EFFECTS OF SALINITY ON MINERAL CONTENTS IN STEM AND LEAF OF RICE CULTIVARS DIFFERING IN SALT TOLERANCE

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CERTIFICATE

This is to certify that the thesis entitled "EFFECTS OF SALINITY ON MINERAL CONTENTS IN STEM AND LEAF OF RICE CULTIVARS DIFFERING IN SALT TOLERANCE" submitted to the *DEPARTMENT OF AGRICULTURAL CHEMISTRY*,, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (M.S.) in AGRICULTURAL CHEMISTRY, embodies the results of a piece of *bona fide* research work carried out by MD. ZAHIRUL ISLAM, Registration. No. 04-01361, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

I further certify that any help or sources of information received during the course of this investigation have been duly acknowledged.

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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

An experiment was conducted in pot culture to study the reclamation of salinity on yield and nutrient content of rice during the Boro season (December-June) of the year 2008-09 at Sher-e-Bangla Agricultural University, Dhaka-1207. The two factors experiment was completed using four varieties namely Pokkali, BR 28, BRRI dhan 29 and IR 29 with five salinity levels (0, 3, 6, 9 and 12 dSm^{-1}). The N, P, K, Na, Ca and Mg contents into *the* stem and leaf of the rice varieties as well as their grain yield $hill^{-1}$ were studied. Significant varietal differences were found in N, P, K, Na and Mg but Ca did not show any significant varietal difference. Grain yield $hill^{-1}$ also showed significant varietal differences. The salinity increased significantly the content of Na, Mg, N, P in stem & leaf of the selected rice varieties and K content significantly decreased under higher salinity levels. The N, Na, and Mg contents were highest at maximum level of salinity and it was lowest at control. P increased upto 6 dSm^{-1} salinity level and then decreased. In both stem and leaf K content decreased with the increase of salinity and reached to the lowest value at the highest salinity treatment. Grain yield $hill^{-1}$ decreased with increasing salinity level. Interaction effect of variety and salinity significantly changed the contents of N, P, K, Na and Mg in both stem and leaf. N was highest in BRRI Dhan 29 at 9 dSm^{-1} & IR 29 at 12 dSm^{-1} and lowest in Pokkali at 6 dSm^{-1} & IR 29 at 3 dSm^{-1} in stem and leaf respectively. In case of P it was highest in IR 29 at 12 dSm^{-1} & BR 28 at 6 dSm^{-1} and lowest in BR 28 at 0 dSm^{-1} & BRRI Dhan 29 at 3 dSm^{-1} in stem and leaf respectively. In both stem & leaf, Na content was highest in IR 29 at 12 dSm^{-1} and lowest in Pokkali at 0 dSm^{-1}. While the K content was highest in Pokkali at 0 dSm^{-1} and the lowest in IR 29 at 12 dSm^{-1} in both stem and leaf. Mg was highest in BRRI Dhan 29 at 9 dSm^{-1} & in BRRI Dhan 29 at 12 dSm^{-1} in stem and leaf respectively and the lowest in Pokkali at 3 dSm^{-1} in both the plant parts. .

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LIST OF ABBREVIATIONS

Abbreviated Form	Elaborated Form
EC	Electrical Conductivity
ha^{-1}	Per hectare
et al.	and others
mmol	Milli mole
BRRI	Bangladesh Rice Research Institute
LSD	Least Significant Difference
TSP	Triple Super Phosphate

CHAPTER I

INTRODUCTION

Soil salinity is a major problem in arid and semi-arid regions, where rainfall is insufficient to leach salts and excess sodium ions down and out of the root zone. These areas often have high evaporation rates, which can encourage an increase in salt concentration at the soil surface through capillary rise. The presence of a cemented hardpan at varying depths and insufficient precipitation for leaching often adds to the problem. At present, out of 1.5 billion hectares (ha) of cultivated land around the world, about 77 million hectares (5 %) is affected by excess salt content (Sheng et al., 2008). According to a report of Alam (2001), saline/sodic soils cover about 26 % of the world's cultivated land. Incidentally, most of the developing and underdeveloped countries of South and Southeast Asia, Africa and South America are the worst affected by this menace. More than 80 million hectares of such soils are in Africa, 50 million hectares in Europe, 357 million hectares in Austral-Asia, nearly 147 million hectares in Central, North and South America. Similarly, a large bulk of about 320 million hectares of land in South and Southeast Asia is under the grip of salinity. It shows that no continent on our planet is free from salt-affected soils .

Rice is the principal food in many countries of Asia and Africa. The alarming growth of population and loss of arable land due to urbanization are main causes of concerns for finding ways and means for augmenting food production particularly rice in countries like Bangladesh and other developing countries. The possibility of increasing food production by increasing land area is quite out of question in Bangladesh and many other countries. The only feasible alternative is to increase the cultivable land areas by bringing salt affected soils under cultivation with high yielding salt tolerant rice cultivars.

