INFLUENCE OF SALINE WATER ON GROWTH AND YIELD OF RICE

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CERTIFICATE

This is to certify that the thesis entitled **“INFLUENCE OF SALINE WATER ON GROWTH AND YIELD OF RICE”** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **Master of Science (MS)** in **Agronomy**, embodies the results of a piece of *bona fide* research work carried out by **MD. REDWANUL ISLAM**, Reg. No. **12-05120** under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.

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

Dated: June, 2018
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DEDICATED

TO

MY BELOVED

PARENTS

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ABSTRACT

A pot experiment was conducted with two rice varieties viz. BRRI dhan28 and BRRI dhan47 in the experimental shed of Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka during boro season (2017-2018) to determine the effect of different level of salinity on rice and finding out the comparative performance of two varieties under salinity. Mixture of fresh water and marine water was used as salinity treatments. Four salinity treatments were used in this experiment viz. control S_0 (only fresh water), Quarter strength marine water S_1 (Three part fresh water and one part marine water), Half strength marine water S_2 (half fresh water and half marine water), Full strength marine water S_3 (only marine water). These mixtures were used for irrigation purpose throughout the life cycle. Salt stress significantly reduced plant height, number of tillers hill^{-1}, leaf relative water content, number of effective tillers hill^{-1}, panicle length, number of filled grains panicle^{-1}, 1000 grain weight, grain yield , straw yield and biological yield but increased the number of non-effective tiller hill^{-1} and unfilled grain panicle^{-1}. Leaf relative water content (RWC) also decreased due to salinity. With rise in salinity level adverse effect of salinity was more clearly visible. Different growth stages showed different sensitivity to salinity. In fact, the primitive growth stages, that is, tillering and panicle initiation showed more sensitivity to salinity than final growth stages (panicle emergence and ripening). Therefore, irrigation with saline water at the early growth stages has more negative effect on yield and its components. Between the two varieties used in this experiment BRRI dhan47 performed better than BRRI dhan28 under salinity stress condition.

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LIST OF ABBREVIATIONS

AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BRRI	Bangladesh Rice Research Institute
cm	Centi-meter
CV%	Percent coefficient of variance
DAT	Days After Transplanting
et al.	And others
Etc.	Etcetera
FAO	Food and Agricultural Organization
G	Gram
HI	Harvest Index
LSD	Least Significant Difference
SRDI	Soil Research and Development Institute
CRD	Completely Randomized Design
^{0}C	Degree Centigrade

Chapter 1

INTRODUCTION

Salinization of Soil is one of the serious environmental factors that limit crops productivity worldwide. Because of this adverse factor, most of the agricultural crops are now considered salt-sensitive due to the high concentration of salts in the soil (Munns and Tester, 2008). Salinity is a serious problem and it affects about 800 million ha of arable lands worldwide. Approximately 33% of irrigated areas (about 74.25 million ha) are currently considered threatened by soil salinization at various degrees. It has been projected that by the year 2050 there will be more than 50% of the farm land worldwide which would become salt-affected.

Rice has shown to be the most sensitive cereal crop (Munns and Tester, 2008). Salinity hampers various physiological and metabolic processes in rice plants depending on its duration and severity. The adverse effect of salinity reflects through the yield characters and productivity. Early vegetative and later reproductive stage are the most susceptible stages of rice life cycle but it is more resistant in reproductive and grain filling stage (Grover *et al.*, 2006). Initially salinity creates osmotic stress then ionic toxicity (Hasanuzzaman *et al.*, 2013). Salinity can be termed as hyper ionic stress. One of the most harmful effects of salinity is the accumulation of Na^+ and Cl^- ions in plants exposed to soil having a higher concentration of NaCl. Entry of these ions cause ionic imbalance in plant cells. High Na^+ ions decreases K^+ uptake which hampers plant growth and development and in serious cases death may occur. But plant can tolerate this stress by changing their cellular metabolism and adopting different defense mechanism (Ghosh *et al.*, 2011). In salinity stress condition survival of a plant depends on its ability to initiate different physiological and biochemical changes (Tanou *et al*., 2009).

The coastal belt in Bangladesh is one of the nearest areas to the Bay of Bengal. This bay is one of the greatest sources of saline water. The adverse impact of this saltwater intrusion is higher in this coastal belt than in any other part of Bangladesh. As a consequence of tropical cyclones, salinity intrusion has been gradually extended toward the inland water and soil (Mahmuduzzaman *et al.*, 2014). This remarkable salinity intrusion into the cropping areas has tremendously reduced the crop production across the coastal belt in Bangladesh which might have led to the shortage of food availability in Bangladesh.

Although agriculture is one of the significant sectors of the economy of Bangladesh and rice is the staple food of this country, rice production level still remains low in the south-west region of this country due to high salinity extent in crop land (Miah *et al*., 2004). The coastal areas are potentially suited for rice production but were left idle due to salinity problem. Rice is widely cultivated in coastal region but is considered extremely salt sensitive (Kana *et al*., 2011). Salinity intrusion is a major barrier to crop cultivation and because of the rising trend of salinity in the south-west region of Bangladesh, the farmers are losing willingness to cultivate various agricultural crops. Soil salinity is not only reducing agricultural productivity but also putting long run impact on the livelihood strategies of the small farmers.

Considering above mentioned points in view, the present study was undertaken with these following objectives:

1) To understand the effect of different kinds of marine water on rice.
2) To understand the performance of a salinity tolerant rice variety under different level of salinity.
3) To understand the comparative performance of sensitive and tolerant variety under different level of salinity.

Chapter 2

REVIEW OF LITERATURE

2.1 Rice

Rice (*Oryza sativa L.*) is centre of lives of about half of world's population and it is possibly the oldest domesticated grain. It is the staple food and mainstay for rural population and food security. Also growing rice is the largest single use of land for producing food, covering 9% of the earth's arable land. Rice provides 21% of global human per capita energy and 15% of per capital protein (IRRI, 2002). It has two cultivated and 22 wild species among these two cultivated species *Oryza sativa* is grown all over the world but *Oryza glaberrima* has been cultivated in west of Africa (IRRI, 2001). *O. sativa* has two sub species *Indica* and *Japonica*. In Bangladesh *Indica* sub-species is mainly cultivated which prefers tropical warm climate. Rice is the principle energy source for 17 countries in Asia and the pacific, 9 countries in North and South America and 8 countries in Africa (FAO, 2014). Bangladesh stands fourth in rice production with an annual production of 35.3 million tons (milled basis) in 2018 (FAO, 2018). Developing countries produce almost 95% of total rice. It is the most common crop in coastal areas that goes under sea water during high tidal period, although it is susceptible to salinity (Akbar and Yabuno, 1972; Korbe and Abdel-Aal, 1974; Mori and Kinoshita, 1987). Rice is a major crop but also an extremely saline sensitive crop (Mass and Hoffman, 1977). In Bangladesh rice production is increasing gradually but population also increasing faster than food production. To attain food security increase in rice production must be more rapid.

2.2 Abiotic Stress

Besides fighting with many challenges like poverty, hunger, climate change and using limited natural resources more effectively people have to produce 70% more food for additional 9.7 billion people by 2050 (Wilmoth, 2015). Food production is not parallel with rising in food demand. Abiotic stress hinders the production in many areas. Decrease in production due to environmental stress and finding ways of handling these stresses is the main concern of today's world (Shankar and Venkateswarlu, 2011). Due to global climate change and unpredictable environmental conditions natural hazards are more common which is worsening the production condition (Mittler, 2002). Plants are facing more abiotic stresses as higher amount of toxic and antagonistic materials are released from industrial areas which pollutes both soil and irrigation channel. Also sudden drought and flood can impose stress on plant. Abiotic stress hampers plant metabolism that negatively affect plant growth and development. If stresses continues rising and stays for a longer period of time it may result in plant death (Hasanuzzaman *et al.*, 2012).

Damage in plants depends on kinds of stress and its duration. Not even a single environmental condition is totally free from plant stress. Stress may be more or less depending on environment. Every plant has to face some extent of stress. This stress can be of any type such as sudden change in air temperature can be stressful at any moment but after a few moment it can come under favorable condition also sudden heavy wind flow can be a stress for plant and it may take few hours to come in favor of plant but stress like nutrient deficiency, water content may take longer time to become stressful and also take much longer time to become favorable to plant (Taiz and Zaiger, 2006).

Abiotic stress not only damages plant metabolism but also limits the area of distribution of a certain species (Araus *et al.,* 2002). Global climate is changing and change in any climatic condition is interconnected with other. Global temperature may rise up to 3-9^{0}C by the end of this 21st century (Wang *et al.,* 2003). Rise in temperature may increase the probability of severe drought and drought condition creates nutrient deficiency as most of the nutrient become available to plant when they are dissolved in water. So heat stress creates drought stress. Abiotic stress negatively changes relation among soil plant and atmosphere which is responsible for reduction in plant growth development and yield (Ahmad, 2012). Heavy metals, drought, salinity are the major abiotic stresses that hampers plant growth and development. These stresses may create toxic chemical components such as Reactive oxygen species (ROS) that contain hydrogen per oxide (H_2O_2), superoxide (O^{2-}), hydroxyl (OH^-) and many more (Dasgupta *et al.*, 2014). Abiotic stress is a major factor in maintaining food security and world economy. Mostly under abiotic stress plant faces increase amount of ROS accumulation in plant which is a threat to plant both in cellular and organ level (Keunen *et al.*, 2013). To overcome these challenges identification of stress tolerant species and biotechnological development needs to be done.

Many researchers have worked on finding out the amount or percentage of crop loss due to abiotic stress. Major abiotic stresses have negative effect on crop productivity as well as shown negative effect on crop biomass production and yield which reduce yield up to 70% compared to normal plant condition (Thakur *et al.*, 2010). Loss due to abiotic stress will increase in future and spread over a larger area due to severe change in global climate which will negatively affect plant life (Evans, 2015). Among all the abiotic stress drought and salinity are the most serious that hampers plant growth, development and productivity. Collins *et al.*, (2008) stated that tolerance to abiotic stress is the most important point for breeding purpose and also a great challenge that needs to be overcome to ensure food security for the vast population. But it is very complex to find out the response of plant under stress condition. Severe yield loss has been observed due to effect of abiotic stresses like salinity, drought and cold.

2.3 Salinity

Salinity is one of the major abiotic stresses in arid and semi-arid regions but salt-affected soils have been recorded in practically all the climatic regions and more than 800 million hectares of land or over 6% of the world surfaces are salt affected. Sodium chloride is the most soluble, pervasive, and superabundant salt in the world (FAO, 2008; Munns and Tester, 2008). Rapid population growth and subsequent food shortage especially in Asia and Africa and advancing salinity in arable land due to climate change have increased the importance of finding salt tolerant genotypes (Blumwald *et al.,* 2004). In the arid and semiarid regions, high rate of evapotranspiration and lack of inorganic salts leaching from the soil surface layers have given rise to increase salinity and sodicity (Shannon *et al.*, 1994). The greatest cause of salinity may be due to the use of poor quality irrigation water (Sifola and Postiglione, 2002). There is a serious competition for fresh water as high quality water is mainly used for industrial or domestic purposes and saline or polluted water is allocated for cultivated lands (Bouwer, 2002). Saline soils can be classified by the electrical conductivity (EC) of the soil saturation extract and soils with EC of 4 ds/m or more are accounted as saline soils and soils with EC exceeding 15 ds/m are considered strongly saline soils (Omami, 2005).

