.33 b	22.00 ab
V_3	9.83 a	66.17 b	24.00 a
V_4	8.33 abc	75.83 ab	15.84 abc
V_5	6.33 bc	83.57 a	10.17 bc
V_6	7.17 abc	73.16 b	19.67 abc
CV (%)	5.21	13.55	5.29

V_1 = BRRI dhan51; V_2 = BRRI dhan46; V_3 = BRRI dhan34; V_4= BRRI hybrid dhan1; V_5 = BRRI hybriddhan2; V_6 = ACI hybrid1

Table. 5. Interaction effect of submergence and varieties on plant with percent dead leaf and fresh leaf and partially damaged leaves of rice

Treatment	Plant with dead leaves (%)		Plant with fresh leaves (%)		Partially damaged leaves (%)	
D_0V_1	2.00	c	92.67	a	5.33	h
D_0V_2	6.00	abc	74.67	abcde	6.67	gh
D_0V_3	4.00	bc	81.33	abc	9.33	gh
D_0V_4	2.67	c	84.00	abc	6.67	gh
D_0V_5	2.05	c	92.67	a	5.33	h
D_0V_6	4.67	bc	87.33	ab	8.00	gh
D_1V_1	10.67	abc	64.00	cde	25.33	bcdef
D_1V_2	6.67	abc	65.33	cde	29.33	abcd
D_1V_3	7.33	abc	56.00	ef	36.67	ab
D_1V_4	12.00	abc	66.67	cde	21.33	cdefg
D_1V_5	14.67	ab	72.67	abcde	12.67	efgh
D_1V_6	9.33	abc	79.33	abcd	18.00	cdefgh
D_2V_1	6.00	abc	87.33	ab	14.67	defgh
D_2V_2	9.33	abc	74.67	abcde	16.00	cdefgh
D_2V_3	4.00	bc	81.33	abc	14.67	defgh
D_2V_4	6.67	abc	84.00	abc	9.33	gh
D_2V_5	6.67	abc	87.33	ab	16.00	cdefgh
D_2V_6	4.67	bc	87.33	ab	8.00	gh
D_3V_1	8.00	abc	78.67	abcd	10.67	fgh
D_3V_2	13.33	abc	60.00	def	26.67	abcde
D_3V_3	16.67	a	43.33	f	40.00	a
D_3V_4	13.33	abc	68.67	bcde	20.00	cdefgh
D_3V_5	8.67	abc	76.67	abcd	14.67	defgh
D_3V_6	11.33	abc	60.00	def	30.00	abc
CV (%)	5.21		13.55		5.29	

D0 = No submergence; D1 = Six days submergence; D2 =Ten days submergence; D3 = Fourteen days submergence; V1 = BRRI dhan51; V2 = BRRI dhan46; V3 = BRRI dhan34 V4 = BRRI hybrid dhan1; V5 = BRRI hybrid dhan2; V6 = ACI hybrid

4.4 Plant with fresh leaf (%)

Statistically variation was recorded for plant with percent of fresh leaves due to the duration of submergence (appendix VI). The maximum percent of fresh leaves (6.49) was obtained from D_0 (No submergence), which was statistically similar with D_2 treatment. The minimum percent of fresh leaves (64.56) was recorded from D_3 (fourteen days submergence) (Table 3).

The percent of fresh leaves was significantly influenced by variety (Table 4 & appendix VI). The V_1 variety (BRRI dhan51) was achieved the maximum percent of fresh leaves (84.67) and the production was observed. The minimum percent of fresh leaves (66.17) was found in V_3 treatment.

The effect of submergence and variety were statistically significant on percent of fresh leaves (Table 5 & appendix VI). The highest percent of fresh leaves (92.67) was found from D_0V_1 and the lowest percent of fresh leaves (43.33) from D_3V_3.

4.5 Plant with partially damaged leaf %

Statistically variation was recorded for plant with partially damage leaves percent due to the duration of submergence (appendix VI). The maximum percent of partially damage leaves (26.67) was obtained from D_3, The minimum percent of partially damage leaves (10) was recorded from D_0 and D_1 (Table 3).

The percent of partially damage leaves was significantly influenced by variety (Table 4 & appendix VI). The V_1 variety (BRRI dhan51) was achieved the minimum percent of partially damage leaves (9.50) and the production was observed. The maximum percent of partially damage leaves (24.00) was found in V_3 treatment.

The effect of submergence and variety were statistically significant on percent of partially damage leaves (Table 5 & appendix VI). The highest percent of partially damage leaves (40.00) was found from D_3V_3 (fourteen submergence with BRRI dhan34) and the lowest percent of partially damage leaves (5.33) from D_0V_1.

4.6 Total tiller hill^{-1}

Statistically variation was recorded for number of tillers hill^{-1} due to the different duration of submergence at days after transplanting (appendix VII). The maximum number of tillers hill^{-1} (4.89, 13.33, 17.04, 18.83, 22.11 and 17.33, at 30, 40, 50, 60, 70, 80 DAT, respectively) was obtained from D_0 while the minimum number of tillers hill^{-1} (3.40, 6.00, 15.91, 17.26, 19.86, 15.18 and 17.33, at 30, 40, 50, 60, 70, 80 DAT, respectively) was recorded from D_3 (fig. 5) treatment.

The number of total tillers hill^{-1} was significantly influenced by variety (fig. 6 & appendix VII). The highest number of tiller hill^{-1} (4.72, 13.28, 18.53, 19.81 and 22.27 at 30, 40, 50, 60, 70, 80 DAT) was achieved from V_1 and the V_3 minimum tiller (4.72, 13.28, 18.53, 19.81, 22.27 and 27.50 at 30, 40, 50, 60, 70 and 80 DAT) 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

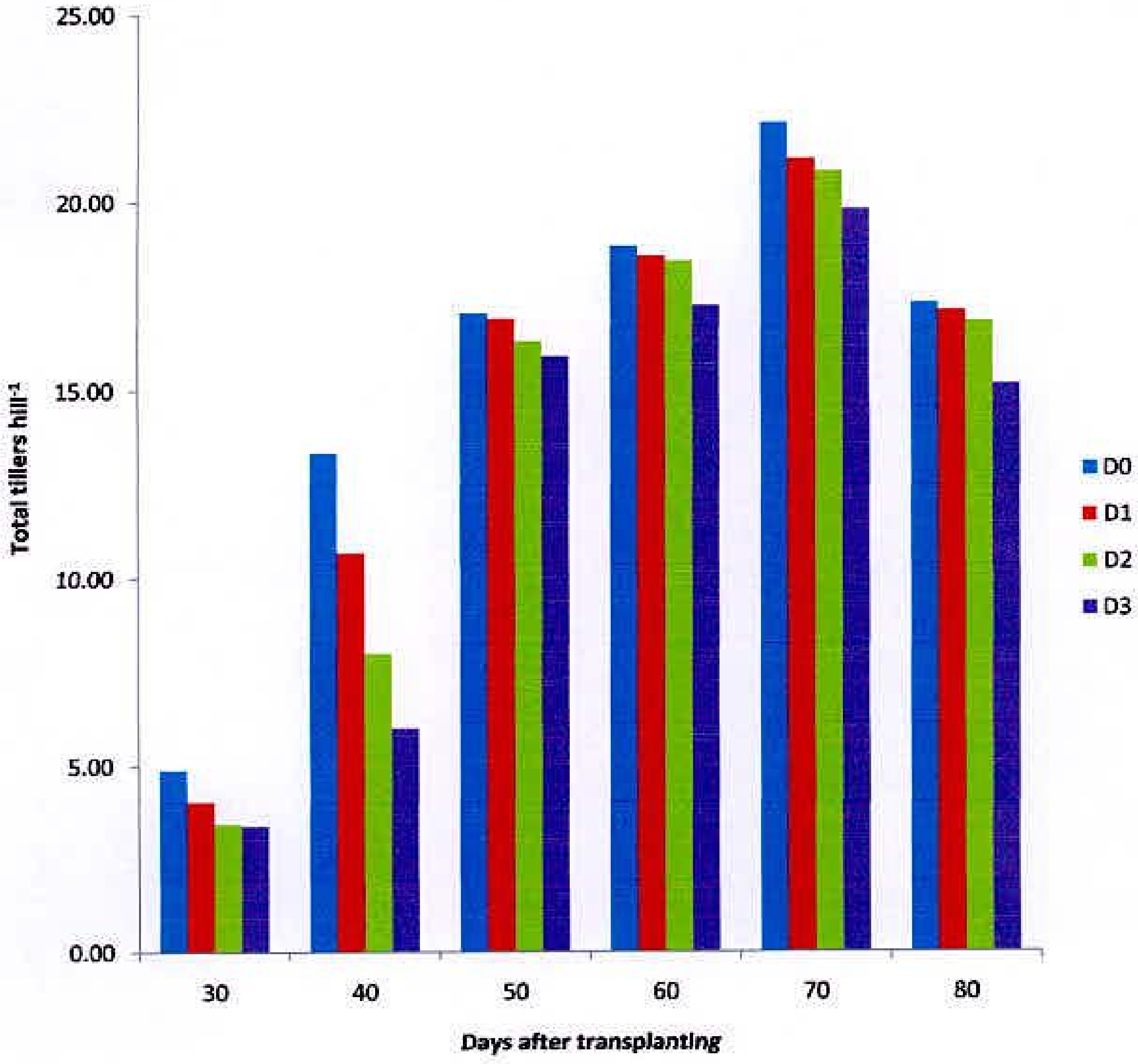
The effect of submergence and variety were statistically significant on number of tillers hill^{-1} (Table 6 & appendix VII). The highest total number of tillers hill^{-1} (5.89, 14.11, 19.45, 22.00, 26.25 and 32.00, at 30, 40, 50, 60, 70, 80 DAT) was found from D_0V_1 and the lowest total number of tillers hill^{-1} (7.44, 13.44, 14.00, 12.00 and 12.67 at 30, 40, 50, 60, 70, 80 DAT, respectively) from D_3V_3 treatment.