In Bangladesh, there are approximately 2.85 million ha of coastal soils (Ponnamperuma, 1977) which occur in the southern parts of the Ganges tidal floodplain, in the young Meghna estuarine floodplain and in tidal areas of the Chittagong coastal plain and offshore islands (Brammer, 1978). About one million ha of land of these coastal and offshore areas are affected by varying degrees of salinity. These coastal saline soils are distributed unevenly in 64 thanas of 13 coastal districts covering 8 agroecological zones

(AEZ) of the country. The majority of the saline land (0.65 million ha) exists in the districts of Satkhira, Khulna, Bagerhat, Barguna, Patuakhali, Pirojpur and Bhola on the western coast and a smaller portion (0.18 million ha) in the districts of Chittagong, Cox's Bazar, Noakhali, Lakshmipur, Feni and Chandpur. According to the report of Soil Resource Development Institute (SRDI) of Bangladesh, about 0.203 million ha of land is very slightly (2-4 dSm^{-1}), 0.492 million ha is slightly (4-8 dSm^{-1}), 0.461 million ha is moderately (8-12 dSm^{-1}) and 0.490 million ha is strongly (>12 dSm^{-1}) salt affected soils in southwestern part of the coastal area of Bangladesh. Large fluctuations in salinity levels over time are also observed at almost all sites in these regions. The common trend is an increase in salinity with time, from November- December to March-April, until the onset of the monsoon rains. The electrical conductivity (EC) of the soils and water are lowest in July-August and highest in March-April at all sites. Soil salinity, at any time, is maximum in the surface layers (0-15 cm), the salinity gradient being vertically downwards. The salinity in subsoil is usually much lower than that in the top soil. The underground water within 1-2 meters below the soil surface at all locations is moderately to strongly saline in the dry season.

Salinity in soil or water is one of the major stresses that severely limit crop production. The deleterious effects of salinity on plant growth are associated with (i) low osmotic potential of soil solution (water stress), (ii) nutritional imbalance, (iii) specific ion effect, or (iv) a combination of these factors (Ashraf, 1994; Sultana et al., 1999; Asch et al., 2000). In fact, under saline conditions, soils contain extreme ratios of Na^+/Ca^{2+}, Na^+/K^+, Ca^{2+}/Mg^{2+}, and Cl^-/NO_3^-, leading to specific ion toxicities (e.g., Na^+ and Cl^-) and ionic imbalance (Grattan and Grieve, 1999).

Rice (*Oryza sativa* L.) is a salt-sensitive crop. However, because of its ability to grow well in standing water, it is recommended as a desalinization crop (Bhumbla and Abrol, 1978). Yeo and Flowers (1982) reported varietal differences in rice for salinity tolerance. Recognition of the potential of saline lands for rice production in the densely populated countries of South and South East Asia prompted the inclusion of salt tolerance as a component of the programme of the International Rice Research Institute (IRRI). Salt seems to affect rice during pollination, decrease seed setting and grain yield (Maloo, 1993).

Salt tolerance in plants is generally associated with low uptake and accumulation of Na^+, which is mediated through the control of influx and/ or by active efflux from the cytoplasm to the vacuoles and also back to the growth medium (Jacoby, 1999). Energy-dependent transport of Na^+ and Cl^- into the apoplast and vacuole can occur along the H^+ electrochemical potential gradients generated across the plasma membrane and tonoplast (Hasegawa *et al.*, 2000). The tonoplast H^+ pumps (H^+-ATPase and H^+-pyrophosphatase) also play a significant role in the transport of H^+ into the vacuole and generation of proton (H^+) motive force across the tonoplast, which operates the Na^+/H^+ antiporters (Mansour *et al.*, 2003).

There is a general lacking of suitable salt tolerant modern variety (MV) of rice to suited different AEZ in the coastal areas of Bangladesh. The scarcity of good quality irrigation water is a major problem in these areas. The surface water resources are insufficient and irrigated agriculture is largely dependent on ground water resource. The use of such water for irrigation without proper management may render the irrigated soils as salt affected and consequently crop production may be hindered.

For centuries, farmers have salt-tolerant cultivars on the saline soils of India, Burma, Thailand, Indonesia, the Philippines and Vietnam. But, because of lodging and susceptibility to disease and insect damage, yields are about l ton ha^{-1}.

As saline soil generally has higher concentration of Na and Mg than K and Ca, high ionic imbalances may impair the selectivity of root membranes. This may result in passive accumulation of Na in root and shoot. Rice is the crop most suited for saline soils because it can tolerate standing water, which is necessary for reclamation of saline soils. Rice that grows under saline condition face at least two stresses, (i) one stress from ion toxicity and (ii) the other arises from low water availability. Promising results have been obtained in field trials on the performance of modern salt-tolerant rice cultivars on saline soils in different countries of South and South East Asia. Kabir and Mia (1995) suggested that slightly to moderately saline coastal soils have good prospects for rice production of Bangladesh especially during the rainy season when salinity levels drop below the critical limit of 4 dS m^{-1}. The present study aims to investigate the effect of different levels of salinity on the yield and mineral nutrient concentrations of different salt tolerant and salt-sensitive rice varieties.

The present work has therefore, been designed and planned with the following objectives:

- To study the composition of different mineral element in stem and leaf of rice plant grown under salinity.
- To observe the yield of different rice cultivars under various salinity levels.