The factors causing salinization are numerous, including salt composition, climate, topography of lands and human activities (Blumwald *et al*., 2004). In terms of salt composition, various cations and anions are involved in salinization but the most important ion precipitate are Na^+ and Cl^- where Na^+ particularly causes the soil dispersion while Cl^- causes high toxicity and nutrient imbalances in plants (Hasegawa *et al.,* 2000). Excess salt in the soil influences plant activities including physiological, biochemical and molecular processes and crop production is suppressed by salinity in terms of quality and quantity (Delamor *et al.*, 2001; Mer *et al.*, 2000; Silvera *et al.*, 2001).

Intensity of salinity depends on the amount of salt in irrigation water, texture and structure of soils, type of plants, plant growth stages and irrigation schedules (Oster, 1994; Shannon *et al.*, 1994; Vicente *et al.*, 2004). One strategy to overcome the problem of salinity is selecting salt tolerant genotypes. At low intensity of salinity the damages are due to osmotic stress, nutritional imbalances and ion toxicity (Carvajal *et al.*, 1999; Grattan and Grieve, 1998; Wahome *et al.*, 2001). At low salt concentration, shoot dehydration is the primary response of plants to osmotic stress (Carvajal *et al.*, 1999) and at moderate up to high salt concentration, nutritional imbalances due to interferences of saline ions and their toxicity caused by accumulating the ions especially Na^+ and Cl^- are the main effects of salinity on physiological and biochemical activities in plants (De-Pascale *et al.*, 2003a; De-Pascale *et al.*, 2003b). More efforts are required for proper understanding of the effects of salinity on plants, responses of plants in terms of physiological, biochemical and molecular activities to salinity and recognition of complex mechanisms of salt tolerance in plants (Apse and Blumwald, 2002; Zhu, 2001).

2.4 Effect of salinity on plant

2.4.1. Germination Stage

Salinity severely affects plants especially at germination stage (Sosa *et al.*, 2005). Seed germination is very important stage for the successful establishment of healthy seedlings which are very sensitive to salinity as compared to other vegetative stages. Salinity accumulates the toxic ion in plants causing a mineral imbalance. The essential ions are reduced and do not meet the demand resulting in hindrance in normal physiological activities of plant. High salt stress retards seed germination process while low salt stress causes seed dormancy (Khan and Weber, 2008). To cope with such nutritional limitation, seeds develop a mechanism of maintaining low water potential (Allen, 1994) or other specific tolerance mechanism to prevent the damage due to salt stress (Rumbaugh *et al.*, 1993). Salinity disturbs germination in a number of ways. From reducing the osmotic potential of soil which declines in water imbibitions by seed (Khan and Weber, 2008) to the creation of ionic toxicity which alters enzymes action involved in nucleic acid metabolism. Other impacts of salt stress on seed germination include change in metabolism of protein (Rasheed, 2009). Seeds are more susceptible to salt stress due to close association to surface of the soil (Dodd and Donovan, 1999). With sodium chloride accumulation to a toxic level in soil, ionic stress decreases the rate of germination (Murillo-Amador *et al.*, 2002). Water absorption by the seed is reduced because of lower water potential caused by salt stress thus posing toxic effects to the developing embryo, resulting in delay in germination process (Khan and Ungar, 1984). The average time of seed germination is dependent on salinity stress, strength and genotypes. With increasing trend of salinity stress there is always decreasing rate of germination (Ditommaso, 2004). According to Farooq *et al.* (2006) toxicity of salts on rice seedlings are reduced if seedlings are treated with ethanol treatment. Salinity has negative effect on the vigor index by raising salt concentration in the growing medium (Djanaguiraman *et al.*, 2003). Heenan *et al.* (1988) and Lutts *et al.* (1995) reported that rice is extremely sensitive to salinity during germination, young seedling and early developmental stages for most commonly used rice varieties. However, in contrast, Khan *et al*. (1997) observed that rice is relatively salt tolerant at germination and in some cases is not affected significantly up to 16.3 dsm^{-1} of salinity. Seed germination, seedling emergence, and their survival are particularly sensitive to salinity (Mariko *et al.*, 1992; Baldwin *et al.*, 1996). High levels of soil salinity can significantly inhibit seed germination and seedling growth, due to the combined effects of high osmotic potential and specific ion toxicity (Grieve and Suarez, 1997).

2.4.2. Growth stage

Once the seed has germinated, next goal for plant growth is crop establishment. Salinity causes reduction in crop establishment by reducing shoot growth, blocking leaf development and expansion, reducing growth of internodes and promoting abscission of leaf (Ziska *et al.*, 1990; Zekri, 1991). Salinity accelerates a number of factors in plants like osmotic stress, ion toxicity and nutrient imbalance; these are identified as most prominent causes of reduction in crop growth which finally lead to crop failure. However, different stages like germination, vegetative growth, flowering, seed establishment and grain filling of crops behave differently with salinity. The main harmful effects of salinity are reduced germination and emergence, stand and establishment of seedlings (Wahid *et al.*, 1999), and enhanced chlorosis and senescence of leaves (Lutts *et al.*, 1996; Wahid *et al.*, 1997; Curtis and Lauchli, 1987). To cope with osmotic stress, plants reduce the leaf area and increase the rooting density (Guo *et al.*, 2002; Han and Wang, 2005; Qureshi *et al.* (2000); Sanadgol, 2002). Ashraf and Bhatti, (2000) stated that in rice, salinity decreased biomass and leaf area. Increased amounts of salt in the soil pose a serious threat to different processes of plants which results in reduction of crop productivity. Epstein, (1980) reported reduction in the uptake of essential ions in the plants due to salinity causes alteration in metabolic rates and leading to reduction in growth rate. Excessive salt concentration in root zone of plant causes change in plant water relations. To deal with the increased amounts of salinity, the osmotic potential decreases (Rodriguez *et al.*, 1997; Gama *et al.*, 2007; Kaymakanova and Stoeva, 2008). Salinity causes reduction in turgidity in plant cells due to reduction in water uptake by the plant. Low water uptake reduces cell division and regulation of stomata aperture which ultimately lead to low photosynthesis and finally death of plant tissues (Marschner, 1995; Munns *et al.*, 2002). Reduction in turgor pressure results in stomata closure which causes reduction in gaseous exchange through transpiration (Munns, 1993; Munns and Tester, 2008). Other physiological activities under the influence of salinity include changes in membrane permeability leading to destabilization of membrane proteins (Gupta *et al.*, 2002; Grattan and Grieve, 1992) and reduction in the process of photosynthesis (Sayed, 2003; Kao *et al.*, 2003; Ashraf and Shahbaz, 2003). Lowering of photosynthesis rate happens due to reduction in enzymes and pigments carrying out photosynthesis (Ashraf and Harris, 2013; Misra, 1997; Saravanavel *et al.*, 2011). It was found that the additional increase of leaf Na^+ and Cl^- also causes the production of ROS followed by reduced photosynthetic capacity leading to low plant growth (Nazar *et al.*, 2011). Many processes which are related with plant physiology and biochemistry are affected by salinity like photosynthesis (Hayat *et al.*, 2010), water conductance through stomata (Perez-Perez *et al.*, 2009), various biomolecules and plant-water relations. All these adversely affected biological processes ultimately reduces crop yield. Plants adopt various strategies in response of salinity that allow them to deal with the problem. Plants with growth in high salt concentration, have more thickness of leaves (Waisel, 1991), epidermis, cell walls and cuticles. The high salt concentration, increases mesophyll cell layers and cell size (Zekri and Parsons, 1990), due to more extension in cell wall at high turgor pressure (Munns and Termaat, 1986). Plants grown in salt stress conditions have large in number but narrow xylem vessels as compared to plant grown in salt free media (Walker *et al.*, 1985). Salinity increases the density of stomata of lower side of leaves and leaf thickness (Raafat *et al.*, 1991) with palisade tissues (Hussein *et al.*, 2012); however, it reduces number of cells per leaf. Salinity reduces the number of stomata on the surface of epidermis (Cavisoglu *et al.*, 2007), the total leaf area, (Awang *et al.*, 1993), leaf plastochron index (Bray and Reid, 2002). Vascular bundle length, xylem rows, number of vessels have also been reported to decline due to salinity (Hussein *et al.*, 2012). Salinity lowered the xylem development and width of vascular bundle in mungbean (Beida and Ho, 1993; Rashid *et al.*, 2004). In rice, stem diameter was reported to be reduced (Pimmongkol *et al.*, 2002), while trichome and stomata density increased. Salt stress reduced cell size, epidermal thickness of leaves, apical meristem, diameter of cortex and central cylinder (Reinhardt and Rost, 1995; Javed *et al.*, 2001). Salinity caused thickening of endodermis as well as exodermises (Gomes *et al.*, 2011; Degenhardt and Gimmler, 2000) and increased development of sclerenchymatous tissues (Javed *et al.*, 2001).

2.4.3. Yield

Salinity causes about 50% downfall in crop growth, productivity and yield throughout the globe. Reddy and Vora, (1986) proposed that salt stress decreases the yield components as a result of change in the normal plant metabolism. Nahar and Hasanuzzaman, (2009) came with a result that that salt stress decreased different components of yield in *V. radiate* and rice (Gain *et al.*, 2004). Kafi and Goldam, (2000) determined the response of plants against salinity stress. They concluded that salinity poses a serious problem in vegetative and reproductive stage in the plants. Sometimes severe salt stress may even threaten survival (Joseph *et al.*, 2010). Yield is a very complex character which comprise of many components and these yield components are related to final grain yield which are also severely affected by salinity (Shereen *et al.*, 2005). Differences in yield response of rice to soil salinity can be related to climatic variations. In particular, a low relative humidity of the air during the growing season can enhance the yield losses per unit increase of salt concentration because the potential yield is higher in the dry season, as a consequence of longer and more intense solar radiation in the dry season than in the wet season (Asch *et al.*, 2000; Eynard *et al.*, 2005). Zeng and Shannon (2000) studied the effect of salinity on seedling growth and yield components of rice and stated that harvest indices were significantly reduced by salinity at 3.4 dsm^{-1} or higher. It has been well documented that the effect of salinity on seedling growth, seedling establishment, grain yield components such as tiller number has successively lead to a reduction in grain yield (Khatun *et al.*, 1995). Salinity also resulted in a decrease of the 1000 grain weight and increased sterility, regardless of the season and development stage (Khatun *et al.*, 1995).