4.7 SPAD values of flag leaf

Statistically significant variation was recorded for SPAD values of leaf which showed differences due to submergence different duration of submergence at different days after transplanting (appendix VIII). The highest SPAD values of flag leaf (13.57, 40.02 and 44.93 at 30, 40 and 50 DAT, respectively) was obtained from D_0 treatment and the lowest SPAD reading of flag leaf (10.85, 29.38, and 41.17 at 30, 40 and 50 DAT, respectively) was attained from D_3 treatment (fig. 7).

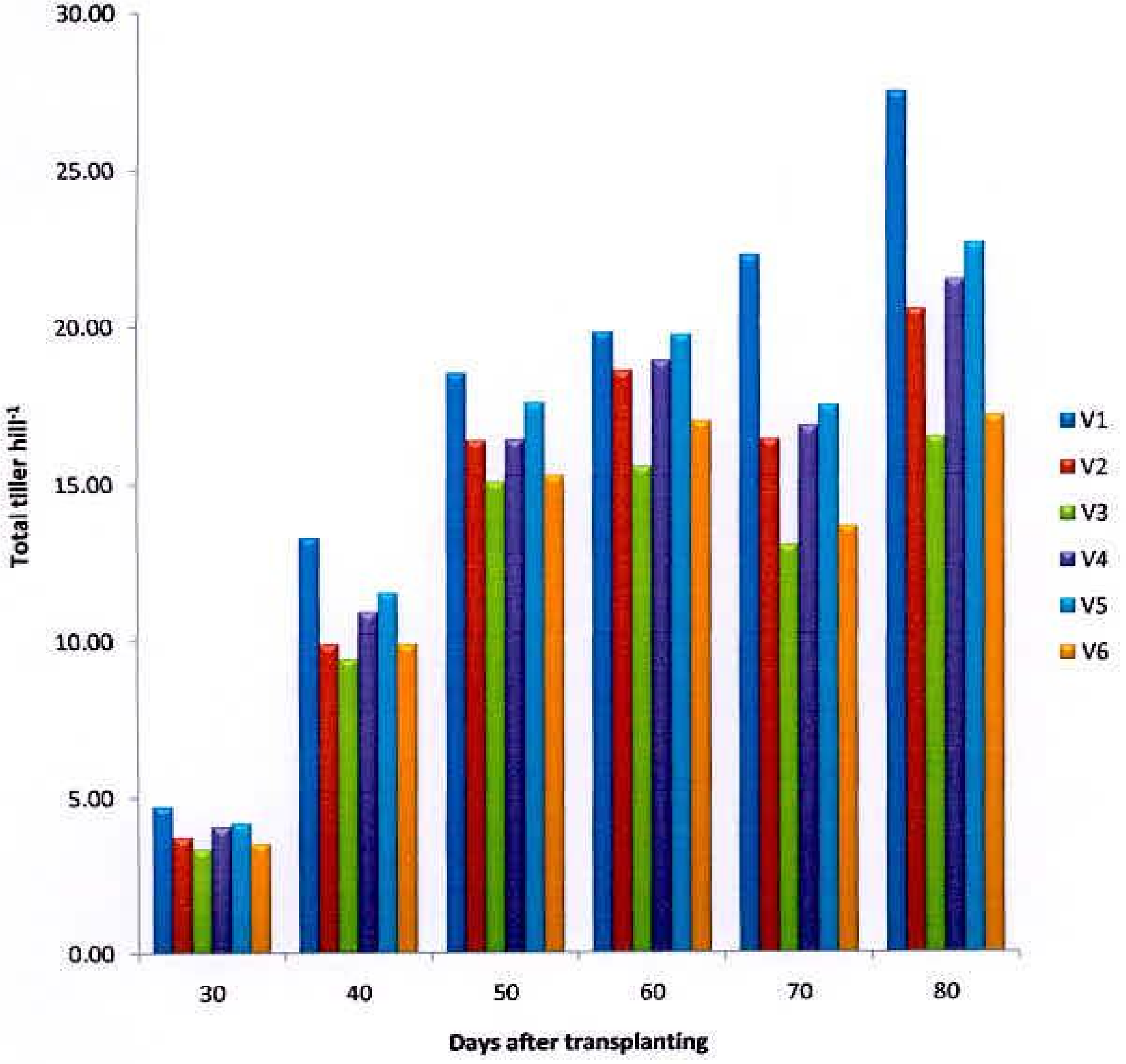
The varieties affected significantly in SPAD reading of flag leaf (appendix VIII). The V_1 (BRRI dhan51) gave significantly highest SPAD values of leaf (13.88, 40.09 and 46.89 at 30, 40 and 50 DAT, respectively). The lowest SPAD values of leaf (10, 29.51 and 42.61, at 30, 40 and 50 DAT, respectively) were found in V_3 treatment (fig. 8).

Interaction effect of submergence and variety was found significant on SPAD values of leaf (Table 7 & appendix VIII). The highest (19.25, 46.87 and 50.5 at 30, 40 and 50 DAT, respectively) SPAD values of leaf was found from the combination of D_0V_1. The lowest SPAD values of leaf (7.33,



D_0 = No submergence; D_1 = Six days submergence; D_2 =Ten days submergence; D_3 = Fourteen days submergence

Figure 5. Effect of submergence on number of tiller per hill of rice at different day after transplanting



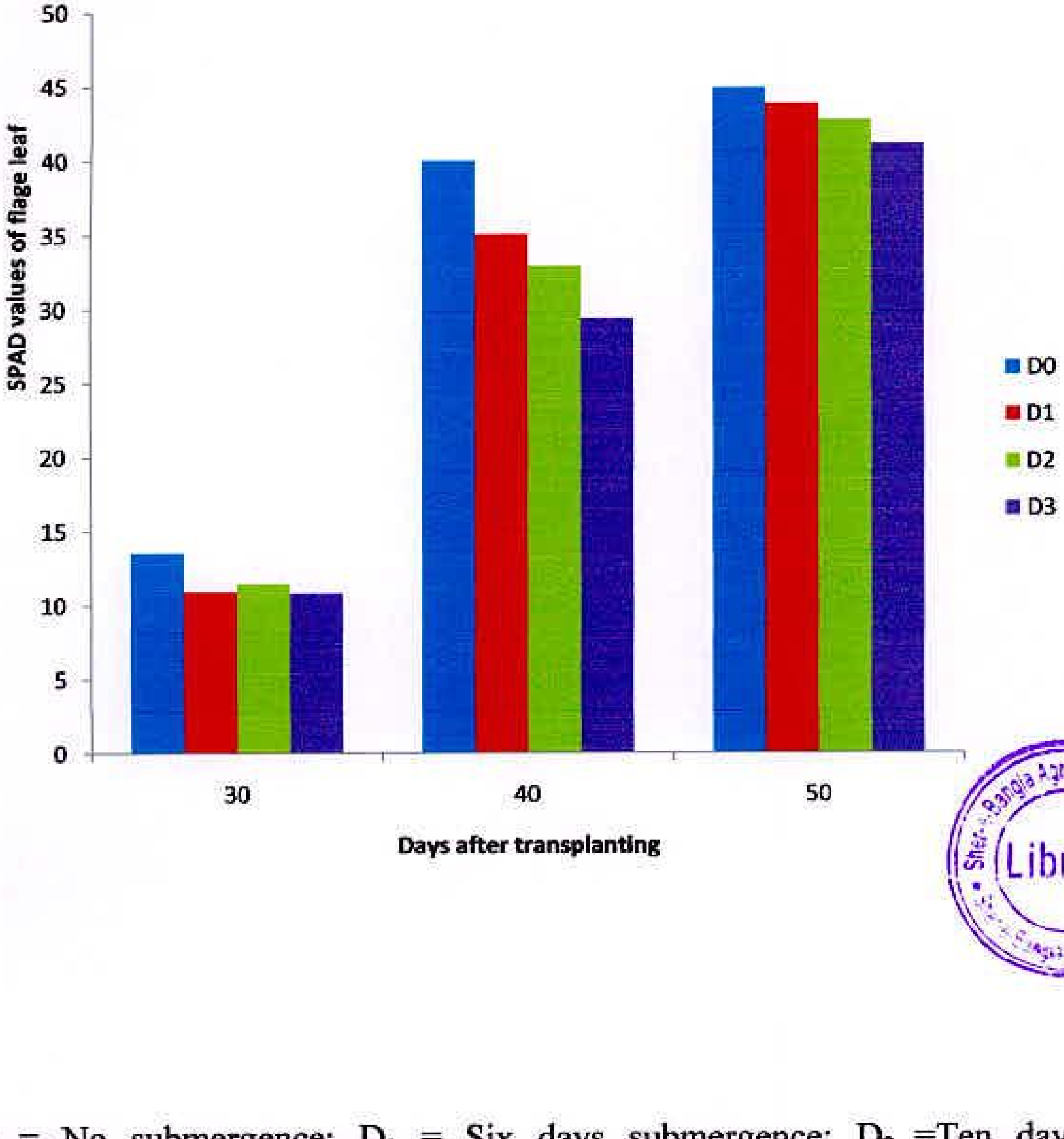
V_1 = BRRI dhan51; V_2 = BRRI dhan46; V_3 = BRRI dhan34 V_4= BRRI hybrid dhan1; V_5 = BRRI hybrid dhan2; V_6 = ACI hybrid1