CHAPTER II

REVIEW OF LITERATURE

Alam *el al.* (2001) stated that the critical EC level of salinity for seedling growth was about 5 dSm^{-1}. They observed that dry matter, seedling height, root length and emergence of new roots of rice decreased significantly at an electrical conductivity value of 5-6 dSm^{-1} and during the early seedling stage, more higher salinity caused rolling and withering of leaves, browning of leaf tips and ultimately death of seedlings. They especulated that both osmotic imbalance and Cl^{-} was responsible for suppress of the growth. These authors maintained that the shoot growth was more suppressed than that of root and salt injury was more severe at high temperature (35°C) and low humidity (64%) due to increased transpiration and uptake of water and salt by rice plants. At the reproductive stage, salinity depressed grain yield much more than that at the vegetative growth stage (Alam *et al.*, 2001). These authors maintained that at critical salinity levels straw yield was normal but produced little or no grain. The decrease in grain yield was found proportional to the salt concentration and the duration of the saline treatment. When the plants were continuously exposed to saline media, salinity affected the panicle initiation, spikelet formation, fertilization of florets and germination of pollen grains hence caused an increase in number of sterile florets. The greatest injurious effect was on the panicle. Salinity severely reduced the panicle length, number of primary branches per panicle, number of spikelet per panicle, seed setting percentage and panicle weight and reduced the grain yield. The weight of 1000 grains was also reduced. Salt injury resulted in the production of small grains in grain length, width and thickness. Most rice cultivars were severely injured in submerged soil cultures at EC of 8-10 dSm^{-1} at 25° C; sensitive ones were hurt even at 2 dSm^{-1}. At comparable EC's injury was less in sea water than in solutions of common salt, in neutral and alkaline soils than in acid soils, at 20°C than at 35°C and in 2-week old seedling than in 1-week old seedlings. Since rice plant is susceptible to salinity at transplanting and gains tolerance with age, they advised that aged seedlings (6 weeks old) be planted in saline fields.

Salinity affected rice during pollination, decreased seed setting and grain yield (Maloo, 1993). Finck (1977) suggested that deficiency of K and Ca elements might play a significant role in plant growth depression in many saline soils. Girdhar (1988) observed that salinity delayed germination, but did not affect the final germination up to the EC of 8 dSm^{-1} by evaluating the performance of rice under saline water irrigation. In normal conditions, the Na^+ concentration in the cytoplasm of plant cells was low in comparison to the K^+ content, frequently 10^{-2} versus 10^{-1} and even in conditions of toxicity, most of the cellular Na^+ content was confined into the vacuole (Apse *et al*., 1999).

Abdullah *et al.* (2001) performed an experiment on the effect of salinity stress (50 mM) on floral characteristics, yield components, and biochemical and physiological attributes of the sensitive rice variety IR-28. The results showed significant decrease in panicle weight, panicle length, primary branches per panicle, filled and unfilled grains, total grains and grain weight per panicle, 1000-grain weight and total grain weight per hill. They further observed significant reduction in both chlorophyll a and chlorophyll b content in different parts of the rice leaves at saline condition. In another experiment, Abdullah *et al.* (2002) studied the effect of salinity on photosynthate translocation in panicle branches and developing spikelets, carbohydrate content of different vegetative parts and suggested that reduction in grain number and grain weight in salinized panicles was not merely due to reduction in pollen viability and higher accumulation of Na^+ and less K^+ in different floral parts but also due to higher accumulation of photosynthates (sugar) in primary and secondary panicle branches, panicle main stalk and panicle stem coupled with reduced activity of starch synthetase in developing grains.

Gypsum ($CaSO_4$, $2H_2O$) is widely used for ameliorating saline/sodic soils due to its tendency of replacing its Ca^{2+} with exchangeable Na^+ on the soil complex. In addition, gypsum application to saline/sodic soils improve yield of paddy and forage grasses in arid and semi arid regions due to the effects of Ca^{2+} on plant composition such as decrease in the concentration of Na and improve plant-tissue concentrations of P, K, Zn, Cu, Mg and K:Na ratio (Rengel, 1992). The addition of supplemental Ca to the root environment was a means of enhancing plant tolerance to salt stress (Epstein, 1998). This might favour the increase of Na^+ inside the cells, change enzyme activity resulting in cell metabolical alterations; disturbance in K^+ uptake and partitioning in the cells, and throughout the plant that might even affect stomatal opening, thereby, impairing the ability of the plant to grow. This author assumed that the addition of Ca^{2+} to the root environment of salt stressed plants would maintain or enhance the selective absorption of K^+ at high Na^+ concentrations and prevent the deleterious effects of the excess of Na^+. Another role attributed to supplemental Ca^{2+} addition was its help in osmotic adjustment and growth via the enhancement of compatible organic solutes accumulation (Girija *et al.*, 2002). Under salt stress conditions there was a decrease in the Ca/Na ratio in the root environment which affected membrane properties, due to displacement of membrane-associated Ca^{2+} by Na^+, leading to a disruption of membrane integrity and selectivity (Cramer *et al.*, 1985; Kinraide, 1998).

Aslam *et al.* (1993) observed significant reduction in shoot and root fresh weights by different types of salinity such as NaCl alone, NaCl + $CaCl_2$, Na_2CO_3 alone and a salts mixture. On the plant growth, NaCl alone was found to be the most toxic, Na_2CO_3 alone was the least harmful, and NaCl + $CaCl_2$ and the salts mixture were intermediate. They found similar results in both solution culture experiment and the experiments conducted in salinized soils. They considered the better root growth under high salinity condition as the capacity of the tolerant cultivars to combat the adverse effect of salinity. Aslam *et al.* (2001) investigated the effect of supplemental Ca on rice growth and yield in solution and soil cultures, and in naturally salt affected field. In solution culture, Ca was applied at 5, 10, 20, 40, 80 and 160 µg/mL with 80 mM NaCl and without NaCl and in soil culture 0, 50, 100 and 200 kg Ca ha^{-1} was applied to artificially prepared salinity (EC 9 dSm^{-1}). Three cultivars, differing in salt tolerance, were used, namely K8-282 (salt tolerant), BG 402-4 (moderately tolerant) and IR-28 (salt sensitive). Application of Ca at 20-40 µg/mL improved tillering capacity, shoot and root length, shoot and root weights in solution culture in the presence of NaCl. Shoot Na^+ and Cl^- decreased, whereas K^+ concentration and K^+/Na^+ ratio increased because of Ca supply to saline medium. Grain and straw yields, plant height and panicle length were significantly higher in saline compared to saline sodic soil. Application of 200 kg Ca ha^{-1} proved statistically superior to the control in respect of panicle length, number of tillers, grain and straw yields under both saline and saline sodic soil as well as in naturally salt-affected field. Seed setting was improved in all cultivars because of external Ca supply to saline and saline sodic soils. Aslam *et al.* (2003) stated that an increase in potassium and K^+/Na^+ ratio was an indication of salt tolerance due to the application of additional Ca in both salt tolerant and susceptible rice cultivars under saline environment. These authors mentioned that salt affected soils showed an improvement in the paddy yield of both salt tolerant and salt sensitive rice cultivars due to Ca application as gypsum at the rate of 25% of gypsum requirement of soil.