2.4.4. Biochemical Response

The effect of salinity on crop plants may be categorized as a two-fold process: an initial osmotic effect followed by ionic stress when salt accumulation reaches its toxic level (Munns and Tester, 2008). The initial osmotic effect in plants refers to the lowered water potential to the increased concentration of salt with an enhanced osmotic potential. One of the important plant defenses is the osmotic adjustment in plants accomplished via accumulations of high concentrations of inorganic ions or low molecular weight organic solutes. These compatible osmolytes found in higher plants are actually certain low molecular weight sugars, organic acids. They also include nitrogen containing compounds such as amino acids, amides, imino acids, proteins and quaternary ammonium compounds. Studies indicated that proline, which occurs widely in higher plants, assimilates in larger amounts in salt stressed plants (Lutts *et al.*, 1996). Proline accumulation in rice has also been reported by Bandurska, (1996) suggesting its active roles in osmotic adjustment, shielding the enzymes and membranes, also providing energy and nitrogen for utilization during exposure to salinity. Soluble sugars and starch has been observed to serve as an osmoticum in a number of plants as a response to salinity (Amirjani, 2011). An increase in sugar content in shoots has been reported by (Hurry *et al*., 1995) and also an increased starch content in roots been showed in the roots of rice which contributes to the osmotic adjustment to the crop exposed to salinity by maximizing sufficient storage reserves to prop up the primary metabolism. The toxic effects of salinity are masked by accumulation of glycine betaine in rice as being reported by (Pareek *et al*., 1997). These compounds are reported to have active role in osmotic adjustment, fortification of the cellular macromolecules, nitrogen storage. They are important to balance the cellular pH, detoxify the cells and scavenge the ROS species. The other way to respond against salinity is alteration or accumulation of protein level. Proteins accumulating in plants under saline conditions act as a storage form of nitrogen which is re-utilized in absence of stress (Jha, 1997). Protein synthesis is also destined to play an active role in osmotic adjustment. A significant increase in soluble protein content and positive correlation has been ensured in tolerant rice seedlings compared to the sensitive ones.

2.5 Mechanism of salt stress on plant

2.5.1 Osmotic effect

Plants are stressed under high salt concentrations either by increased osmotic potential or by toxic effects of high ionic concentrations (Brady and Weil, 2002). In osmotic or H_2O deficit environments, soluble salts reduce the water potential and make water not freely available to plants for uptake which is the major reason for stunted growth under salinity. It is very difficult to distinguish between either water deficiency is due to salinity or drought (Nawaz *et al.*, 2010). The water potential of soil controls new leaf formation. Rapidly growing cells have the capacity to store higher levels of salts in their expanding vacuoles, so the growth of the new leaves is not restricted due to gathering of salts in the cytoplasm (Munns, 2005a). Root and shoot growth is more disturbed because of water stress than salt specific effect during the early days of stress (Munns, 2002). At moderate osmotic stress, root growth is not much affected whereas the reduction of shoot growth is maximum (Hsiao and Xu, 2000). Damage due to osmotic effect is governed by plant species, time period of stress, types of cells and tissues and the method of stress application (Munns *et al.*, 2000).

2.5.2. Specific ion effect

Ion specific toxicity, generally, is because of certain ions like sodium, chloride and sulphate which are taken up in larger quantities than routine. It affects the crop right from emergence to physiological maturity. Crops fail especially when specific ions affect at lateral growth stages. Regarding tolerance against salt stress different crops have different levels of responses. Most of the higher plants especially agricultural crops are highly susceptible to this stress (Abrol *et al.*, 1988). Under saline or sodic environments, high concentrations of sodium and chloride ions coupled with low concentration of potassium ions was observed in leaves of wheat varieties (Maas *et al.*, 1986). Mostly the salts are accumulated in the older leaves of plants. With higher concentration of salt accumulation there may be death of leaves; this happens when the salt concentration is too high, hence cannot be retained inside the vacuoles. In such cases the excessive salts go to the cytoplasm where they affect the normal mechanisms of enzyme action. On the other hand, excessive salts cause cell dehydration by being accumulated in the cell walls (Munns, 2005). In defense against this effect, plants either try to restrict the salt entry in their bodies or reduce the amount of salts in their cytoplasm. Concentration of sodium in the cytoplasm of the root cells is from 10-30 mM (Tester and Davenport, 2003). Due to high concentrations of sodium and chloride ions inside leaf sap, root and shoot fresh weight reduces up to 50% (Parveen and Qureshi, 1992).

2.5.3. Nutritional imbalance

Ions discrepancy is caused by higher accumulation of sodium and chloride and consequently less absorption of the other minerals such as calcium, manganese and potassium (Karimi *et al.*, 2005). Elevated Na^+: K^+ ratio causes enzyme inactivation and affects normal metabolic functions of the plants (Booth and Beardall, 1991). Building up of salt deposition disturbs water relations of the plants; this results in limited uptake and utilization of important nutrients. As a result, metabolic activities of the cell and functioning of the enzymes is disturbed (Lacerda *et al.*, 2003). Nutrients and salt interaction cause deficiencies and imbalances of the major nutrients (McCue and Hanson, 1990). More uptake of Na^+ causes reduction in the uptake of potassium and symptoms like potassium deficiency are observed (Gopal and Dube, 2003). The regulation of calcium within the plant under saline condition is a crucial parameter of plant salt tolerance (Soussi *et al.*, 2001). Potassium is main component for protein formation, osmoregulation, photosynthesis and maintenance of cell turgor pressure (Ashraf, 2004). Decrease in potassium ion uptake in due to salinity stress was observed (Marcar *et al.*, 1991). K^+ along with Ca^{2+} are necessary for maintaining the integrity and proper working of the cell membranes (Wenxue *et al.*, 2003). Sufficient amount of K+ in plant cell under salinity depends on the uptake on selection basis of the potassium ions and discriminatory compartmentalization of K^+ and Na^+ ions in the shoots (Munns *et al.*, 2000).

2.5.4. Oxidative stress

A major effect of salinity is elevation in production of ROS (reactive oxygen species) e.g. H_2O_2, O^{2-}, and OH^- (Mittler, 2002; Munns, 2002). Proteins, lipids and nucleic acids are damaged oxidatively by ROS and hence negatively affect the normal cellular metabolism (Imlay, 2003). Reduction of oxygen causes formation of these ROS that disturb plant metabolic routes (Asada, 1999). ROS production occurs at minute level during the normal body and cell growth (Polle, 2001) but increased production occurs during stressed conditions (Laloi *et al.*, 2004). Osmotic effect inhibits the stomata opening and decreases the CO_2 supply for photosynthesis which stimulates the deposition of super oxides in chloroplast. This deposition of super oxides promotes the photoinhibation and photo oxidation in plant cells (Ashraf, 2009). Plants have unique appliances to salvage these ROS such as stimulation of the enzymes of antioxidative pathway (Smirnoff, 2005).

2.6. Differences between tolerant and sensitive varieties

There are differences between tolerant and sensitive varieties in terms of compartmentalization of salt. The sensitive varieties cannot compartmentalize salt in vacuoles and the salt accumulate very fast in cytoplasm and subsequently the photosynthesis and assimilation is reduced but in tolerant varieties the salt is rapidly compartmentalized in vacuoles and the vital actions change slowly (Munns, 1993; Munns and Tester, 2008). Overall, the factors that are relevant to degree of salt stress in plants include physiological, biochemical, molecular and morphological characteristics. Some saline tolerant varieties are BRRI dhan47, BRRI dhan53, BRRI dhan54 etc. and sensitive varieties are BRRI dhan28, BRRI dhan52 etc.

Chapter 3

MATERIALS AND METHODS

This chapter describes about experimental site, climate, soil condition, planting materials, crop growing condition, fertilizer application and data collection at different period after transplanting.

3.1 Location

The experiment was conducted in plastic pots and the pots were placed in experimental shed of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka. The location of the experimental site has been shown in Appendix I.

3.2 Soil

The experimental site belongs to Modhupur tract (AEZ No. 28). The plastic pots used in the experiment were 14 inch in diameter and 18 inch in depth. The experimental pots were filled with soil collected from SAU farm. The pH value of soil was 5.6 and non-calcareous dark grey in color. The physical and chemical properties of soil used in experiment have been showed in Appendix II.

3.3 Climate

Site of experiment is under sub-tropical climate that characterized by three distinct seasons. Monsoon or rainy season from May to October, winter or dry season from November to February and the pre-monsoon period or hot season from March to April. The detailed meteorological data of rainfall, Air temperature, Relative humidity, Sunshine during the experiment has been presented in Appendix III.

3.4 Plant Materials

BRRI dhan28: BRRI dhan28 is a Boro season rice variety released by Bangladesh Rice Research Institute (BRRI). It completes its life cycle in 145 days. Grain is medium slender and white. Its yield is 6.0 ton ha^{-1}.

BRRI dhan47: BRRI dhan47 is a salt tolerant variety grown in Boro season released by BRRI. It completes its life cycle in 152 days. It can tolerate salinity 12-14 dSm^{-1} during seedlings stage and 6 dSm^{-1} during maturity stage. Grain is medium and there is a white spot in the grain. Its plant height is 105 cm and yield is 6.0 ton ha^{-1}.

3.5 Preparation of saline water

Marine water and fresh water was used in the experiment for irrigation throughout the growing season. Fresh water was mixed with marine water in different concentration to prepare different strength of salinity. Salinity levels were S_0 (Control where no marine water used, only fresh water), S_1 (Three part fresh water and one part marine water), S_2 (Half marine water and half fresh water) and S_3 (Only marine water, no fresh water).

3.6 Treatments

The experiment consists of two factors as mentioned below

a) Factor A: 2 Varieties
   1. BRRI dhan28 (V_1)
   2. BRRI dhan47 (V_2)

b) Factor B: 4 Salinity level
   1. Control (S_0)
   2. Quarter strength marine water (S_1)
   3. Half strength marine water (S_2)
   4. Full strength marine water (S_3)

3.7 Design and layout

The experiment was done in Completely Randomized Design (CRD) with two factors and three replications using 24 plastic pots. Pots of same variety were placed together.

3.8 Seed collection

Seeds of BRRI dhan28 and BRRI dhan47 were collected from Bangladesh Rice Research Institute, Joydebpur, Gazipur.

3.9 Pot preparation

The collected soil was sun dried, crushed and sieved. The soil and fertilizers were mixed well before placing the soils in the pots. Pots were placed in the experimental shed of Dept. of

Agronomy, Sher-e-Bangla Agricultural University. The pots were pre-labeled for each variety and treatment. Finally, water was added to bring soil water level to field capacity.

3.10 Fertilizer application

Urea, Triple super phosphate, Muriate of potash and Gypsum were applied in the experimental pots @ 250 kg ha^{-1}, 110 kg ha^{-1}, 140 kg ha^{-1}, 50 kg ha^{-1} respectively. One-third of urea and the whole amount of other fertilizers were incorporated with soil at final pot preparation before sowing. Rest of the Urea were applied in two equal splits one at 30 days after transplanting (DAT) and second at 45 days after transplanting (DAT).