Figure 6. Effect of varieties on number of tiller per hill of rice at different day after transplanting

Table 6. Combined effect of submergence and varieties total tiller hill^{-1} of rice at different day after transplanting

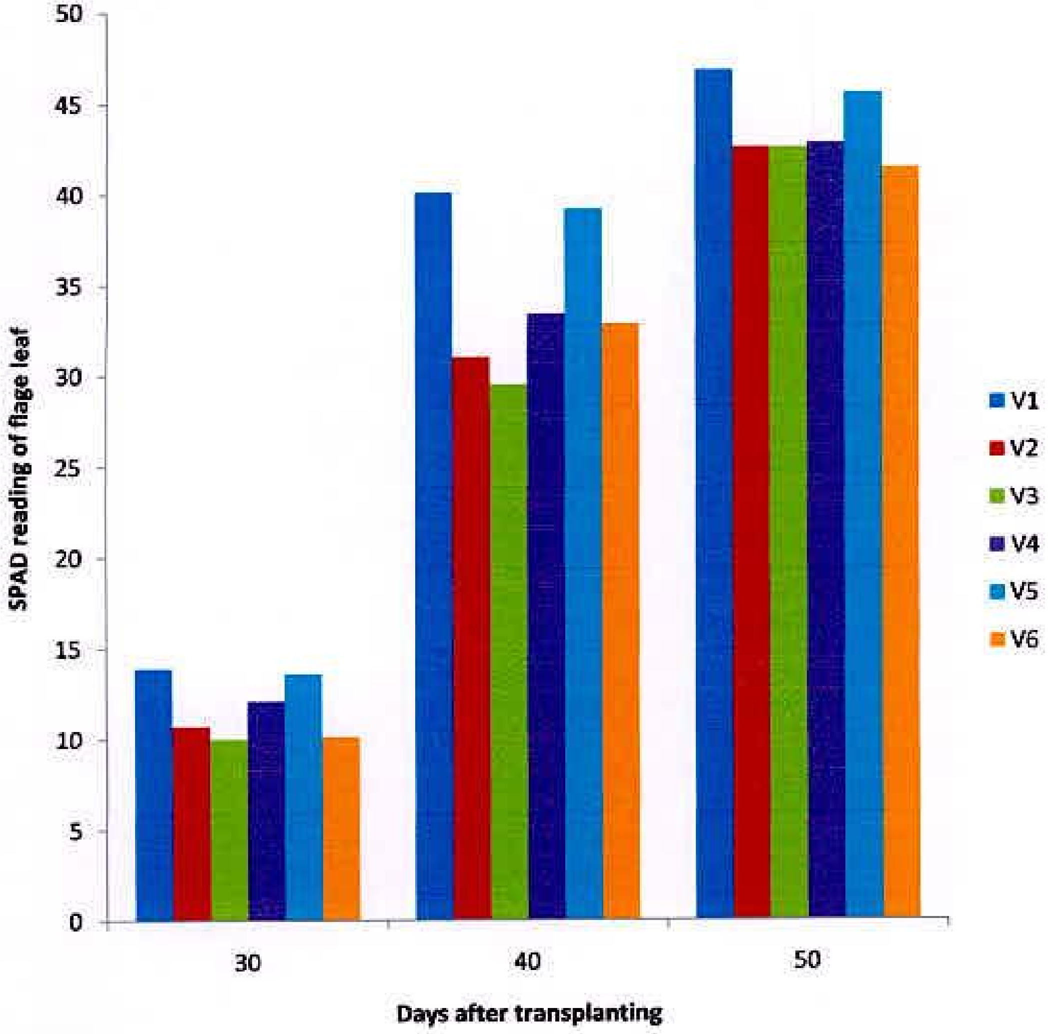
Treatment	Total tiller hill^{-1} 30 DAT		40 DAT		50 DAT		60 DAT		70DAT		80DAT	
D_0V_1	5.89	a	14.11	a	19.45	a	22.00	a	26.25	a	32.00	a
D_0V_2	3.44	bcd	11.44	a-h	17.11	abc	18.33	a-d	18.00	cd	18.33	c-g
D_0V_3	3.56	bcd	11.11	a-i	16.67	abc	18.00	a-d	16.00	cd	22.33	b-f
D_0V_4	4.44	abc	11.45	a-h	17.78	ab	20.67	ab	15.42	cd	22.33	b-f
D_0V_5	5.22	ab	13.22	abcd	19.11	a	21.00	ab	13.42	cd	26.67	a-d
D_0V_6	3.67	bcd	11.11	a-i	15.22	bc	17.33	a-d	17.25	cd	17.33	efg
D_1V_1	4.33	a-d	13.78	ab	19.11	a	20.67	ab	26.33	a	30.67	ab
D_1V_2	2.89	cd	11.67	a-h	15.22	bc	18.33	a-d	15.83	cd	22.33	b-f
D_1V_3	2.89	cd	8.67	ghi	16.78	abc	17.77	a-d	17.75	cd	21.00	c-g
D_1V_4	3.55	bcd	12.22	a-g	16.22	abc	17.90	a-d	16.25	cd	20.33	c-g
D_1V_5	3.89	bcd	13.44	abc	17.78	ab	20.33	ab	13.75	cd	18.00	d-g
D_1V_6	2.83	cd	9.00	f-i	15.22	bc	19.33	abc	14.08	cd	21.33	c-g
D_2V_1	2.89	cd	13.00	a-e	17.11	abc	18.57	a-d	24.25	ab	27.33	abc
D_2V_2	3.44	bcd	8.33	hi	15.89	abc	19.77	abc	18.92	bc	24.67	a-e
D_2V_3	4.55	abc	9.45	d-i	14.89	bc	18.00	a-d	13.58	cd	16.00	efg
D_2V_4	4.22	a-d	10.00	b-i	17.22	ab	19.67	abc	18.92	bc	20.33	c-g
D_2V_5	4.00	bcd	10.33	a-i	17.56	ab	16.33	bcd	13.58	cd	26.67	a-d
D_2V_6	3.67	bcd	9.33	e-i	16.33	abc	19.00	abc	13.50	cd	17.67	d-g
D_3V_1	5.11	ab	12.56	a-f	16.44	abc	18.00	a-d	18.33	cd	20.00	c-g
D_3V_2	5.22	ab	9.56	d-i	16.67	abc	14.90	cd	12.25	d	15.67	efg
D_3V_3	2.44	d	7.44	i	13.44	c	14.00	d	12.00	d	12.67	g
D_3V_4	3.89	bcd	9.11	f-i	14.78	bc	17.00	bcd	13.83	cd	17.00	efg
D_3V_5	4.56	abc	9.67	c-i	16.33	abc	17.67	a-d	16.83	cd	18.33	c-g
D_3V_6	4.00	bcd	9.67	c-i	14.66	bc	14.00	d	12.58	cd	14.67	fg
CV (%)	5.38		7.91		11.26		13.54		12.27		9.38	

D0 = No submergence; D1 = Six days submergence; D2 =Ten days submergence; D3 = Fourteen days submergence; V1 = BRRI dhan51; V2 = BRRI dhan46; V3 = BRRI dhan34 V4 = BRRI hybrid dhan1; V5 = BRRI hybrid dhan2; V6 = ACI hybrid



D_0 = No submergence; D_1 = Six days submergence; D_2 =Ten days submergence; D_3 = Fourteen days submergence

Figure 7. Effect of submergence on SPAD values of flag leaf of rice at different day after transplanting