Franco *et al.* (1999) studied the effect of supplemental $CaCl_2$ on growth and osmoregulation in NaCl stressed cowpea seedlings. They found that salinity inhibited the length of root and shoot of cowpea but the inhibitory effect could be ameliorated by the addition of Ca^{2+}. The concentration of organic osmoregulators (proline, soluble carbohydrates, soluble amino-nitrogen, and soluble proteins) increased in root tips of seedlings grown in salt-stressed condition with supplemental Ca. They indicated that Ca^{2+} could have a protective effect in root tips, which is of fundamental importance for the maintenance of root elongation in NaCl stressed cowpea seedlings.

Considerable improvements in salinity tolerance have been made in crop species in recent times through conventional selection and breeding techniques (Shannon, 1998; Ashraf, 1994a; 2002). Most of the selection procedures have been based on differences in agronomic characters, which represent the combined genetic and environmental effects on plant growth and include the integration of the physiological mechanisms conferring salinity tolerance. Typical agronomic selection parameters for salinity tolerance are yield, biomass, plant survivality, plant height, leaf area, leaf injury, relative growth rate and relative growth reduction.

Many scientists have suggested that selection is more convenient and practicable if the plant species possesses distinctive indicators of salt tolerance at the whole plant, tissue or cellular level (Ashraf, 2002; Epstein and Rains, 1987; Jacoby, 1999; Munns, 2002).

Physiological criteria are able to supply more objective information than agronomic parameters or visual assessment while screening for component traits of complex characters (Yeo, 1994). There are no well-defined plant indicators for salinity tolerance that could practically be used by plant breeders for improvement of salinity tolerance in a number of important agricultural crops. This is partly due to the fact that the mechanism of salt tolerance is so complex that variation occurs not only amongst species but, in many cases, also among cultivars within a single species (Ashraf, 1994a; 2002). During the course of plant growth, the form and functions of various organs undergo significant change and the ability of the plant to react to salinity stress depend on those genes that are expressed at the stage of development during which the stress is imposed (Epstein and Rains, 1987). The mechanism of salinity tolerance becomes even more complicated when the response of a plant also varies with the concentration of saline medium and the environmental conditions in which the plant is grown.

Osmotic adjustment in plants subjected to salt stress can occur by the accumulation of high concentration of either inorganic ions or low molecular weight organic solutes. Although both of these play a crucial role in higher plants grown under saline conditions, their relative contribution varies among species, among cultivars and even between different compartments within the same plant (Ashraf, 1994a). The compatible osmolytes generally found in higher plants are of low molecular weight sugars, organic acids, amino acids, proteins and quaternary ammonium compounds.

Choi *et al.* (2003) observed that the plant height decreased in the 0.5% saline water in the soil. Khan *et al.* (1997) conducting a pot experiment with three rice cultivars reported that plant height was seriously decreased by salinity. Similar opinion was also postulated by

Saleque *et al.* (2005). During vegetative period, the most common salinity effect was stunting of plant growth, whereas leaf withering was less apparent (Alam *et al.*, 2001). The mutant variety maintained its superiority in various characteristics such as plant height, higher number of fertile panicles per plant and high plant yield (Baloch *et al.*, 2003).

According to Cram (1976), of the various organic osmotica, sugars contribute up to 50% of the total osmotic potential in glycophytes subject to saline conditions. The accumulation of soluble carbohydrates in plants has been widely reported as response to salinity or drought, despite a significant decrease in net CO_2 assimilation rate (Popp and Smirnoff, 1995; Murakeozy *et al.*, 2003). Ashraf and Tufail (1995) determined the total soluble sugars content in five sunflower accessions differing in salt tolerance. They found that the salt tolerant lines had generally greater soluble sugars than the salt sensitive ones. Ashraf and Harris (2004) suggested that considerable variations in the accumulation of soluble sugars in response to salt stress were evident at both inter-specific and/or intra-specific levels and even among lines of which all were salt tolerant.

Several salt-induced proteins have been identified in plant species and have been classified into two distinct groups such as (i) salt stress proteins, which accumulate only due to salt stress and (ii) stress associated proteins, which also accumulate in response to heat, cold, drought, water-logging and high and low mineral nutrients (Pareek *et al.*, 1997; Ali *et al.*, 1999; Mansour, 2000). Proteins that accumulate in plants grown under saline conditions may provide a storage form of nitrogen that is neutralized when stress is over and may play a role in osmotic adjustment (Singh *et al.*, 1987). A higher content of soluble proteins has been observed in salt tolerant than in salt sensitive cultivars of barley, sunflower (Ashraf and Tufail, 1995) and rice (Lutts *et al.*, 1996; Pareek *et al.*, 1997).