3.11 Sowing of seeds in seedbed

Previously collected seeds were soaked for 48 hours and then washed thoroughly in fresh water and incubated for sprouting, the sprouted seeds sown in the wet seedbed.

3.12 Uprooting and transplanting of seedlings

Thirty day old seedlings were carefully uprooted and transplanted in the respective pots at the rate of single seedling $hill^{-1}$.

3.13 Intercultural operation

3.13.1 Weeding and Irrigation

Small aquatic plants were uprooted by hand pulling and 3-4 cm depth of water was maintained throughout the growing season. Different strength of saline water was used for irrigation purpose after 20 DAT.

3.13.2 Plant protection

Net was used to protect the rice grain from the attack of birds. Green leafhopper and Rice stem borer were controlled by using Dursban 20ml/10L and Furadan 5G 2.5g/pot respectively.

3.14 General observation

Regular observations were made and the effect of salinity was clearly visible. Tiller initiation, maximum tillering and flowering were not uniform.

3.15 Maximum tillering and panicle initiation detection

The number of tiller after which it catches the decreasing trend was indicated maximum tillering and a small dome like growth at top of uppermost nodes indicated panicle initiation.

3.16 Data collection

The following parameters were observed carefully during experimental period

3.16.1. Crop growth parameters

a) Plant height at 30 days interval

b) Number of tiller hill^{-1} at 30 days interval

3.16.2. Physiological parameter

a) Relative water content (RWC)

3.16.3. Yield contributing character

a) Number of effective tillers plant^{-1}

b) Number of effective tillers plant^{-1}

c) Panicle length

d) Number of grains panicle^{-1}

e) Number of filled grains panicle^{-1}

f) Number of unfilled grains panicle^{-1}

g) 1000 grain weight

3.16.4. Yield

a) Grain yield pot^{-1}

b) Straw yield pot^{-1}

c) Biological yield

d) Harvest index (%)

3.17. Procedure of sampling for growth study during the crop growth period

3.17.1 Plant height

Thirty days after transplanting plant height was recorded at 30 days interval (30, 60, 90 DAT and at harvest. Plant height was measured from ground level up to the tip of leaf.

3.17.2 Number of tillers hill^{-1}

Number of tiller hill^{-1} was recorded at 30, 60, 90 DAT and at final harvest.

3.18 Procedure of sampling physiological parameters

3.18.1 Relative water content (RWC)

Relative water content was measured in Barrs and Weatherley (1962) method. From each pot three leaves were randomly selected and cut with scissors. Fresh weight (FW) of leaf lamina was taken and then keeps on distilled water in a Petridis for 4 hour in dark. After removing excess surface water turgid weight (TW) was taken and dried at 80^{0}c for 48 hours to measure dry weight (DW). Calculation was done by the following formula.

$$\text{RWC (\%)} = \frac{\text{FW}-\text{DW}}{\text{TW}-\text{DW}} \times 100$$

3.19 Procedure of recording data on yield contributing parameters

3.19.1 Number of effective tillers hill^{-1}

Total number of tillers hill^{-1} was counted and separated into effective and non effective tillers based on the bearing panicles.

3.19.2 Panicle length

Panicle length was measured from the basal nodes of the rachis to apex of each panicle.

3.19.3 Number of total grains panicle^{-1}

Grains from 5 randomly selected panicles were counted and average number of grains for each panicle was determined. Filled and unfilled grain was also determined from the panicle.

3.19.4 Thousand grains weight

One thousand sun dried grains were counted and weighed using an electric balance.

3.20 Yield

3.20.1 Grain yield pot^{-1}

Threshing was done and grains were separated then sun dried and weighed

3.20.2 Straw yield pot^{-1}

Straw were separated by threshing and weighed after drying.

3.20.3 Biological yield pot^{-1}

The biological yield was calculated with the following formula-

Biological yield = Grain yield + Straw yield

3.20.4 Harvest index (%)

Harvest index was calculated on dry basis using following formula-

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

3.21 Statistical analysis

Statistical analysis was done for the data obtained in case of various parameters using Statistix10 and mean separation was done by LSD at 5% level of significance.

Chapter 4

RESULTS AND DISCUSSION

The present research work was conducted in the experimental shed of Department of Agronomy of Sher-e- Bangla Agricultural University, Dhaka, during Boro season 2017-18 to investigate the growth and yield of Rice as influenced by different strength of marine water. Therefore, it was carried out to see the performance of rice at various treatment combinations in respect of growth and yield. The results have been presented and discussed, and possible interpretations have been drawn under the following headings:

1. Crop Growth Parameters

1.1. Plant height

Effect of variety

Plant height was taken at different growth period (Figure 1). BRRI dhan47 produced taller plant throughout the growing period (21.75, 76.25, 93.16 and 73.70 cm at 30, 60, 90 DAT and harvest, respectively) compared to BRRI dhan28 (16.40, 68.33, 84.91 and 45.55 cm at 30, 60, 90 DAT and harvest, respectively). Plant height increased upto 90 DAT more or less similar rate in both varieties but after 90 DAT plant height decreased and the rate of reduction was higher in BRRI dhan28 compared to BRRI dhan47.

Effect of salinity

Significant variation was observed on plant height at different level of salinity (Figure 2). From 30 DAT to harvest plant height decreased with increasing the level of salinity. The result was significantly different and the effect of salinity was clearly visible (Figure 2). The highest plant height was observed in control (S_0) at 90 DAT (99.75 cm). On the other hand the highest salinity level (S_3) gave the lowest plant height (17.23, 66.83, 78.08 and 29.86 cm at 30, 60, 90 DAT and final harvest, respectively). The magnitude of decrease in plant height increased with time. At 30 DAT the magnitude of decrease in plant height was lowest compared to 60, 90 DAT and harvest, respectively. Alam *et al.*, (2001) stated that stunted plant growth is the most common symptom of salinity at the vegetative stage.

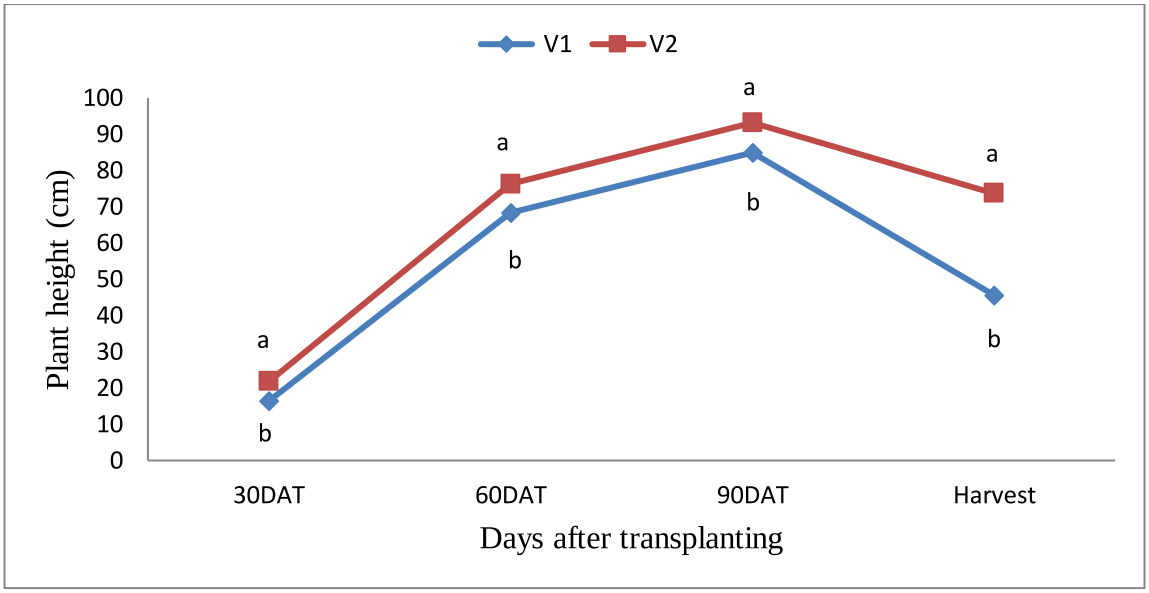

Figure 1: Effect of variety on plant height at different growth period of boro rice (Values with different letters are significantly different at 5% level of probability)

[Note: V_1 = BRRI dhan28, V_2 = BRRI dhan47]

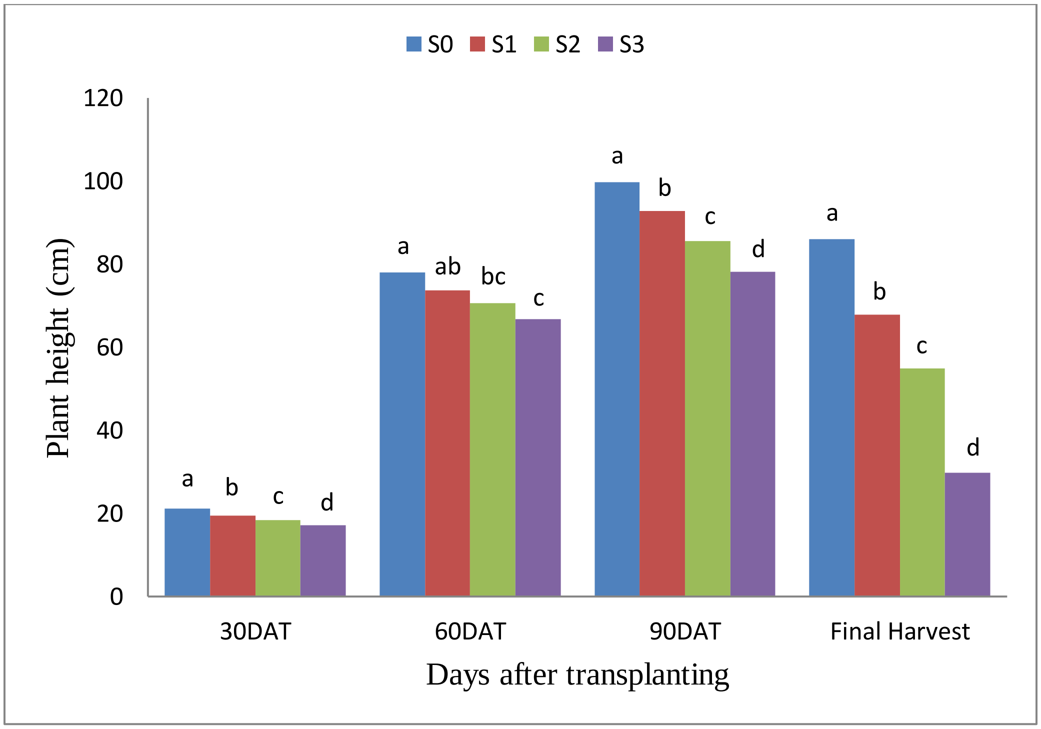

Figure 2: Effect of different level of salinity on plant height at different growth period of boro rice (Values with different letters are significantly different at 5% level of probability)

[Note: S_0 = Control, S_1 = Quarter strength marine water, S_2 = Half strength marine water, S_3 = Full strength marine water]

Combined effect of variety and salinity

Decrease in plant height was observed with increase in salinity level. From 30 DAT to harvest effect of salinity was comparably less in BRRI dhan47 than in BRRI dhan28 (Table 1). At harvest there was no alive BRRI dhan28 plant in salinity treatment S_3. This indicates BRRI dhan28 is sensitive to salt stress. Islam *et al.*, (2007) also witnessed the differences in plant height of rice varieties with different salinity levels.