V_1 = BRRI dhan51; V_2 = BRRI dhan46; V_3 = BRRI dhan34 V_4= BRRI hybrid dhan1; V_5 = BRRI hybrid dhan2; V_6 = ACI hybrid1

Figure 8. Effect of varieties on SPAD reading of flag leaf of rice at different day after transplanting

Table. 7. Interaction effect of submergence and varieties on SPAD reading of flag leaf of rice at different day after transplanting

	SPAD reading of flage leaf					
Treatment	30 DAT		40 DAT		50 DAT	
D_0V_1	19.25	a	46.87	a	50.5	a
D_0V_2	10.56	cd	30.1	bcd	43.27	abc
D_0V_3	10.11	cd	27.33	bcd	39.27	bc
D_0V_4	14.49	abc	33.97	abcd	43.87	abc
D_0V_5	10.62	bcd	39.07	ab	44.63	abc
D_0V_6	16.84	ab	43.00	ab	41.73	abc
D_1V_1	13.20	bcd	33.93	abcd	42.27	abc
D_1V_2	11.89	bcd	33.33	abcd	37.67	bc
D_1V_3	11.14	bcd	36.97	abcd	45.03	abc
D_1V_4	12.45	bcd	34.53	abcd	43.90	abc
D_1V_5	13.94	abc	39.17	ab	48.13	ab
D_1V_6	12.92	bcd	38.4	abcd	46.57	abc
D_2V_1	8.333	cd	38.6	abc	40.83	abc
D_2V_2	10.78	bcd	35.27	abcd	43.27	abc
D_2V_3	10.56	bcd	28.73	bcd	45.3	abc
D_2V_4	14.26	abc	42.9	ab	43.87	abc
D_2V_5	10.53	cd	39.23	ab	45.1	abc
D_2V_6	11.24	bcd	37.2	abcd	44.43	abc
D_3V_1	8.887	cd	38.07	abcd	45.00	abc
D_3V_2	11.89	bcd	22.33	cd	46.33	abc
D_3V_3	7.333	d	22.03	d	37.03	c
D_3V_4	9.557	cd	26.7	bcd	39.83	abc
D_3V_5	9.743	cd	29.8	bcd	44.67	abc
D_3V_6	10.67	bcd	26.77	bcd	46.07	abc
CV (%)	7.07		12.44		6.79	

D0 = No submergence; D1 = Six days submergence; D2 =Ten days submergence; D3 = Fourteen days submergence; V1 = BRRI dhan51; V2 = BRRI dhan46; V3 = BRRI dhan34 V4 = BRRI hybrid dhan1; V5 = BRRI hybrid dhan2; V6 = ACI hybrid

22.03 and 37.03 at 30, 40 and 50 DAT, respectively) were found from the combination of D_3V_3 treatment.

4.8 Survival percent after submergence

Survival percent after submergence was statistically influenced by duration of submergence (appendix IX). The maximum survival percent after submergence (84.56) was obtained from D_0 treatment. The minimum survival percent after submergence (23.56) was recorded from D_3 treatment (Table 8).

The survival percent after submergence was significantly influenced by variety (Table 9 & appendix IX). The maximum survival percent after submergence (66.17) was found in V_1 treatment. The V_3 variety (BRRI dhan34) was achieved the minimum survival percent after submergence (55.17).

The effect of submergence and variety were statistically significant on survival percent after submergence (Table 10 & appendix IX). The highest survival percent after submergence (92.67) was found from D_0V_1 (No submergence with BRRI dhan51) and the lowest survival percent after submergence (9.33) from D_3V_3 (fourteen submergence with BRRI dhan34).

4.9 Days to 50% booting

A significant variation was observed in days to 50% booting due to different duration of submergence (Table 8 & appendix IX). The D_1 treatment required the earliest of days to 50% booting initiation (60.78 days). D_0 treatment was the longest time of 50% booting initiation (63.83 days).

Table 8. Effect of submergence on survival percentage after submergence, days to 50% and 100% booting, days to 50% and 100% panicle emergence and days to maturity of rice

Treatment	survival percent after submergence	Day to 50% booting	Days to 100% booting	Days to 50% panicle emergence	Days to 100% panicle emergence	Days to maturity
D_0	84.56 a	63.83 a	65.22 c	65.44 b	67.22 b	121.30 d
D_1	67.78 a	60.78 c	65.83 c	68.39 ab	70.17 ab	124.30 c
D_2	64.56 a	61.67 ab	66.67 b	69.50 ab	71.17 ab	125.30 b
D_3	23.56 b	61.89 ab	68.33 a	72.11 a	73.83 a	126.30 a
CV (%)	13.22	10.19	5.31	5.47	6.49	8.23

D_0 = No submergence; D_1 = Six days submergence; D_2 =Ten days submergence; D_3 = Fourteen days submergence

Table 9. Effect of varieties on survival percentage after submergence, days to 50% and 100% booting initiation, days to 50% and 100% panicle initiation and days to maturity of rice

Treatment	**survival percent after submergence**	**Day to 50% booting**	**Days to 100% booting**	**Days to 50% panicle emergence**	**Days to 100% panicle emergence**	**Days to maturity**
V_1	66.17 a	72.75 a	79.33 a	81.67 a	82.83 a	120.00 d
V_2	56.17 c	72.42 a	78.83 a	82.08 a	83.33 a	120.00 d
V_3	55.17 c	66.92 ab	71.00 b	72.67 b	74.67 b	134.00 a
V_4	60.33 bc	61.42 b	65.75 b	67.33 c	69.33 c	124.00 c
V_5	62.83 ab	50.25 c	51.50 c	54.67 d	56.67 d	124.00 c
V_6	60.00 bc	48.50 c	52.67 c	54.75 d	56.75 d	130.00 b
CV (%)	13.22	10.19	5.31	5.47	6.49	8.23

V_1 = BRRI dhan51; V_2 = BRRI dhan46; V_3 = BRRI dhan34 V_4= BRRI hybrid dhan1; V_5 = BRRI hybrid dhan2; V_6 = ACI hybrid1

Table 10. Combined effect of submergence and varieties on survival percentage after submergence, days to 50% and 100% booting initiation, days to 50% and 100% panicle initiation and days to maturity of rice

Treatment	Survival percent after submergence	Day to 50% booting initiation	Days to 100% booting initiation	Days to 50% panicle initiation	Days to 100% panicle initiation	Days to maturity
D_0V_1	92.67 a	74.33 ab	77.67 abc	78.67 cd	80.00 def	120.00 d
D_0V_2	74.67 a-e	73.33 ab	77.33 abc	79.33 c	80.67 cde	120.00 d
D_0V_3	81.33 abc	65.67 a-f	68.67 d-g	65.33 gh	67.33 ij	134.00 a
D_0V_4	87.33 ab	60.33 c-g	63.33 gh	64.33 h	66.33 j	124.00 c
D_0V_5	87.33 ab	45.67 h	49.33 j	52.33 j	54.33 l	124.00 c
D_0V_6	84.00 abc	45.33 h	58.33 hi	52.67 j	54.67 l	130.00 b
D_1V_1	79.33 a-d	73.67 ab	78.67 ab	80.67 bc	82.00 bcd	120.00 d
D_1V_2	65.33 cde	72.33 abc	77.67 abc	81.00 bc	82.33 bcd	120.00 d
D_1V_3	56.00 ef	65.67 a-f	70.33 def	74.00 e	76.00 g	134.00 a
D_1V_4	76.67 a-d	59.67 d-g	64.33 fgh	68.00 fg	70.00 hi	124.00 c
D_1V_5	78.67 a-d	56.00 e-h	50.67 j	53.33 j	55.33 l	124.00 c
D_1V_6	67.33 b-e	55.67 fgh	49.67 j	53.33 j	55.33 l	130.00 b
D_2V_1	72.67 a-e	66.00 a-f	80.00 a	82.67 ab	83.67 abc	120.00 d
D_2V_2	60.00 def	73.67 ab	80.00 a	83.33 ab	84.33 ab	120.00 d
D_2V_3	43.33 f	68.33 a-d	71.67 cde	75.00 e	77.00 fg	134.00 a
D_2V_4	68.67 b-e	63.67 b-g	66.67 efg	67.67 fg	69.67 hi	124.00 c
D_2V_5	66.00 cde	52.33 gh	52.00 j	54.00 j	56.00 l	124.00 c
D_2V_6	60.00 def	46.00 h	49.67 j	54.33 j	56.33 l	130.00 b
D_3V_1	43.33 f	77.00 a	81.00 a	84.17 a	85.67 a	120.00 d
D_3V_2	21.33 g	70.33 a-d	80.33 a	84.67 a	86.00 a	120.00 d
D_3V_3	9.33 g	68.00 a-e	73.33 bcd	76.33 de	78.33 efg	134.00 a
D_3V_4	23.33 g	62.00 b-g	68.67 d-g	69.33 f	71.33 h	124.00 c
D_3V_5	24.67 g	47.00 h	53.67 ij	59.00 i	61.00 k	124.00 c
D_3V_6	19.33 g	47.00 h	53.00 ij	58.67 i	60.67 k	130.00 b
CV (%)	13.22	10.19	5.31	5.47	6.49	8.23

D0 = No submergence; D1 = Six days submergence; D2 =Ten days submergence; D3 = Fourteen days submergence; V1 = BRRI dhan51; V2 = BRRI dhan46; V3 = BRRI dhan34 V4 = BRRI hybrid dhan1; V5 = BRRI hybrid dhan2; V6 = ACI hybrid

A significant difference was observed among the varieties in the days to 50% booting (Table 9 & appendix IX). Delayed 50% booting initiation (72.75 days) was found in V_1 treatment and 50% booting initiation was earliest (48.5 days) in V_6, which was statistically similar to V_5 treatment. The combined effect of duration of submergence and variety on days of 50% booting initiation was found to be significant (appendix IX). Data in table 10 Shows that, the days of 50% booting initiation was minimum (45.33 days) in D_0V_6 (control with ACI hybrid1), while it was maximum (77.00 days) in D_3V_1 (fourteen days submergence with BRRI dhan51) treatment.