Pareek *et al.* (1997) also suggested that stress proteins could be used as important molecular markers for improvement of salt tolerance using genetic engineering techniques.

Amino acids have been reported to have accumulated in higher plants under salinity stress (Ashraf, 1994b; Mansour, 2000). The important amino acids are alanine, arginine, glycine, serine, leucine and valine, together with the imino acid - proline and the non-protein amino acids- citrulline and ornithine (Mansour, 2000). Lutts *et al.* (1996) found that proline did not take part in osmotic adjustment in salt stressed rice and its accumulation seemed to be a symptom of injury rather than an indicator of salt tolerance. On the contrary, Garcia *et al.* (1997) reported that exogenously applied proline exacerbated the deleterious effects of salt on rice. The salt tolerant rice cultivars Nona Bokra and IR 4630 accumulated less proline in their leaves than the salt sensitive Kong Pao and IR 31785 (Lutts *et al.*,1996). These contrasting reports on the role of proline in salt tolerance and its use as selection criterion for salt tolerance in rice has been questioned.

Regulation of ion transport is one of the important factors responsible for salt tolerance of plants. Membrane proteins play a significant role in selective distribution of ions within the plant or cell (Ashraf and Harris, 2004). According to Du-Pont (1992) the membrane proteins involved in cation selectivity and redistribution of Na^+ and K^+. These proteins are: (a) primary H^+-ATPases which generate the H^+ electrochemical gradient that drives ion transport, (b) Na^+/H^+ antiports in the plasma membrane for pumping excess Na^+ out of the cell, (c) Na^+/H^+ antiports in the tonoplast for extruding Na^+ into the vacuole and (d) cation channels with high selectivity for K^+ over Na^+. It is well established that Na^+

moves passively through a general cation channel from the saline growth medium into the cytoplasm of plant cells (Marschner, 1995; Jacoby, 1999; Mansour *et al.*, 2003) and the active transport of Na^+ through Na^+/H^+ antiports in plant cells is also evident (Shi *et al.*, 2003). Salt tolerance in plants is generally associated with low uptake and accumulation of Na^+, which is mediated through the control of influx and/ or by active efflux from the cytoplasm to the vacuoles and also back to the growth medium (Jacoby, 1999). Energy-dependent transport of Na^+ and Cl^- into the apoplast and vacuole can occur along the H^+ electrochemical potential gradients generated across the plasma membrane and tonoplast (Hasegawa *et al.*, 2000). The tonoplast H^+ pumps (H^+-ATPase and H^+-pyrophosphatase) also play a significant role in the transport of H^+ into the vacuole and generation of proton (H^+) which operates the Na^+/H^+ antiporters (Mansour *et al.*, 2003; Blumwald, 2000).

CHAPTER III
MATERIALS AND METHODS

The materials and methods followed during entire period of the experiment are described in this chapter.

3.1 Site of the experiment

The experiment was conducted at the Nethouse and Laboratory of Department of Agricultural Chemistry of the Sher-e-Bangla Agricultural University, Dhaka. The experimental site falls under the AEZ (Agro-Ecological-Zone)-28 (Madhupur Tract) of Bangladesh.

3.2 Experimental period

The experiment was conducted in pots during Boro rice cropping season (December to June) of the year of 2008- 09.

3.3 Selection of cultivars

There were 4 rice cultivars used as salt tolerant and susceptible which were collected from Bangladesh Rice Research Institute (BRRI). These cultivars were Pokkali, BR-28, BRRI Dhan 29 and IR 29.

3.4 Experimental design

The experiment was set in Completely Randomized Design (CRD) having two factors with three replications.

Factor 1: Cultivar- 4 (V_1-Pokkali, V_2-BR 28, V_3- BRRI Dhan 29 and V_4- IR 29)

Factor 2: Salinity level- 5 (0, 3, 6, 9 and 12 dS m^{-1})

Replication: 3

The four cultivars in combination with five salinity levels were randomly assigned to 60 experimental pots.

3.5 Salinity treatments

The five salinity treatments were 0(control), 3, 6, 9 and 12 dSm^{-1}. The different salinity levels were obtained by dissolving commercial salt (NaCl) at the rate of 640 mg per litre distilled water for 1 dSm^{-1} salinity level. The control *i.e.* 0 dSm^{-1} was maintained using distilled water only.

3.6 Collection and preparation of soil

The soils of the experiments were collected from the Sher-e-Bangla Agricultural University (SAU) farm. The soil was non-calcarious Red Brown Terrace soil with loamy texture belonging to the AEZ Madhupur Tract. The collected soil was pulverized and inert materials, visible insect pest and plant propagules were removed. The soil was dried in the sun, crushed carefully and thoroughly mixed.

3.7 Sterilization of seed

Prior to germination seeds were surface sterilized with 1% sodium hypochlorite solution. The glass vials containing distilled water for seed rinsing was sterilized for 20 minutes .

3.8 Sowing of seeds in seed bed

Sterilized seeds were soaked with water for 24 hours, washed thoroughly in clean water, and incubated for sprouting, which were sown in the wet seed bed. Required amount of fertilizers were applied one day before sowing seeds in the seed bed.