Table 1: Combined effect of variety and different level of salinity on plant height at different growth period of boro rice

Treatments	Plant height (cm)			
	30 DAT	60 DAT	90 DAT	Harvest
V_1S_0	18.56 d	72.00 bcd	99.17 a	84.46 a
V_1S_1	16.73 e	68.66 cd	90.17 bc	57.93 d
V_1S_2	15.66 f	68.00 cd	80.67 d	39.83 e
V_1S_3	14.66 f	64.66 d	69.67 e	0.00 f
V_2S_0	23.83 a	84.00 a	100.33 a	87.50 a
V_2S_1	22.10 b	78.66 ab	95.33 ab	77.66 b
V_2S_2	21.26 b	73.33 bc	90.50 bc	69.90 c
V_2S_3	19.80 c	69.00 cd	86.50 c	59.73 d
LSD $_{(0.05)}$	0.47	3.57	2.64	1.55
CV (%)	1.02	7.66	5.67	3.32

Values with different letters are significantly different at 5% level of probability

[Note: V_1 = BRRI dhan28, V_2 = BRRI dhan47, S_0 = Control, S_1 = Quarter strength marine water, S_2 = Half strength marine water, S_3 = Full strength marine water]

1.2. Number of tillers hill^{-1}

Effect of variety

Salinity intrusion not only reduced the development of tillers but also reduced plant viability. BRRI dhan47 has showed higher number of tillers hill^{-1} (6.25, 16, 22.5 and 17 at 30, 60, 90 DAT and harvest, respectively) compared to BRRI dhan28 throughout the growing period (Figure 3). This result is in agreement with the experiment conducted by Zeng and Shannon (2000b). In the experiment they experienced that salinity tolerant variety produced more number of tillers hill^{-1} compared to sensitive variety.

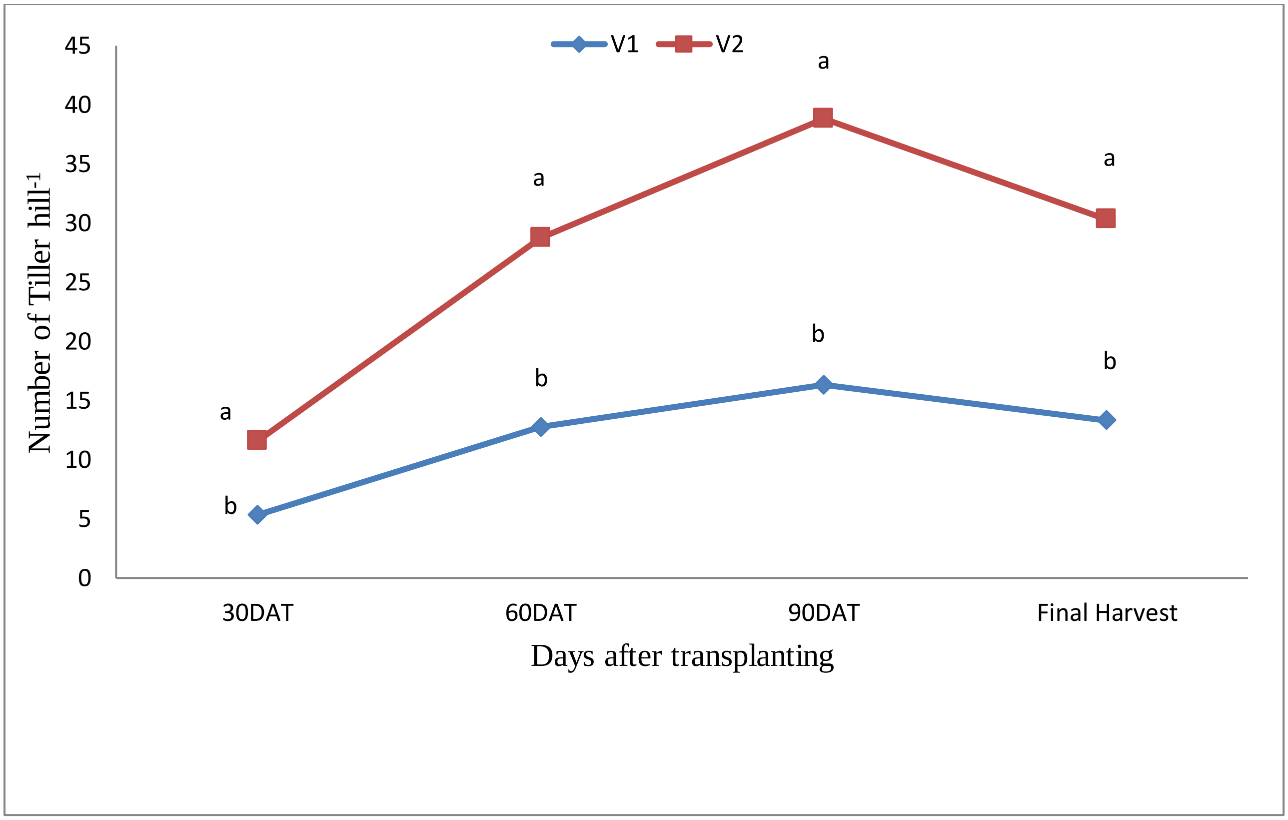

Figure 3: Effect of variety on number of tiller hill^{-1} at different growth period of boro rice (Values with different letters are significantly different at 5% level of probability)

[Note: V_1 = BRRI dhan28, V_2 = BRRI dhan47]

Effect of salinity

Salinity intrusion has inversely affected tillers production throughout the entire growth period of rice. Number of tillers decreased gradually with increase in salinity level compared to control (Figure 4). Thus tiller number was found 80.41% in S_1, 69.58% in S_2, 52.21% in S_3 at 30DAT, 78.16% in S_1, 61.32% in S2, 50.42% in S3 at 60DAT, 80.39% in S_1 ,70.58% in S_2 ,53.56% in S_3 at 90DAT and 76.88% in S_1 ,67.75% in S_2 ,56.20% in S_3 at harvest compared to control. It was also reported that number of tiller decreased progressively with increase in salinity level (Javed and Khan, 1975).

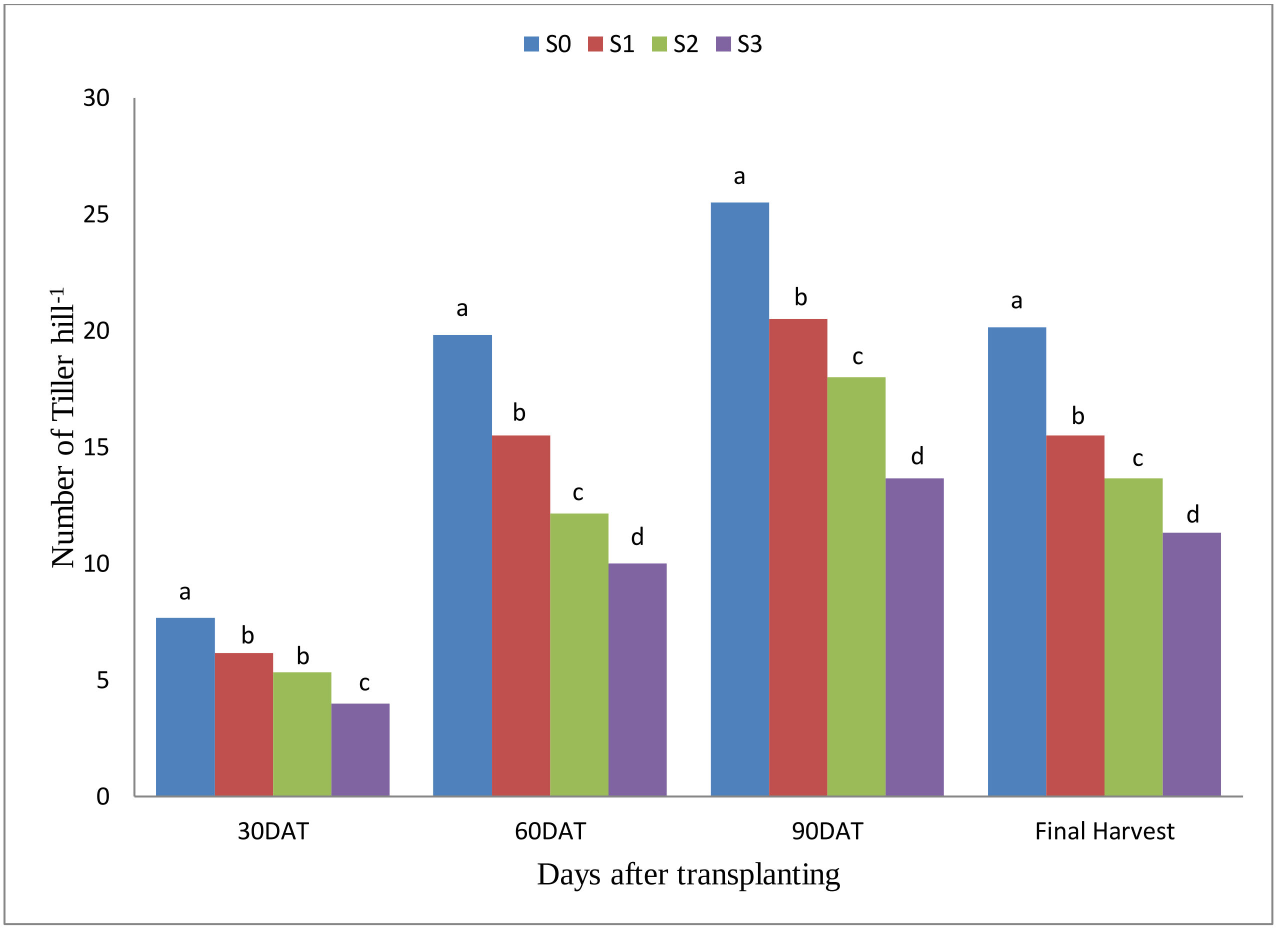

Figure 4: Effect of different level of salinity on number of tillers hill^{-1} at different growth period of boro rice (Values with different letters are significantly different at 5% level of probability)

[Note: S_0 = Control, S_1 = Quarter strength marine water, S_2 = Half strength marine water, S_3 = Full strength marine water]

Combined effect of variety and salinity

Salinity intrusion reduced the number of tillers hill^{-1} in case of both the variety. Magnitude of decrease was lower in BRRI dhan47 compared to BRRI dhan28 (Table 2). In case of BRRI dhan47 magnitude of decrease was 16.75, 29.25 and 41.75% at 30 DAT; 20, 36.94 and 47.70% at 60 DAT; 11.12, 18.52 and 37.04% at 90 DAT; 22.73, 28.82 and 39.41% at Final harvest in S_1, S_2 and S_3 respectively, compared to control. In case of BRRI dhan28 magnitude of reduction was (22.79, 31.79 and 54.58% at 30 DAT; 24.12, 40.78 and 51.89% at 60 DAT; 29.17, 41.67 and 56.96% at 90 DAT; 23.67, 36.39 and 49.10% at Final harvest in S_1, S_2 and S_3 respectively, compared to control. Zeng *et al.*, (2003) reported that salinity decreases number of tillers while imposing before panicle emergence.