4.10 Days to 100% booting

The submergence shows significant variation in the days to 100% booting initiation (appendix IX). The D_3 treatment required the maximum time of days to100% booting (68.33 days). D_0 treatment was the earliest in 100% booting (65.22 days) (Table 8).

There was a marked difference among the varieties in the days to 100% booting (appendix IX). 100% booting (79.33 days) was delayed in V_1 treatment and 100% booting initiation was earliest (51.50 days) in V_5 treatment (Table 9).

The combined effect of different submergence duration and variety on days to100% booting was found to be significant (appendix IX). Data in table 10 Shows that, the days to100% booting was minimum (49.33 days) in D_0V_5 (no submergence and BRRI hybrid dhan2), while it was maximum (81.00 days) in D_3V_1 (fourteen days submergence with BRRI dhan51) treatment.

4.11 Days to 50% panicle emergence

A significant variation was observed in days to 50% panicle emergence due to duration of submergence (Table 8 & appendix IX). The D_0 treatment required the earliest to 50% panicle initiation (65.44 days). D_3 treatment showed the longest period to 50% panicle emergence (72.11 days).

A significant difference was observed among the varieties in the days to 50% panicle emergence (Table 9 & appendix IX). 50% panicle emergence (82.08 days) was delayed in V_2 treatment and 50% panicle emergence was earliest (54.67 days) in V_5, which was statistically similar to V_6 treatment.

The combined effect of different duration of submergence and variety on days to 50% panicle emergence was found to be significant (appendix IX). Data in table 10 Shows that, the days of 50% panicle emergence was minimum (52.33 days) in D_0V_5 (no submergence and BRRI hybrid dhan2), while it was maximum (84.67 days) in D_3V_2 (fourteen days submergence with BRRI dhan46) treatment.

4.12 Days to 100% panicle emergence

The submergence shows significant variation in the days to 100% panicle emergence (appendix IX). The D_3 treatment required the maximum days to100% panicle emergence (73.83 days). D_0 treatment was the earliest in 100% panicle emergence (67.22 days) (Table 8).

There was a marked difference among the varieties in the days to 100% panicle emergence (appendix IX). Delayed 100% panicle emergence (83.33 days) was found in V_2 treatment and 100% panicle emergence was earliest (54.67 days) in V_5 treatment (Table 9).

The combined effect of duration of submergence and variety on days of 100% panicle emergence was found to be significant (appendix IX). Data in table 10 Shows that, the days to 100% panicle emergence was minimum (54.33 days) in D_0V_5 (no submergence and BRRI hybrid dhan2), while it was maximum (86.00 days) in D_3V_2 (fourteen days submergence with BRRI dhan46) treatment.

4.13 Days to maturity

The submergence shows significant variation in the days to maturity (appendix IX). The D_3 treatment required the maximum time of days of maturity (126.30 days). D_0 treatment was the earliest in maturity (121.3 days) (Table 8).

There was a marked difference among the varieties in the days to maturity (appendix IX). Delayed maturity (134.00 days) was found in V_3 treatment and maturity was earliest (120.00 days) in V_1 and V_2 treatment (Table 9).

The combined effect of duration of submergence and variety on days of maturity was found to be significant (appendix IX). Data in table 10 Shows that, the days of maturity was minimum (120.00 days) in D_0V_1 (no submergence and BRRI dhan51), while it was maximum 134.00 days) in D_3V_3 (fourteen days submergence with BRRI dhan34) treatment.

4.14 Panicle length

Length of panicle showed statistically significant differences due to different duration of submergence (appendix X). The longest panicle length

(23.56 cm) was found at D_0 and the lowest panicle length (23.11 cm) was recorded D_3 treatment (Table 11).

The panicle length varied significantly due to variety shown in Table 12 & appendix X. The longest panicle length (24.83 cm) was obtained in cultivar BRRI dhan51 and the lowest panicle length (22.33 cm) was recorded in BRRI dhan34.

Interaction effect of submergence and variety was found significant on panicle length (Table 13 & appendix X). The highest panicle length (26.33 cm) was recorded in combination of no submergence with BRRI hybrid dhan2. However, the lowest panicle length (24.00) was recorded combination of fourteen days duration submergence with BRRI dhan34.

4.15 Grains panicle^{-1}

Significant variation was recorded for number of grains panicle^{-1} due to differences in duration of submergence (appendix X). The highest number of filled spikelets panicle^{-1} (102.20) was obtained from D_0 treatment and the lowest number of filled spikelets panicle^{-1} (75.99) was attained from D_3 treatment (Table 11).

The tested varieties affected significantly for different submergence duration in number of grains panicle^{-1} (Table 12 & appendix X). The V_1 (BRRI dhan51) showed significantly highest number (122.5) grains panicle^{-1}. The lowest number of grains panicle^{-1} (65.93) was found in V_3 treatment. BRRI (1994) found that number of grains panicle^{-1} significantly differed among different varieties.

Interaction effect of submergence and variety was found significant on grains panicle^{-1} (Table 13 & appendix X). From the results of Table 5 it was observed that the highest (135.90) number of grains panicle^{-1} was found

Table 11. Effect of submergence on yield contributing character of rice

Treatment	Panicle length	*Grains panicle^{-1}*	Sterile grains panicle^{-1}
D_0	23.56 a	102.20 a	17.64 c
D_1	23.39 a	100.20 ab	18.95 bc
D_2	23.28 a	97.96 ab	22.11 ab
D_3	23.11 a	75.99 b	22.63 a
CV (%)	13.99	10.08	14.70

D_0 = No submergence; D_1 = Six days submergence; D_2 =Ten days submergence; D_3 = Fourteen days submergence

Table 12. Effect of varieties on yield contributing character of rice

Treatment	Panicle length	*Grains panicle^{-1}*	Sterile grains panicle^{-1}
V_1	24.83 a	122.5 a	12.31 c
V_2	22.75 c	78.86 bc	15.9 bc
V_3	22.33 c	65.93 c	17.95 abc
V_4	23.33 b	98.29 abc	24.26 ab
V_5	23.58 b	115.9 ab	24.38 ab
V_6	23.17 b	83.01 abc	27.79 a
CV (%)	13.99	10.08	14.70

V_1 = BRRI dhan51; V_2 = BRRI dhan46; V_3 = BRRI dhan34 V_4= BRRI hybrid dhan1; V_5 = BRRI hybrid dhan2; V_6 = ACI hybrid1

Table 13. Interaction effect of submergence and varieties on yield contributing character of rice

Treatment	*Panicle length*		*Grains panicle^{-1}*		Sterile grains *panicle^{-1}*	
D_0V_1	26.00	ab	135.90	a	11.00	i
D_0V_2	23.67	abcd	121.80	abc	14.99	efghi
D_0V_3	22.67	abcd	121.30	abcd	18.14	defghi
D_0V_4	24.00	abcd	133.10	ab	12.82	fghi
D_0V_5	26.33	a	135.30	a	11.41	hi
D_0V_6	22.00	bcd	130.90	ab	11.60	ghi
D_1V_1	23.00	abcd	101.30	abcdef	19.98	defghi
D_1V_2	23.33	abcd	98.05	bcdef	11.60	ghi
D_1V_3	23.67	abcd	84.34	defg	18.72	defghi
D_1V_4	23.67	abcd	84.93	cdefg	27.05	abcd
D_1V_5	23.00	abcd	100.20	abcdef	24.09	bcde
D_1V_6	22.00	bcd	80.33	efg	31.24	ab
D_2V_1	22.67	abcd	112.80	abcde	15.08	efghi
D_2V_2	23.33	abcd	86.15	cdefg	15.75	efghi
D_2V_3	23.33	abcd	86.21	cdefg	20.44	defghi
D_2V_4	22.33	abcd	85.62	cdefg	24.89	bcde
D_2V_5	24.33	abcd	84.69	cdefg	20.20	defghi
D_2V_6	25.33	abc	81.28	efg	21.48	cdefg
D_3V_1	21.67	cd	87.19	cdefg	27.52	abcd
D_3V_2	24.00	abcd	57.18	g	22.98	bcde
D_3V_3	21.00	d	11.87	h	21.23	cdefgh
D_3V_4	23.33	abcd	72.95	fg	34.03	a
D_3V_5	22.00	bcd	85.82	cdefg	22.14	bcdef
D_3V_6	23.33	abcd	78.56	efg	30.92	abc
CV (%)	13.99		10.08		14.70	

D0 = No submergence; D1 = Six days submergence; D2 =Ten days submergence; D3 = Fourteen days submergence; V1 = BRRI dhan51; V2 = BRRI dhan46; V3 = BRRI dhan34 V4 = BRRI hybrid dhan1; V5 = BRRI hybrid dhan2; V6 = ACI hybrid

from the combination of D_0V_1. The lowest grains panicle^{-1} (11.87) was found from the combination of D_3V_3 treatment.