3.9 Raising of seedlings

The seedlings were grown in pots and the soil was used as growth medium. Chemical fertilizers namely urea, triple supper phosphate (TSP) and muriate of potash (MOP) were used for N, P and K at the rate of 120, 100 and 75 kg/ha respectively before final preparation of the seed bed. The fertilizers were applied one day before sowing seeds in the seed bed. Sterilized seeds were imbibed in distilled water for 24 hours and then washed thoroughly in fresh water, and the seeds were incubated for sprouting. After sprouting, they were placed in the pots.

3.10 Seedling transplant in the pots:

The pots containing soil were moistened with water. Five weeks old seedlings of selected rice cultivars were transplanted in the respective pots. Two weeks after transplanting the salt solutions were applied in each pot according to the treatments. To avoid osmotic shock, salt solutions were added in three equal installments on alternate days until the expected conductivity was reached. The electric conductivity (EC) of each pot was measured everyday with a EC meter and necessary adjustments were made by adding water.

3.11 Intercultural operations

Weeds and algae grown in the pots and visible insects were removed by hands when necessary in order to keep the pots neat and clean. The soil was loosening by hand during the period of experiment. Watering was done in each pot to hold the soil water level and to keep the salt concentration constant when needed.

3.12 Harvesting

Plant samples were collected from the pots after ripening the grain of the selected rice varieties. After harvest, the plant samples were separated into roots, shoots and grains. In case of dead plants at the higher salinity levels were collected after completely dead and plant samples were separated into roots and shoots.

3.13 Collection of data

a. Grain yield hill^{-1}

The grain yield hill^{-1} was recorded by weighing after proper drying the grain.

b. Analysis of different chemical constituents of rice plant samples

Rice plants after harvest were separated into roots and shoots and rinsed repeatedly with tap water and finally with distilled water and then dried in an oven at 70° C to obtain constant weight.

c. Grinding:

Oven-dried samples were ground in a Wiley Hammer Mill, passed through 40 mesh screens, mixed well and stored in plastic vials.

d. Digestion

Rice plant samples such as stem and leaf were analysed to determine the amount of N (nitrogen), P (phosphorous), Na (sodium), K (potassium), Ca (calcium) and Mg (magnesium) content therein. All elemental analyses were conducted on acid digested material through Micro-Kjeldahl digestion system (Thomas *et al*., 1967). The content of total N was measured by Kjeldahl distillation method and P was measured by Spectrophotometer. Na and K were measured by Flame Emission Spectrophotometer and Ca and Mg were measured by Atomic Absorption Spectrophotometer.

3.14 Statistical analysis

The collected data were analyzed statistically following completely randomized design by MSTAT-C computer package programme developed by Russel (1986). The treatment means were compared by Least Significance Differences (LSD), Duncan's Multiple Range Test (DMRT) and regression lines were performed as and when necessary.

CHAPTER IV
RESULTS AND DISCUSSION

This chapter includes the experimental results along with discussions. Effects of different salinity levels on the content of N, P, K, Na, Ca and Mg in stem and leaf of four rice varieties i.e., Pokkali, BR 28, BRRI dhan 29 and IR 29 has been discussed in this chapter.

The results are discussed under the following heads-

4.1 Nitrogen

4.1.1 Effects of variety

Nitrogen (N) concentration in leaf and stem of four rice cultivars significantly varied under different salinity levels. The highest N (0.46%) content in leaf was recorded in IR 29 which was statistically identical with BRRI Dhan 29 and BR 28 and it was lowest (0.32 %) in Pokkali. The highest N (0.42%) content in stem was recorded in Pokkali and it was lowest (0.39%) in BRRI Dhan 29 (Table 1).

Table 1. Effects of variety on the N (%) of stem & leaf (mean of 5 salinity levels)

Variety	N in stem	N in leaf
Pokkali	0.42 a	0.32 b
BR 28	0.41 ab	0.44 a
BRRI Dhan 29	0.39 b	0.45 a
IR 29	0.41 ab	0.46 a
Significant level	**	**
$LSD_{0.05}$	**0.023**	**0.023**
CV (%)	**5.67**	**5.12**

** 1% level of significance

4.1.2 Effects of salinity

The effect of different salinity levels on Nitrogen content in stem and leaf of rice plant significantly differed (Fig. 1). The highest (0.61%) and the lowest (0.31%) nitrogen (N) in leaf were found under 9 and 0 dSm^{-1} levels of salinity, respectively. On the other hand the highest (0.43%) and the lowest (0.39 %) N in stem were found under 12 dSm^{-1} and 3 dSm^{-1} levels of salinity, respectively (Appendix 1).