Table 2: Combined effect of variety and different level of salinity on number of tiller hill^{-1} at different growth period of boro rice

Treatments	Number of tiller hill^{-1}			
	30 DAT	60 DAT	90 DAT	Final Harvest
V_1S_0	7.33 a	18.00 b	24.00 b	18.33 b
V_1S_1	5.66 bc	13.66 c	17.00 d	14.00 de
V_1S_2	5.00 c	10.66 de	14.00 e	11.66 f
V_1S_3	3.33 d	8.66 e	10.33 f	9.33 g
V_2S_0	8.00 a	21.66 a	27.00 a	22.00 a
V_2S_1	6.66 ab	17.33 b	24.00 b	17.00 bc
V_2S_2	5.66 bc	13.66 c	22.00 c	15.66 cd
V_2S_3	4.66 cd	11.33 d	17.00 d	13.33 ef
$LSD_{(0.05)}$	0.76	0.96	0.77	0.77
CV (%)	1.64	2.07	1.66	1.67

Values with different letters are significantly different at 5% level of probability

[Note: V_1 = BRRI dhan28, V_2 = BRRI dhan47, S_0 = Control, S_1 = Quarter strength marine water, S_2 = Half strength marine water, S_3 = Full strength marine water]

2. Physiological Parameter

2.1. Relative Water Content

Effect of variety

Salt stress decreased the RWC of both cultivars and the effect increased with salinity level (Figure 5). BRRI dhan47 (60.41%) showed higher relative water content compared to BRRI dhan28 (36.83%). hence BRRI dhan47expressed more salinity tolerance than BRRI dhan28.

Effect of salinity

Significant variation was observed in relative water content with increase in salinity level (Figure 6). Salinity treatment S_1, S_2, S_3 showed 85.56, 76.29 and 56.13% relative water content (RWC) compared to control. Katerji *et al*., (1997) found out that decrease in relative water content results in limited water availability for cellular extension.

Figure 5: Effect of variety on relative water content (%) at different growth period of boro rice (Values with different letters are significantly different at 5% level of probability)

[Note: V_1 = BRRI dhan28, V_2 = BRRI dhan47]

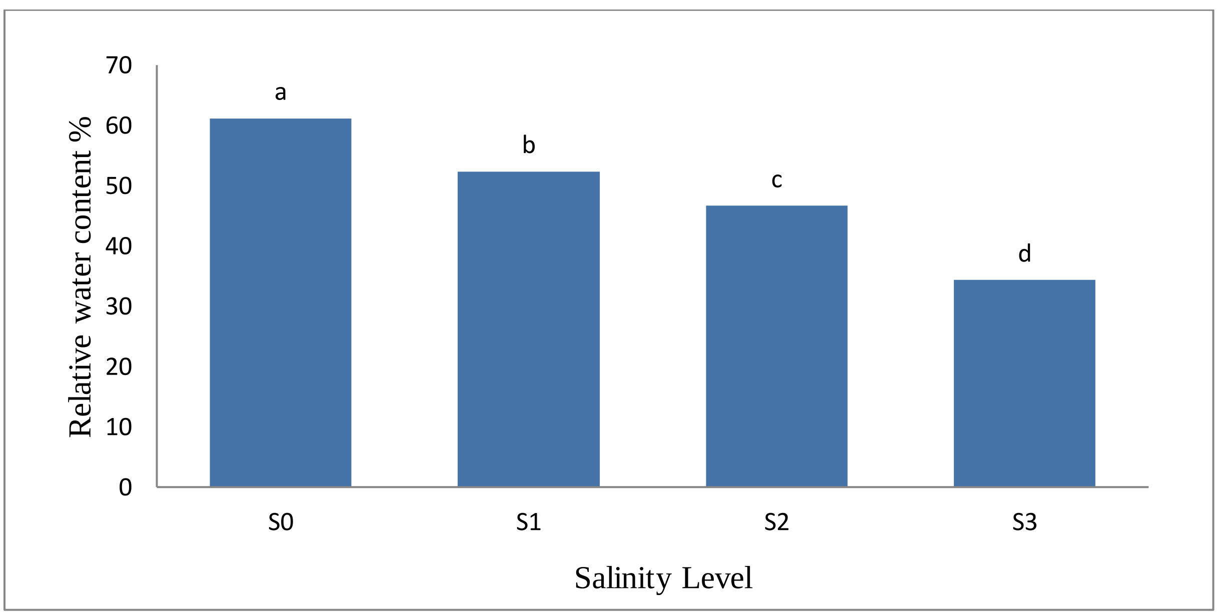

Figure 6: Effect of different level of salinity on relative water content (%) at different growth period of boro rice (Values with different letters are significantly different at 5% level of probability)

[Note: S_0 = Control, S_1 = Quarter strength marine water, S_2 = Half strength marine water, S_3 = Full strength marine water]

Combined effect of variety and salinity

It is observed that decrease in relative water content (RWC) was higher in BRRI dhan28 than BRRI dhan47 as BRRI dhan47 is a salt tolerant variety (Figure 7). BRRI dhan47 showed 12.74, 16.51 and 28.78% decrease in relative water content in S_1, S_2 and S_3 respectively compared to control. Whereas BRRI dhan28 showed 16.77, 33.55 and 64.52% decrease in S_1, S_2 and S_3 respectively compared to respective control. However highest decrease was seen in salinity treatment S_3 for BRRI dhan28.

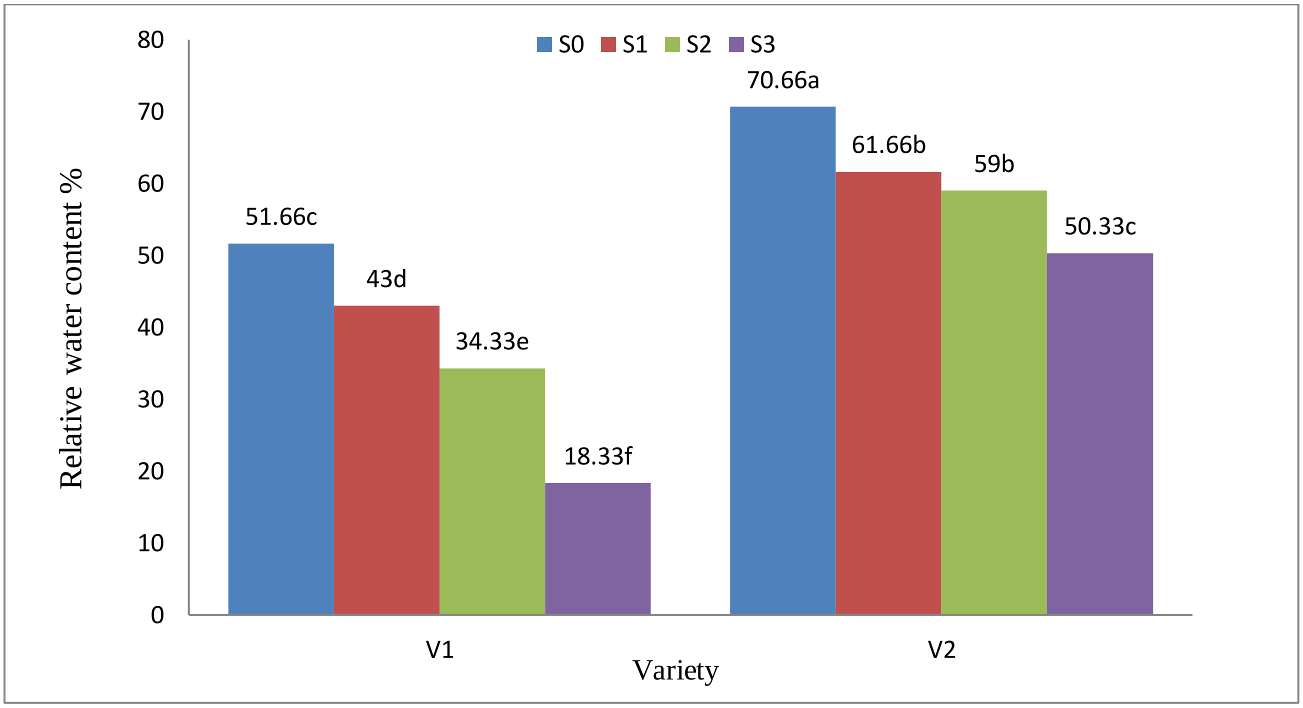

Figure 7: Combined effect of variety and different level of salinity on relative water content (%) at different growth period of boro rice (Values with different letters are significantly different at 5% level of probability)

[Note: V_1 = BRRI dhan28, V_2 = BRRI dhan47, S_0 = Control, S_1 = Quarter strength marine water, S_2 = Half strength marine water, S_3 = Full strength marine water]

3. Yield contributing character

3.1. Effective tillers hill^{-1}

Effect of variety

The number of effective tillers hill^{-1} varied significantly due to variety (Table 3). BRRI dhan47 showed higher number of effective tiller hill^{-1} (12.25) in compared to BRRI dhan28 (6.75).

Effect of salinity

Salinity stress reduced the number of effective tillers hill^{-1} to a great extent (Table 3). Increase in salinity strength proportionally decreased the number of effective tillers hill^{-1}. Number of effective tillers hill^{-1} was 17.16, 10.83, 7.17 and 2.38 in S_0, S_1, S_2 and S_3 respectively. Khatun *et al.*, (1995) found that salinity delayed flowering, reduced the number of productive tillers, the number of fertile florets per panicle. Salt tolerance indexes in terms of seed yield, seed weight panicle^{-1}, spikelet number panicle^{-1} and tiller number plant^{-1} were reduced with increasing salinity (Zeng *et al.*, 2002).

Combined effect of salinity and variety

Salt stress showed significant effect on number of effective tillers hill^{-1} (Table 3). With rise in salinity strength number of effective tillers hill^{-1} reduced for both the variety. Highest number of effective tillers hill^{-1} was found for BRRI dhan47 at salinity treatment S_0 and the number of effective tillers hill^{-1} was lowest in BRRI dhan28 at salinity treatment S_3. Increase in salinity level decreased the number of effective tillers hill^{-1}. BRRI dhan28 died at salinity strength S_3. This result is in agreement with Sultana *et al.*, (2014). They have conducted an experiment taking two boro rice variety BRRI dhan47 and BINA dhan10. In the experiment lowest number of effective tillers hill^{-1} was found at 12 dsm^{-1}. On the other hand both the variety died at 16 dsm^{-1} salinity level.