4.16 Sterile spikelets panicle^{-1}

Number of unfilled grains panicle^{-1} varied significantly for duration of submergence (appendix X). The lowest number of unfilled grains panicle^{-1} was found from D_0 (17.64) treatment and the highest number was recorded from D_3 (22.53) treatment (Table 11).

Among the traits made, number of unfilled grains panicle^{-1} plays a vital role in yield reduction (appendix X). Results showed that variety had significant effect in respect of the number of unfilled grains panicle^{-1} (Table 12). The V_1 variety (BRRI dhan51) showed the lowest number (12.31) of unfilled grains panicle^{-1} and V_3 produced highest number (27.79) 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.

Combined effect of different submergence duration and varieties showed significantly response on unfilled grains panicle^{-1} (Table 13 & appendix X). 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_4.

4.17 1000-grain weight

Statistically significant difference was recorded for weight of 1000 grains for duration of submergence (appendix XI). The highest weight of 1000 grains (27.15 g) was observed from D_0 treatment, while the lowest weight was recorded from D_3 (26.33 g) treatment (table 14).

Variety had significant effect on 1000-grain weight (Table 15 & appendix XI). The maximum 1000-grain weight (29.37 g) was found in V_1 treatment. The lowest thousand seed weight (19.95g) was found in V_3 treatment.

Interaction effect of submergence and variety showed significant effect on 1000-grain weight (Table 16 & appendix XI). The lowest (19.43 g) thousand seed weight was observed from D_3V_3 treatment which was statistically similar with D_3V_2, D_3V_4, and D_3V_6 and the highest (31.39 g) thousand seed weight from D_0V_1.

4.18 Yield m^{-2}

Grain yield $m^{-2}$of rice varied significantly for different submergence duration (appendix XI). The highest grain yield m^{-2} was found from D_0 (0.62 kg) whereas the lowest yield was recorded from D_3 (0.38 kg) treatment (Table 14).

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 (Hassan *et al.*, 2003). In present experiment variety had significant effect on grain yield (Table 15 & appendix XI). The V_4 (BRRI hybrid dhan1) produced the highest (0.78 kg) grain yield m^{-2} and the lowest grain weight m^{-2} (0.23 kg) was found from V_3 (BRRI dhan34). Grain yield differences due to varieties were reported by Suprithatno and Sutaryo (1992). Variable

Table 14. Effect of submergence on thousand grain weight and yield of rice

Treatment	1000 grain wt	Yield/m^2	Yield t/ha	Percent reduction of yield
D_0	27.15 b	0.62 a	6.23 a	0.00 d
D_1	27.06 b	0.60 a	5.95 ab	5.23 c
D_2	27.09 b	0.50 b	5.00 b	19.02 b
D_3	26.33 a	0.38 c	3.78 c	31.03 a
CV (%)	7.70	6.88	6.93	7.89

D_0 = No submergence; D_1 = Six days submergence; D_2 =Ten days submergence; D_3 = Fourteen days submergence

Table 15. Effect of varieties on thousand grain weight and yield of rice

Treatment	1000 grain weight	Yield/m^2	Yield t/ha	Percent reduction of yield
V_1	29.37 a	0.36 d	3.58 cd	3.86 e
V_2	27.32 b	0.44 c	4.38 c	6.91 d
V_3	19.95 c	0.23 e	2.30 d	30.43 a
V_4	28.23 ab	0.78 a	7.83 a	6.63 d
V_5	29.32 a	0.73 a	7.33 ab	9.00 c
V_6	27.26 b	0.61 b	6.05 b	26.10 b
CV (%)	7.70	6.88	6.93	7.89

V_1 = *BRRI dhan51; V_2 = BRRI dhan46; V_3 = BRRI dhan34* V_4= BRRI hybrid dhan1; V_5 = BRRI hybrid dhan2; V_6 = ACI hybrid1

Table 16. Combined effect of submergence and varieties on thousand grain weight and yield of rice

Treatment	1000 grain weight		*Yield/m²*		*Yield t/ha*		% reduction of yield	
D_0V_1	31.39	a	0.45	cd	4.50	de	0.00	n
D_0V_2	28.69	abcde	0.47	bcd	4.70	cde	0.00	n
D_0V_3	27.96	abcde	0.35	de	3.50	ef	0.00	n
D_0V_4	28.49	abcde	0.85	a	8.50	a	0.00	n
D_0V_5	26.69	bcde	0.80	a	8.00	a	0.00	n
D_0V_6	30.09	ab	0.82	a	8.20	a	0.00	n
D_1V_1	29.71	abc	0.44	cd	4.40	de	2.22	m
D_1V_2	28.41	abcde	0.45	cd	4.50	de	4.25	kl
D_1V_3	29.87	abc	0.30	def	3.00	efg	14.0	g
D_1V_4	27.76	abcde	0.82	a	8.20	a	3.52	l
D_1V_5	28.11	abcde	0.76	a	7.60	a	5.00	k
D_1V_6	28.31	abcde	0.80	a	8.00	a	2.40	m
D_2V_1	27.07	bcde	0.42	cd	4.20	de	6.60	j
D_2V_2	27.72	abcde	0.43	cd	4.30	de	8.50	i
D_2V_3	25.59	de	0.15	ef	1.50	fg	42.00	c
D_2V_4	30.51	ab	0.78	a	7.80	a	8.00	i
D_2V_5	29.79	abc	0.72	a	7.20	ab	10.00	h
D_2V_6	29.15	abcd	0.50	bcd	5.00	bcde	39.00	d
D_3V_1	25.87	cde	0.42	cd	4.20	de	6.60	j
D_3V_2	19.79	f	0.40	d	4.00	e	14.89	f
D_3V_3	19.43	f	0.12	f	1.20	g	65.71	a
D_3V_4	20.45	f	0.68	ab	6.80	abc	15	f
D_3V_5	24.81	e	0.65	abc	6.50	abcd	21	e
D_3V_6	20.11	f	0.30	def	3.00	efg	63	b
CV (%)	7.70		6.88		6.93		7.89	

D0 = No submergence; D1 = Six days submergence; D2 =Ten days submergence; D3 = Fourteen days submergence; V1 = BRRI dhan51; V2 = BRRI dhan46; V3 = BRRI dhan34 V4 = BRRI hybrid dhan1; V5 = BRRI hybrid dhan2; V6 = ACI hybrid

grain yield among tested varieties of rice was reported by Alam (1988) and IRRI (1978).

Interaction of submergence and variety significantly affected the grain yield m^{-2} (Table 16 & appendix XI). The highest (0.85 kg) grain yield was found from the combination of D_0V_4 (no submergence with BRRI hybrid dhan1) and the lowest (0.12 kg) from D_3V_3 (Fourteen days submergence with BRRI dhan34).

4.19 Grain yield

Grain yield per hectare of rice varied significantly for submergence duration (appendix XI). The highest grain yield was found from D_0 (6.23 t/ha) whereas the lowest yield was recorded from D_3 (3.78 t/ha) treatment (Table 14).

Grain yield is a function of interplay of various yield components such as number of productive tillers, grains $panicle^{-1}$ and 1000-grain weight (Hassan *et al.*, 2003). In present experiment variety had significant effect on grain yield (Table 15 & appendix XI). It was evident from Table 15 that V_4 (BRRI hybrid dhan1) produced the highest (7.83 t ha^{-1}) grain yield. Grain yield differences due to varieties were reported by Suprithatno and Sutaryo (1992), Alam (1988) and IRRI (1978) reported variable grain yield among tested varieties of rice.

From the table 16 it was evident that interaction of submergence and variety significantly affected the grain yield (appendix XI). Significantly the highest (8.50 t ha^{-1}) grain yield was found from the combination of D_0V_4 (no submergence with BRRI hybrid 1) and the lowest (1.20 t ha^{-1}) from D_3V_3 (fourteen days submergence with BRRI dhan34).

4.20 Percent reduction of yield

Percent reduction of yield of rice varied significantly for submergence (appendix XI). The highest percent reduction over control (31.00) was found from D_3 whereas the lowest percent reduction over control (5.23) was recorded from D_1 (six days submergence) treatment (Table 14).