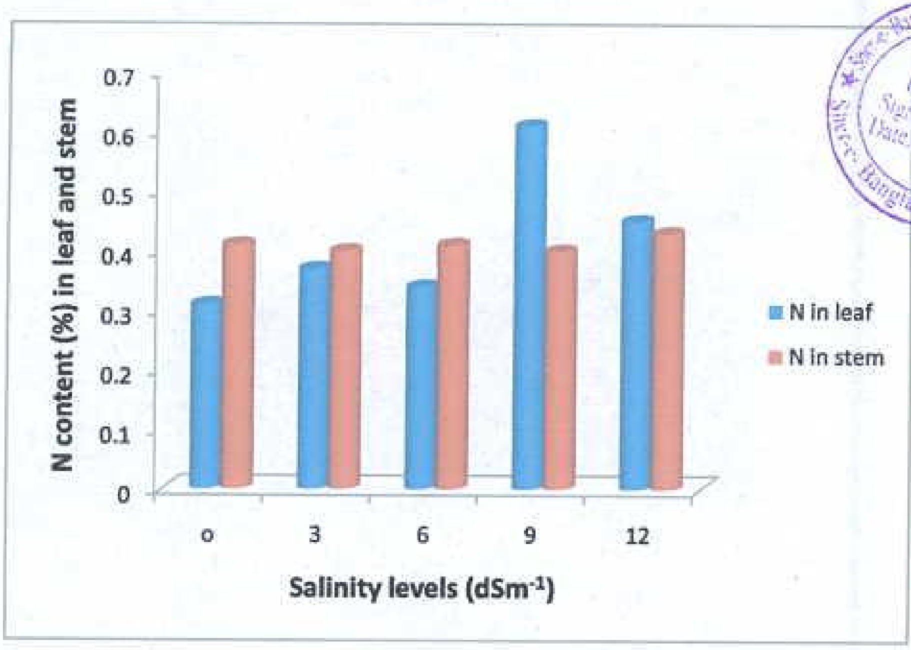
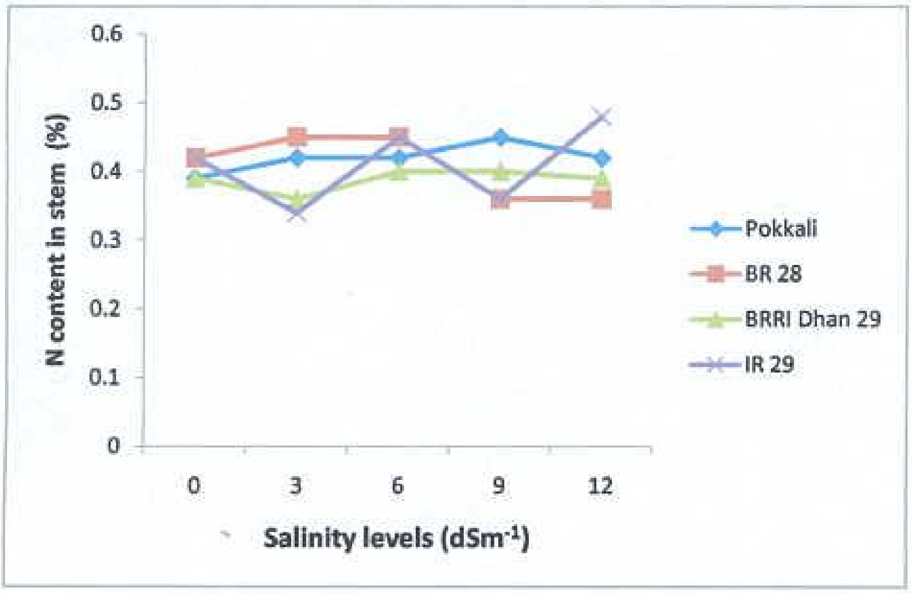


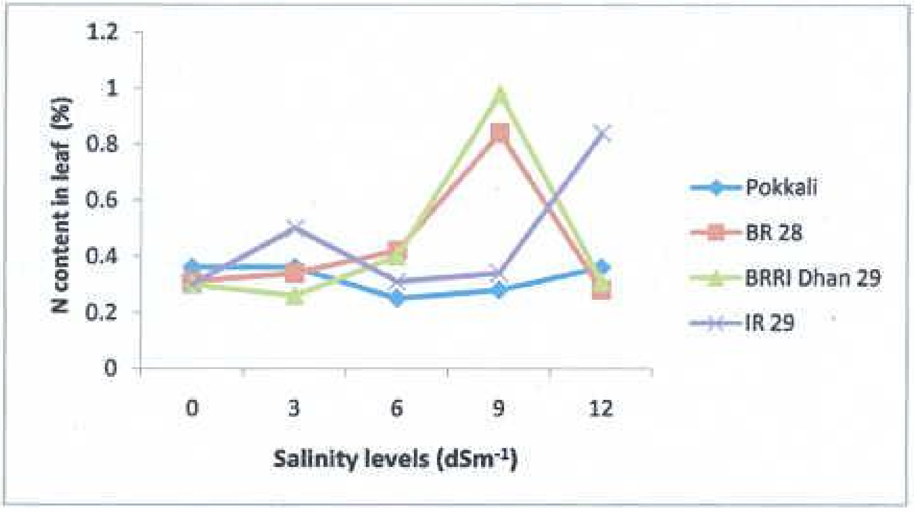
Figure 1. Effects of different salinity levels on nitrogen content of rice leaf and stem (mean of 4 cultivars)

4.1.3 Interaction effect of variety and salinity

The effect of different salinity levels on % N content in stem and leaf of four varieties significantly differed where % N content in stem increased with increase in salinity levels at cultivars Pokkali and BRRI Dhan 29 {Figure. 2 (A) }. In case of leaf, % N content increased in varieties BR 28 and BRRI Dhan 29 upto 9 dSm^{-1} salinity level and thereafter decreased {Figure 2(B)}.



(A)



(B)

Figure 2. Interaction effect of variety and salinity on (A) N content in stem and (B) N content in leaf

Considering the combined effect of salinity and cultivars, the % N content in stem of rice was highest (0.48 %) in IR 29 at 12 dSm^{-1} salinity and it was lowest (0.34 %) in IR 29 at 3 dSm^{-1} level of salinity. The % N content in leaf of rice was highest (0.98 %) in BRRI

Dhan 29 at 9 dSm^{-1} salinity and it was lowest (0.25 %) in Pokkali at 6 dSm^{-1} level of salinity. Salinity had positive effect on % N in rice stem (Appendix 2).