3.2. Non-Effective tillers hill^{-1}

Effect of variety

Varietal differences showed significant effect on number of non-effective tiller hill^{-1} (Table 3). Number of non effective tillers hill^{-1} was lower in BRRI dhan47 than BRRI dhan28. BRRI dhan47 is a salt tolerant variety and this result justifies the salinity resistant character (BRRI dhan47 showed 4.75 and BRRI dhan28 6.58 non-effective tillers hill^{-1}).

Effect of salinity

Salinity increased the number of non-effective tillers hill^{-1}. Among all the treatment control showed lowest number of non-effective tillers hill^{-1} (Table 3). Salinity intrusion increased the number of non-effective tillers hill^{-1} compared to control (Magnitude of increase was 55.33, 116.66 and 183.33% in S_1, S_2 and S_3 respectively, compared to control). Number of non effective tillers hill^{-1} increased with increase in salinity level in the experiment conducted by Zeng and Shannon, (2002).

Combined effect of salinity and variety

Exposure to salinity increased the number of non effective tillers hill^{-1} for both the variety. Number of non-effective tillers hill^{-1} was higher in BRRI dhan28 compared to BRRI dhan47 at every salinity treatment (Table 3). The highest number of non effective tillers hill^{-1} was found in BRRI dhan28 at salinity level S_3 and the lowest was found in BRRI dhan47 at salinity treatment S_0. Alam *et al*., (2001) stated that the salinity at reproductive stage of rice depressed grain yield much more than that of vegetative growth stage and at critical salinity levels it might give a normal straw yield of rice but produced little or no grain. They also observed that when the plants were continuously exposed to saline media, salinity affected the panicle initiation, spikelet formation, fertilization of the florets and germination of pollen grains and hence caused an increase in number of sterile florets.

3.3. Panicle length

Effect of variety

Significant variation was observed in panicle length due to variety (Table 3). BRRI dhan47 produced longer panicle (21.99cm) than BRRI dhan28 (14.35cm). Asch *et al.*, (1997) conducted an experiment taking eight rice cultivars and found out that salinity tolerant cultivars has lower effect of salinity on yield contributing characters than normal one.

Effect of salinity

Panicle length was significantly affected by salinity level (Table 3). With rise in salinity level panicle length reduced and magnitude of reduction was 86.43, 73.16 and 37.21% in S_1, S_2 and S_3 respectively, compared to control. Alam *et al.*, (2001) reported that salinity severely reduces the panicle length and panicle weight, thereby reducing the grain yield.

Combined effect of variety and salinity

Panicle length of BRRI dhan47 and BRRI dhan28 was decreased 10.58 and 16.92% in S_1, 20.24 and 34.26% in S_2, 29.62 and 100% in S_3 respectively, in comparison with their respective control

(Table 3). Maximum reduction was observed in BRRI dhan28 (100%) at salinity level S_3 where no panicle was found for BRRI dhan28. Zeng and Shannon, (2002) conducted an experiment taking two rice variety of which one is salinity tolerant and other is salinity sensitive. They found similar result. Increase in salinity level decreased the panicle length but magnitude of decrease was lower in tolerant variety.

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

Effect of variety

Due to variety significant variation was observed in number of filled grain panicle^{-1} (Table 3). BRRI dhan47 (83.75) showed higher number of filled grain panicle^{-1} than BRRI dhan28 (58.91).

Effect of salinity

Salinity intrusion affected number of filled grain panicle^{-1} throughout the growing period (Table 3). Increasing salinity level decreased the number of filled grain panicle^{-1} (27.35, 62.74 and 80.44% decrease in S_1, S_2 and S_3 respectively compared to control). Lowest filled grain panicle^{-1} was found at highest salinity strength (S_3). This result is in line with Nahar *et al.* (2009). They reported that increase in salinity decreased the numbers of filled grain panicle^{-1}.

Combined effect of variety and salinity

No of filled grain panicle^{-1} of BRRI dhan47 and BRRI dhan28 were decreased by 18.06 and 35.52% in S_1; 35.83 and 86.4% in S_2; 58.72 and 100% (no filled grain panicle^{-1}) in S_3 compared to their respective control (Table 3). BRRI dhan28 showed higher filled grain panicle^{-1} compared to BRRI dhan47 only at salinity treatment S_0 but at highest salinity level (S_3) BRRI dhan28 died and no filled grain panicle^{-1} was found which indicated the adverse effect of salinity on BRRI dhan28. Choi *et al.*, (2003) conducted an experiment with four levels of salt solution mixed with seawater (0.1, 0.3, 0.5 and 0.7%) and control (tap water). They found that panicle number per unit area and percentage of ripened grain i.e. filled grain dramatically decreased in 0.5% saline water in the soil with low salinity level and in 0.1% saline water in soil with medium salinity level.

3.5. Number of unfilled grains panicle^{-1}

Effect of variety

Significant varietal difference was observed in number of unfilled grains panicle^{-1} (Table 3). BRRI dhan28 (22.25) produced higher number of unfilled grain panicle^{-1} compared to BRRI dhan47 (16.00).

Effect of salinity

Salinity intrusion increased number of unfilled grains panicle^{-1} (Table 3). Highest number of unfilled grain panicle^{-1} was found in salinity level S_2 (36.5) and lowest was found in control S_0 (6.5). At salinity level S_3 BRRI dhan28 died and no grain was found. Because of this effect higher number of unfilled grain panicle^{-1} was found in salinity treatment S_2 instead of S_3.

Combined effect of variety and salinity

Number of unfilled grains panicle^{-1} increased with rise in salinity strength (Table 3). The highest number of unfilled grains panicle^{-1} was found in BRRI dhan28 at salinity treatment S_2 (55) and the lowest was also found at BRRI dhan28 at salinity level S_3 (0). Strength of salinity in treatment S_3 is higher than S_2 but in full strength salinity (S_3) BRRI dhan28 died and no grain was found. This phenomenon decreased the number of unfilled grain panicle^{-1} in salinity level S_3. Asch *et al*., (1999) observed that salinity was a major yield-reducing stress in much arid and coastal irrigation system for rice.

Table 3: Effect variety, salinity and their combination on panicle Length, effective tiller hill^{-1}, non-effective tiller hill^{-1}, number of filled grain panicle^{-1}, number of unfilled grain panicle^{-1} at different growth period of boro rice

Treatments	Panicle length (cm)	Effective tillers hill^{-1}	Non-effective tillers hill^{-1}	No of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}
Variety					
V_1	14.35 b	6.75 b	6.58 a	58.91 b	22.25 a
V_2	21.99 a	12.25a	4.75 b	83.75 a	16 b
LSD (0.05)	0.36	0.57	0.27	1.56	1.15
Salinity					
S_0	24.48 a	17.16 a	3 d	124.33a	6.5 c
S_1	21.16 b	10.83 b	4.66 c	90.33b	17 d
S_2	17.91 c	7.16 c	6.5 b	46.33c	36.5 a
S_3	9.11 d	2.38 d	8.5 a	24.33d	16.5 b
LSD (0.05)	0.52	0.81	0.38	2.21	1.62
Combined effect of variety and salinity					
V_1S_0	23.06 b	14.66 b	3.66 d	132.33 a	8 e
V_1S_1	19.16 cd	8.33 c	5.66 e	85.33 d	26 c
V_1S_2	15.16 e	4 d	7.66 b	18 g	55 a
V_1S_3	0 f	0 e	9.33 a	0 h	0 f
V_2S_0	25.9 a	19.66 a	2.33 c	116.33 b	5 e
V_2S_1	23.16 b	13.33 b	3.66 d	95.33 c	8 e
V_2S_2	20.66 c	10.33 c	5.33 c	74.66 e	18 d
V_2S_3	18.23 d	5.66 d	7.66 b	48.66 f	33 b
LSD $_{(0.05)}$	0.73	1.14	0.54	3.12	2.3
CV (%)	1.58	2.46	1.17	6.71	4.93

Values with different letters are significantly different at 5% level of probability

[Note: V_1 = BRRI dhan28, V_2 = BRRI dhan47, S_0 = Control, S_1 = Quarter strength marine water, S_2 = Half strength marine water, S_3 = Full strength marine water]

3.6. Thousands grain weight

Effect of variety

Significant variation was observed in 1000 grain weight with varietal variation (Table 4). BRRI dhan47 (16.80g) showed higher 1000 grain weight than BRRI dhan28 (13.92g).

Effect of salinity

Increase in salinity strength reduced 1000 grain weight (Table 4). Highest (22.97 g) 1000 grain weight was found in control and lowest (4.19 g) was found in salinity treatment S_3. Khatun and Flowers, (1995) reported that 1000 grain weight decreases with increase in salinity.

Combined effect of variety and salinity

Salinity intrusion reduced 1000 grain weight (Table 4). Magnitude of decrease in 1000 grain weight was observed 13.36, 38.04, 64.59% for BRRI dhan47 and 14.82, 35.28, 100% for BRRI dhan28 in S_1, S_2, S_3 treatments respectively, compared to their respective control. BRRI dhan47 showed higher 1000 grain weight in every salinity treatment compared to BRRI dhan28. No grain was found at S_3 in case of BRRI dhan28. Salam *et al*., (2007) conducted an experiment with BRRI dhan47 and BRRI dhan28 in which 1000 grain weight reduced with rise in salinity. BRRI dhan47 showed higher thousand grain weight compared to BRRI dhan28 under salinity.

3.7. Grain yield pot^{-1}

Effect of variety

Significant difference has been observed in grain yield pot^{-1} for both the varieties (Table 4). Highest grain yield pot^{-1} was observed in BRRI dha47 (90g) compared to BRRI dhan28 (41.83g).

Effect of salinity

Grain yield pot^{-1} decreased with increase in salinity level (Table 4). Decrease in Grain yield pot^{-1} was seen 36.61, 66.63 and 83.85% for salinity treatment S_1, S_2 and S_3 respectively, compared to control. This loss in grain yield is the result of reduction in spikelet number, fertility and harvest index. Among these, fertility of grain is most badly affected and reduce total grain yield. Salinity also reduced panicle length and panicle numbers which is also a reason for reduction in grain yield. Linghe and Shannon, (2001) stated that salt stress is responsible for grain yield reduction.

Combined effect of variety and salinity

Salinity caused significant reduction in grain yield for BRRI dhan28 compared to BRRI dhan47 (Table 4). Rate of decrease was 26.58, 49.66 and 70.03% in S_1, S_2, S_3 treatment respectively, compared to control for BRRI dhan47 and 50.33, 89.82 and 100% decrease was observed in S_1, S_2, S_3 treatments respectively compared to control for BRRI dhan28. Lowest or no grain was found on highest salinity treatment S_3 for BRRI dhan28. This result is similar with the experiment conducted by Salam *et al*., (2007). They found out that gradual increase in salinity level decrease grain yield pot^{-}1. BRRI dhan47 showed higher grain yield pot^{-1} than BRRI dhan28 under salinity condition.