Percent reduction of yield over control was evident from Table 15 that V_3 (BRRI dhan34) showed the highest (30.43 %) yield reduction. The lowest percent reduction of yield (3.86%) was found in V_1 (BRRI dhan51).

From the table 16 it was evident that the highest percent reduction of yield (65.71) was found from the combination of D_3V_3 (fourteen days submergence with BRRI dhan34) and the lowest (2.22) from D_1V_1 (six days submergence with BRRI dhan51).

The response of 6 rice genotypes under different duration of submergence levels have been presented in different tables and discussed in this thesis. Susceptible genotypes could be distinguished from submergence tolerant genotypes in respect of yield reduction. Difference among tolerant and moderate tolerant genotypes was clear even at 10 days and 14 days submergence. These results indicate 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 reduction in different submergence duration. BRRI dhan51 followed by BRRI hybrid dhan1 showed lower grain yield reduction % in submerged conditions compare to control by attaining good yield contributing characters and thus proved as tolerant varieties. On the other hand, BRRI dhan34 and ACI hybrid1 were susceptible to submergence.

Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from June to December, 2011 in T. *Aman* season to observe the effect of submergence stress at vegetative phase on the morphological attributes and yield of some 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 hybrid dhan1, BRRI hybrid dhan2, ACI hybrid1 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.

Statistically variation was influenced on plant height of rice at 10, 20, 30, 40, 50 and 60 days after transplanting and at harvest. The tallest plant (21.93, 38.57, 63.91, 74.00, 86.04, and 85.65 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 (3.49, 5.07, 15.39, 29.10, 52.33 and 52.0 at 10, 20, 30, 40, 50 and 60 DAT, respectively) was recorded from D_0 (no submergence) treatment. The minimum percent of dead leaves (5.10) and maximum percent of fresh leaves (6.49) was obtained from D_0. The minimum percent of partialy damage leaves (10) was recorded from D_0 and D_1. The maximum number of tillers hill^{-1} (4.89, 13.33, 17.04, 18.83, 22.11 and 17.33, at 30, 40, 50, 60, 70, 80 DAT, respectively), SPAD values of leaf (13.57, 40.02 and 44.93 at 30, 40 and 50 DAT, respectively), servival percent after submergence (84.56) was obtained from D_0. The D_1 treatment required the earliest of days to 50% booting (63.83 days). D_0 treatment was the earliest in 100% booting (65.22 days), days to 50% panicle emergence (65.44 days), 100% panicle emergence (67.22 days) and maturity (121.3 days). The longest panicle (23.56 cm) was found at D_0. The highest number of filled grains panicle^{-1} (102.2) and weight of 1000 grains (27.15 g) was obtained from D_0 treatment. The highest grain yield m^{-2} was found from D_0 (0.62 kg) whereas the lowest yield was recorded from D_3 (0.38 kg) treatment. The highest grain yield was found from D_0 (6.23 t/ha) whereas the lowest yield was recorded from D_3 (3.78 t/ha) treatment. The highest percent reduction of yield over control (31.00) was found from D_3 whereas the lowest percent reduction over control (5.23) 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 (Fig. 2). The height of the plant was significantly influenced by variety at all the sampling dates. The V_5 (BRRI hybrid 2) variety produced the tallest plant (21.94, 37.58, 65.72, 72.81, 83.19 and 96.50 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively). The V_1 (BRRI dhan51) variety produced the highest number of leaves (3.31, 4.42, 14.60, 30.46, 53.00 and 54.46 cm at 10, 20, 30, 40, 50 and 60 DAT, respectively). The minimum percent of dead leaves (5.83) and maximum percent of fresh leaves (84.67) was found in V_1 treatment. The V_1 variety (BRRI dhan51) was achieved the minimum percent of partialy damage leaves (9.50) and the production was observed. The highest number of tiller hill^{-1} (4.72, 13.28, 18.53, 19.81 and 22.27 at 30, 40, 50, 60, 70, 80 DAT, respectively), SPAD reading of leaf (13.88, 40.09 and 46.89 at 30, 40 and 50 DAT, respectively), servival percent after submergence (66.17) was achieved from V_1 (BRRI dhan 51). 50% booting initiation was earliest (48.5 days) in V_6 (ACI hybrid1). 100% booting initiation (51.50 days), 50% panicle initiation (54.67 days) and 100% panicle initiation (54.67 days) was earliest in V_5. Maturity was earliest (120.00 days) in V_1 and V_2 treatment. The longest panicle length (24.83 cm) was obtained in cultivar BRRI dhan51. The V_1 (BRRI dhan51) showed significantly highest number (122.5) grains panicle^{-1} and 1000-grain weight (29.37 g). The V_4 (BRRI hybrid dhan1) produced the highest (0.78 kg) grain yield m^{-2} and the lowest grain weight m^{-2} (0.23 kg) was found V_3 (BRRI dhan34). The V_4 (BRRI hybrid dhan1) produced the highest (7.83 t ha^{-1}) grain yield. V_3 (BRRI dhan34) produced the highest (30.43 t ha^{-1}) percent of yield reduction. The lowest percent of yield reduction (3.86) was found in V_1 (BRRI dhan51).

All parameter was significantly affected by the interaction effect between submergence and variety. The tallest plant (23.33, 40.56, 71.33, 81.78, 97.67 and 104.90 at 10, 20, 30, 40, 50 and 60 DAT, respectively) was found from D_3V_5 (Fourteen days submergence with BRRI hybrid dhan2). The maximum number of leaves per plant (3.83, 5.67, 19.08, 35.50, 59.58 and 64.25 at 10, 20, 30, 40, 50 and 60 DAT, respectively) was found from D_0V_1 (no submergence with BRRI dhan51). The lowest percent of plant with dead leaves (2.00) and highest percent of plant with fresh leaves (92.67) was found from D_0V_1. The lowest percent of partialy damage leaves (5.33) was found from D_0V_1. The highest total number of tillers hill^{-1} (5.89, 14.11, 19.45, 22.00, 26.25 and 32.00, at 30, 40, 50, 60, 70, 80 DAT, respectively), SPAD values of leaf (19.25, 46.87 and 50.5 at 30, 40 and 50 DAT, respectively), servival percent after submergence (92.67) was found from D_0V_1. The days to 50% booting was minimum (45.33 days) in D_3V_6 (fourteen days submergence and ACI hybrid1). The days to100% booting

(49.33 days), days of 50% panicle emergence (52.33 days), days of 100% panicle emergence (54.33 days) was minimum in D_0V_5. The days to maturity was minimum (120.00 days) in D_0V_1. The highest panicle length (26.33 cm) was recorded in combination of no submergance with BRRI hybrid dhan2. The highest (135.90) number of grains panicle^{-1} and (19.43 g) thousand seed weight was found from the combination of D_0V_1. Significantly the highest (0.85 kg) grain yield m^{-2} was found from the combination of D_0V_4 (no submergence with BRRI hybrid dhan1) and the lowest (0.12 kg) from D_3V_3 (Fourteen days submergence with BRRI dhan 34). Significantly the highest (8.50 tha^{-1}) grain yield was found from the combination of D_0V_4 (no submergence with BRRI hybrid dhan1) and the lowest (1.20 tha^{-1}) from D_3V_3 (fourteen days submergence with BRRI dhan34). The highest percent reduction of yield (65.71) was found from the combination of D_3V_3 (fourteen days submergence with BRRI dhan34) and the lowest (2.22) from D_1V_1 (six days submergence with BRRI dhan51).

Conclusions:

Based on the results of the present study, the conclusion has been drawn as:

- BRRI dhan51 showed the highest submergence tolerance level among the tested varieties followed by BRRI hybrid dhan1.
- From the calculated grain yield reduction (%) , it was observed that the highest reduction of yield was shown by BRRI dhan34 followed by ACI hybrid1 at 14 days submergence compare to control.
- **Recommendation:**

However, to reach a specific conclusion and to provide reasonable recommendation, more research works on inbreeds and hybrid rice regarding the influence of submergence levels in *Aus* and *Boro* season are needed.