3.8. Straw yield pot^{-1}

Effect of variety

Significant variation was observed in Straw yield pot^{-1} due to varietal variation (Table 4). The highest straw yield pot^{-1} was found in BRRI dhan47 (239.9 g) compared to BRRI dhan28 (192.3 g).

Effect of salinity

Sharp decrease in straw yield was observed due to salinity intrusion (Table 4). 26.12, 40.71 and 67.59% decrease was observed in S_1, S_2 and S_3 respectively, compared to control. Siddique *et al*., (2015) mentioned that reduced straw yield under salinity condition might be due to inhibited photosynthesis under salinity stress that caused less amount of nutrient uptake by the plant

Combined effect of variety and salinity

Salinity stress reduced the straw yield pot^{-1} of both BRRI dhan47 and BRRI dhan28 (Table 4). 25.14, 41.52 and 60.48% decrease in straw yield pot^{-1} was found for BRRI dhan47 compared to control. Magnitude of decrease for BRRI dhan28 was 27.27, 39.76 and 79.53% compared to control. Both the variety showed decrease in straw yield with rise in salinity strength but BRRI dhan28 showed more decrease compared to BRRI dhan47.

3.9. Biological yield

Effect of variety

Data regarding biological yield showed significant variation between varieties (Table 4). BRRI dhan47 (329.92) showed higher biological yield compared to BRRI dhan28 (234.17)

Effect of salinity

Increase in salinity strength gradually decreased biological yield (Table 4). Biological yield was found 449.33, 319, 234.33 and 125.5 gm in S_0, S_1, S_2 and S_3 respectively. Gain *et al.*, (2004) stated that the biomass of the rice plant decreased significantly from 7.81dsm^{-1} level of salinity.

Combined effect of variety and salinity

It was observed that the combined effect of variety and salinity on the biological yield was statistically significant (Table-4) at 5% level of significance. However the highest biological yield (494.67gm) was found in treatment combination V_2S_0 and the lowest biological yield was found in treatment combination V_1S_3.

Table-4: Effect variety, salinity and their combination on 1000 grain wt, grain yield pot^{-1}, straw yield pot^{-1} and biological yield at different growth period of boro rice.

Treatments	1000 grain wt	Grain yield pot^{-1}	Straw yield pot^{-1}	Biological yield
Variety				
V_1	13.92b	41.83b	192.33b	234.17b
V_2	16.8a	90a	239.92a	329.92a
LSD (0.05)	0.48	2.81	8.26	8.21
Salinity				
S_0	22.97a	123.83a	325.5a	449.33a
S_1	19.74b	78.5b	240.5b	319b
S_2	14.54c	41.33c	193c	234.33c
S_3	4.19d	20d	105.5d	125.5d
LSD (0.05)	0.67	3.97	11.68	11.61
Combined effect of variety and salinity				
V_1S_0	22.28ab	104.67b	299.33b	404b
V_1S_1	18.98c	52c	217.67d	269.67d
V_1S_2	14.42d	10.66e	180.33e	191e
V_1S_3	0f	0e	72g	72f
V_2S_0	23.66a	143a	351.67a	494.67a
V_2S_1	20.5bc	105b	263.33c	368.33c
V_2S_2	14.66d	72c	205.67de	277.67d
V_2S_3	8.38e	40d	139f	179e
LSD $_{(0.05)}$	0.96	5.62	16.53	16.42
CV (%)	2.05	12.07	35.45	35.23

Values with different letters are significantly different at LSD $_{(0.05)}$

[Note: V_1 = BRRI dhan28, V_2 = BRRI dhan47, S_0 = Control, S_1 = Quarter strength marine water, S_2 = Half strength marine water, S_3 = Full strength marine water]

Chapter 5

SUMMARY AND CONCLUSION

This experiment was conducted to know about the effect of different level of salinity on two boro rice variety. Two varieties BRRI dhan28 and BRRI dhan47 were used in this experiment. BRRI dhan47 is salinity tolerant and BRRI dhan28 is sensitive to salinity. This experiment was done in the experimental shed of Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka during the period from October 2017 to February 2018. Seeds of the rice varieties used in this experiment were collected from Bangladesh Rice Research Institute (BRRI), Gazipur, Dhaka.

The experiment was laid out in Completely Randomized Design (CRD) with three replications. Twenty four plastic pots with 14 inch in diameter and 18 inch in depth were used to conduct the experiment. There were 8 treatment combinations. The treatments were control (S_0), Quarter strength marine water (S_1), half strength marine water (S_2) and Full strength Marine water (S_3) for two rice varieties. Different level of fresh water and marine water mixtures were used for irrigation purpose.

Different level of salinity had significant effect on crop growth parameters viz. plant height and number of tillers hill^{-1}. Higher plant height was found with control for BRRI dhan47 (30 DAT 23.83 cm, 60 DAT 84 cm, 90 DAT 100.33 cm and Final harvest 87.5cm) compared to BRRI dhan28. Number of tiller hill^{-1} also showed similar result. Higher number of tiller hill^{-1} was found for BRRI dhan47 at control (30 DAT 8, 60 DAT 21.66, 90 DAT 27 and Final harvest 22) compared to BRRI dhan28.

Significant effect of salinity was also found in physiological parameter viz. relative water content (RWC). Highest relative water content was found for BRRI dhan47 in control (70.66%) compared to BRRI dhan28 in control (51.66%).

Significant difference due to different salinity treatments was seen on yield contributing characters viz. panicle length, number of effective tiller hill^{-1}, 1000 grain weight, Grain yield, straw yield, biological yield was higher for BRRI dhan47 in control where non- effective tiller hill^{-1} and unfilled grain panicle^{-1} was higher for BRRI dhan28 at treatment full strength marine water S_3.

According to the result of the present experiment and the results collected from different literature we can conclude saying that salinity has significant effect on both the rice variety. Salinity negatively affects the plant physiology and yield contributing characters. With rise in salinity level its adverse effect is more clearly visible. Among these two varieties BRRI dhan47 showed better performance compared to BRRI dhan28. BRRI dhan47 showed some extent of salinity tolerance even though increasing salinity decreased its growth and yield. All the parameters showed negative result or decreased with rise in salinity except non-effective tiller hill^{-1} and unfilled grain panicle^{-1}. Number of non-effective tiller hill^{-1} and unfilled grain panicle^{-1} increased with increase in salinity.

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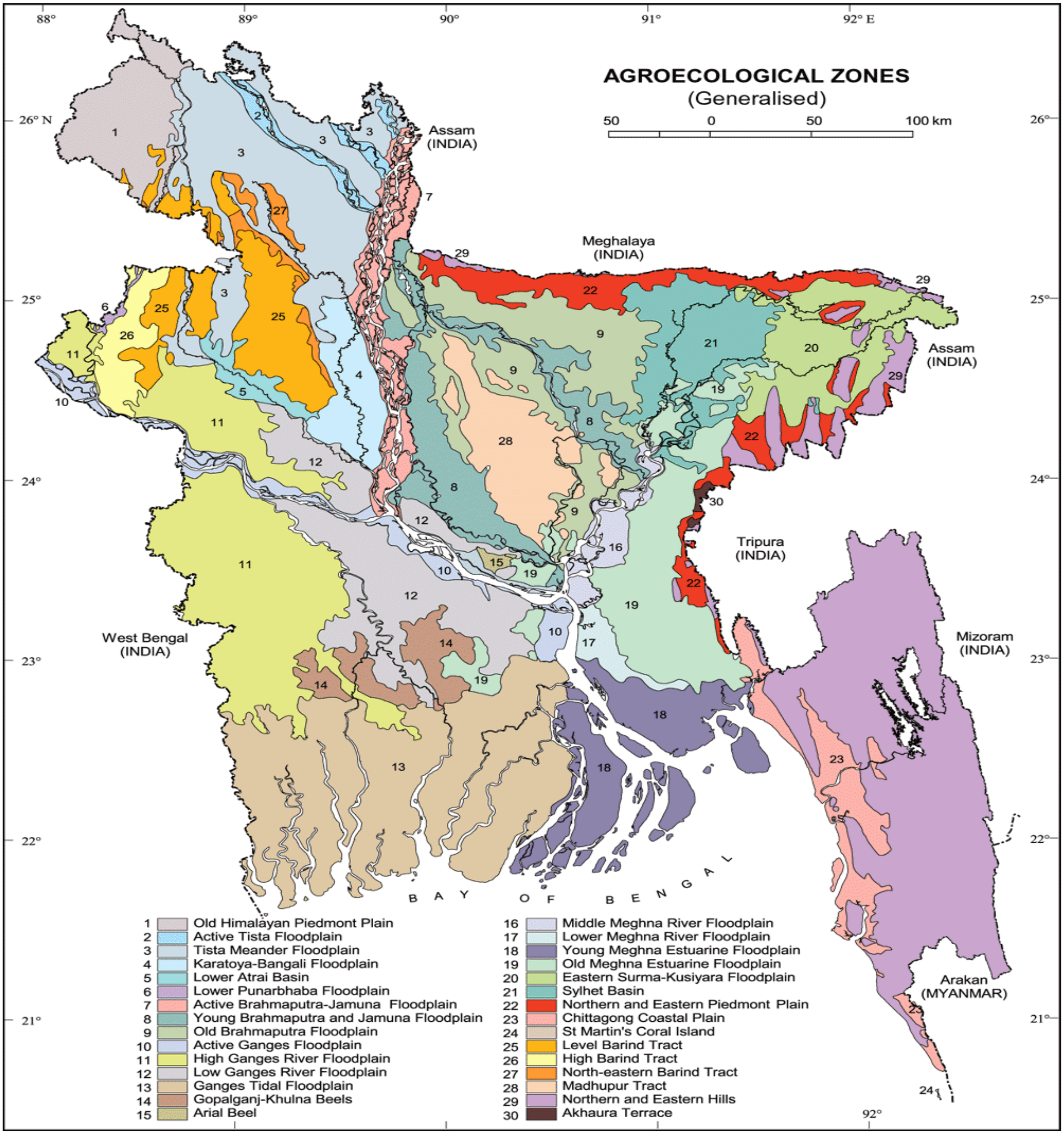
Appendices

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



Appendix II Physical and chemical properties of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

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

Source: SRDI, Farmgate, Dhaka

Appendix III Monthly average air temperature, rainfall and relative humidity of the experimental site during the period from November 2017 to March 2018

Months	**Air temperature (°C)**		**Relative humidity (%)**	**Total rainfall (mm)**
	Maximum	**Minimum**		
November, 2017	29.60	19.20	53	5.25
December, 2017	26.40	14.10	50	17.61
January, 2018	25.40	12.70	46	00
February, 2018	28.10	15.50	37	1.21
March, 2018	32.50	20.40	38	17.62

Source: https://www.weather-atlas.com/en/bangladesh/dhaka-climate