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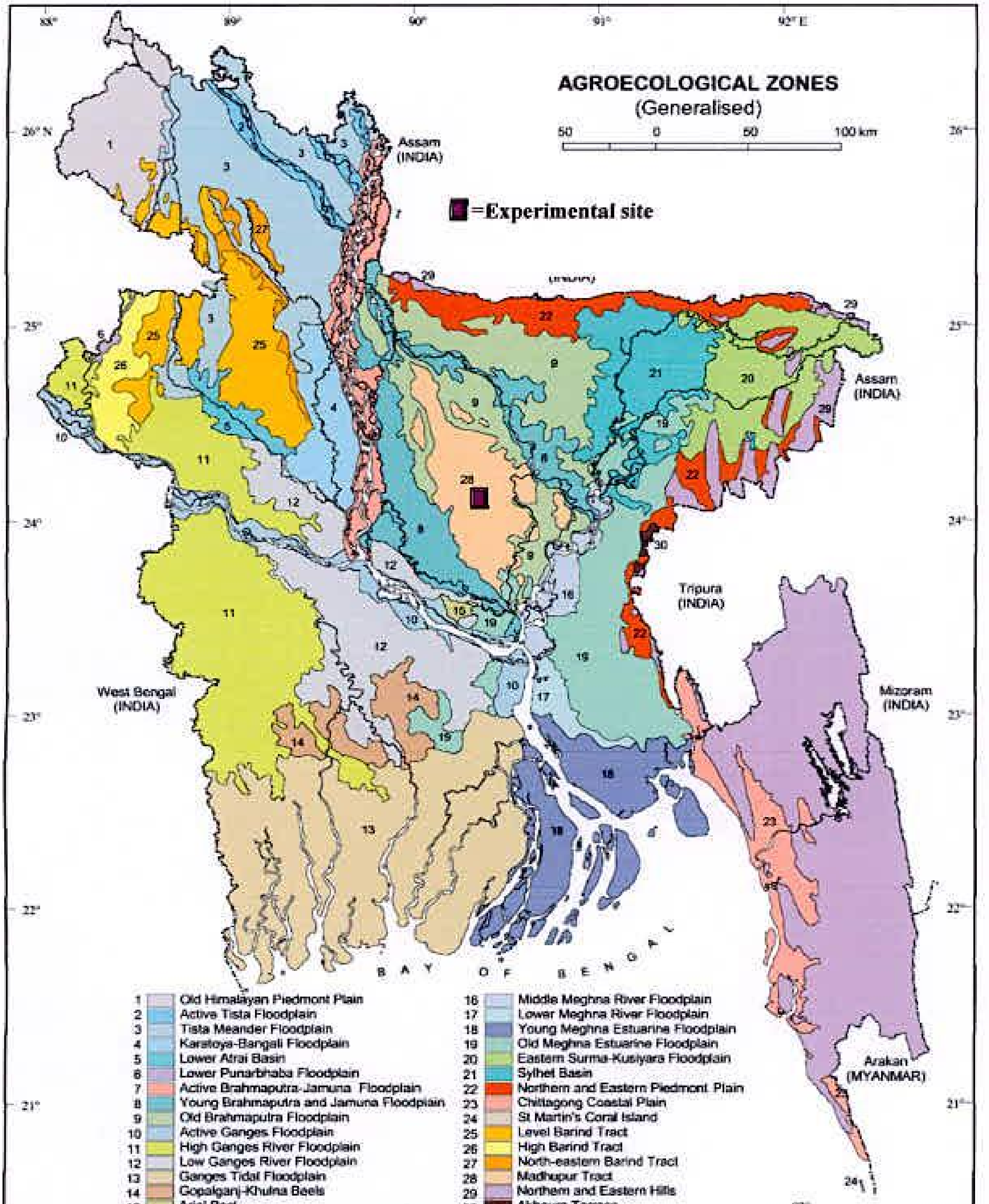
Appendices

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 2011

Month	Air temperature (^0C)			RH (%)	Total rainfall (mm)
	Maximum	Minimum	Mean		
July 2011	33.00	27.40	30.20	77.00	167
August, 2011	33.10	27.00	30.05	78.00	340
September, 2011	32.50	26.60	29.55	79.00	169
October, 2011	32.40	25.00	28.70	74.00	174
November, 2011	30.00	20.90	25.45	68.00	0
December, 2011	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 submergence (%)	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
Varieties	3.32 μg/g soil
Potassium	0.30 μg/g soil

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

Appendix IV: Analysis of variance of the data on plant height of rice as influenced by different levels of submergence and varieties.

Sources of Variation	Degrees of freedom	Mean Square					
		Plant height					
		10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	19.81	4.30	93.92	37.56	41.63	27.37
Factor A (duration of submergence)	3	20.81*	48.32*	208.04*	482.58*	440.37*	488.00*
Factor B (Variety)	5	7.81*	74.96*	684.35*	677.93*	545.08*	1117.58*
A×B	15	6.96*	15.60*	26.33*	27.77*	42.86*	93.91*
Error	46	8.84	9.04	26.88	26.85	48.32	68.59

*significant at 5% level of probability,

Appendix V: Analysis of variance of the data on number of leaves per plant of rice as influenced by duration of submergence and varieties.

Sources of Variation	Degrees of freedom	Mean Square					
		No. of Leaves per plant					
		10 DAS	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS
Replication	2	0.049	2.85	19.83	11.883	0.933	13.44
Factor A (duration of submergence)	3	0.605*	11.578*	69.79*	50.27*	126.317*	51.75*
Factor B (Variety)	5	0.041*	1.062*	10.18*	107.66*	86.87*	208.37*
A×B	15	0.065*	1.714*	11.07*	38.27*	40.15*	108.10*
Error	46	0.136	1.166	16.442	25.409	37.467	98.233

*significant at 5% level of probability,

Appendix VI: Analysis of variance of the data on plant with percent dead leaf and fresh leaf and partially damaged leaves of rice as influenced by duration of submergence and varieties.

Sources of Variation	Degrees of freedom	*Mean Square*		
		Plant with (%) dead leaf	Plant with (%) fresh leaf	Partially (%) damaged leaves
Replication	2	104.22	1418.17	951.72
Factor A (duration of submergence)	3	175.04*	2101.39*	1139.11*
Factor B (Variety)	5	31.16	554.23*	420.76*
A×B	15	31.22*	125.34*	86.09
Error	46	35.70*	103.91*	58.51*

*significant at 5% level of probability,

Appendix VII: Analysis of variance of the data on number of tiller of rice as influenced by duration of submergence and varieties.

Sources of Variation	Degrees of freedom	Mean Square					
		Number of tiller					
		30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS
Replication	2	0.68	4.19	0.89	4.66	17.56	29.05
Factor A (duration of submergence)	3	8.71*	14.32*	5.01*	8.68*	15.90*	17.33*
Factor B (Variety)	5	2.94*	24.60*	21.30*	33.64*	192.95*	130.69*
A×B	15	0.77*	5.20*	2.25*	6.67*	45.77*	29.50*
Error	46	0.92	3.76	3.47	6.12	21.85	10.67

*significant at 5% level of probability,

Appendix VIII: Analysis of variance of the data on SPAD reading of flage leaf of rice as influenced by duration of submergence and varieties.

Sources of Variation	Degrees of freedom	Mean Square		
		SPAD reading of flage leaf		
		30 DAS	40 DAS	50 DAS
Replication	2	16.47	32.79	3.47
Factor A (duration of submergence)	3	28.83*	356.23*	2.25*
Factor B (Variety)	5	36.10*	226.56*	52.20*
A×B	15	15.01*	47.44*	27.56*
Error	46	30.06	68.32	29.53

*significant at 5% level of probability,

Appendix IX: Analysis of variance of the data on survival percentage after submergence, days to 50% and 100% booting initiation, days to 50% and 100% panicle initiation and days to maturity of rice as influenced by duration of submergence and varieties.

Sources of Variation	**Degrees of freedom**	**Mean Square**					
		survival percent after submergence	Day to 50% booting initiation	Days to 100% booting initiation	Days to 50% panicle initiation	Days to 100% panicle initiation	Days to maturity
Replication	2	1370.06	26.38	17.10	3.56	8.01	1.79
Factor A (duration of submergence)	3	12074.22*	29.83*	32.79*	137.20*	134.24*	0.06*
Factor B (Variety)	5	201.96*	1365.33*	1809.55*	1814.96*	1718.15*	0.83*
A×B	15	326.13*	39.74*	13.81*	7.22*	7.15*	0.43*
Error	46	107.10	40.00	12.49	2.89	3.10	1.65

*significant at 5% level of probability,

Appendix X: Analysis of variance of the data on yield contributing character of rice as influenced by duration of submergence and varieties.

Sources of Variation	Degrees of freedom	Mean Square		
		Panicle length	**No. of grain/panicle**	**No. of sterile grains/panicle**
Replication	2	19.042	1039.95	35.98
Factor A (duration of submergence)	3	0.63^{NS}	2668.76*	105.24*
Factor B (Variety)	5	8.833*	5869.76*	424.92*
A×B	15	4.53*	1115.30	47.75
Error	46	10.65*	356.90*	25.61*

*significant at 5% level of probability,
NS- Non significant

Appendix XI: Analysis of variance of the data on yield of rice as influenced by duration of submergence and varieties.

Sources of Variation	**Degrees of freedom**	**Mean Square**			
		1000 grain wt	**Yield/m²**	**Yield t/ha**	**Percent reduction of yield**
Replication	2	1.45	1.402	140.167	17.854
Factor A (duration of submergence)	3	2.74*	0.22*	22.022*	3528.336*
Factor B (Variety)	5	149.68*	0.572*	57.239*	1556.605*
A×B	15	7.32*	0.023*	2.26*	467.651*
Error	46	4.30	0.015	1.536	0.259

*significant at 5% level of probability,