Baba and Fujiyama (2003) found that Na-salinization resulted in nutritional imbalance in rice but supplemental K and Ca prevented the deterioration of the nutrient status by enhancing the transport of cations (NH_4^+-N). Khan *et al.* (1992b) observed that the concentration of N, P, K, Ca, and Zn decreased, and that of Na and S increased with increasing salinity. They further stated that application of gypsum and Zn in coastal saline soil increased N, K, Ca, Mg, S and Zn concentrations but decreased Na and P. Transpiration rate and N content increased due to increasing salinity (Dobermann and Fairhurst, 2000).

4.2 Phosphorus

4.2.1 Effects of variety

It has been revealed from the Table 2 that the percent content of phosphorus (P) in leaf and stem of four selected rice cultivars significantly varied under different salinity levels. The highest P content in leaf (0.17%) was recorded in BR 28 which was statistically similar to Pokkali and it was lowest (0.12 %) in IR 29 that was similar to BRRI Dhan 29. The highest P content (0.25%) in stem was recorded in Pokkali and it was lowest (0.19 %) in IR 29 (Table 2).

Table 2. Effects of variety on the % P content in stem and leaf (mean of 5 salinity levels)

Variety	P in stem	P in leaf
Pokkali	0.25 a	0.16 a
BR 28	0.21 b	0.17 a
BRRI Dhan 29	0.23 a b	0.14 b
IR 29	0.19 c	0.12 b
Significant level	**	**
$LSD_{0.05}$	**0.023**	**0.023**
CV (%)	**11.22**	**9.74**

** 1% level of significance

4.2.2 Effects of salinity

The P content in stem and leaf of rice also significantly varied due to the effect of different salinity levels; where the P content in both stem and leaf increased upto 6 dSm^{-1} salinity level and then on ward it successively decreased (Figure 3). The highest P content in leaf (0.20%) was recorded in 6 dSm^{-1} and it was lowest (0.12 %) in 0 and 3 dSm^{-1} levels of salinity. The highest P content in stem (0.28%) was recorded in 6 dSm^{-1} and it was lowest (0.17 %) in 0 dSm^{-1} (Appendix 3).

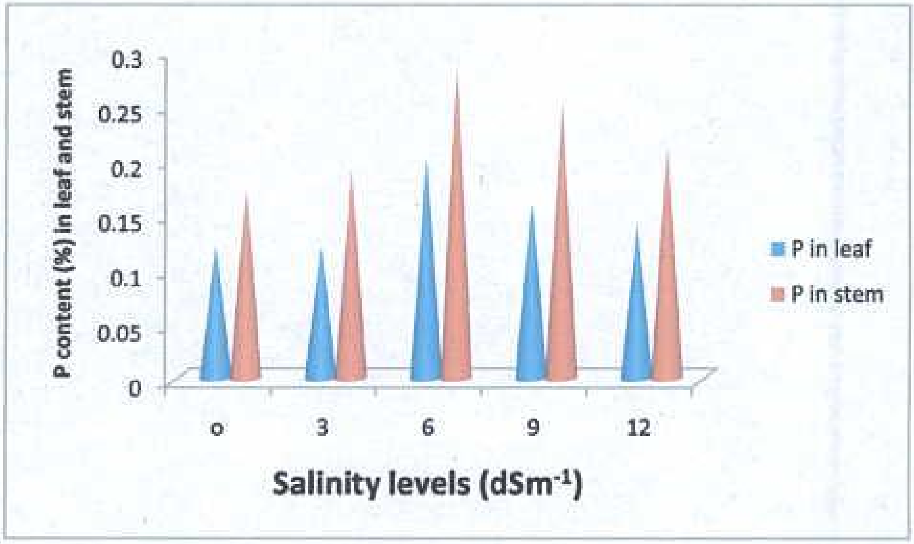
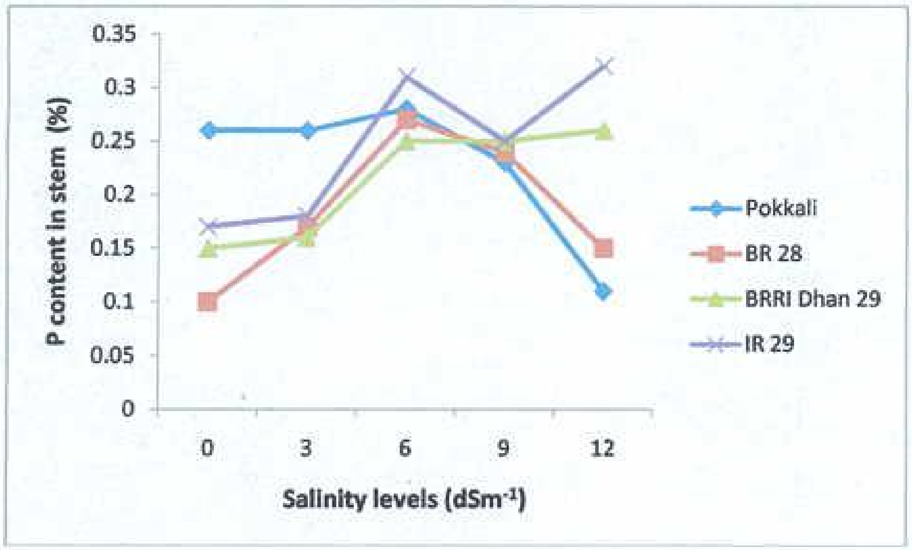


Figure 3. Effects of different salinity levels on phosphorus content of rice leaf and stem (mean of 4 cultivars)

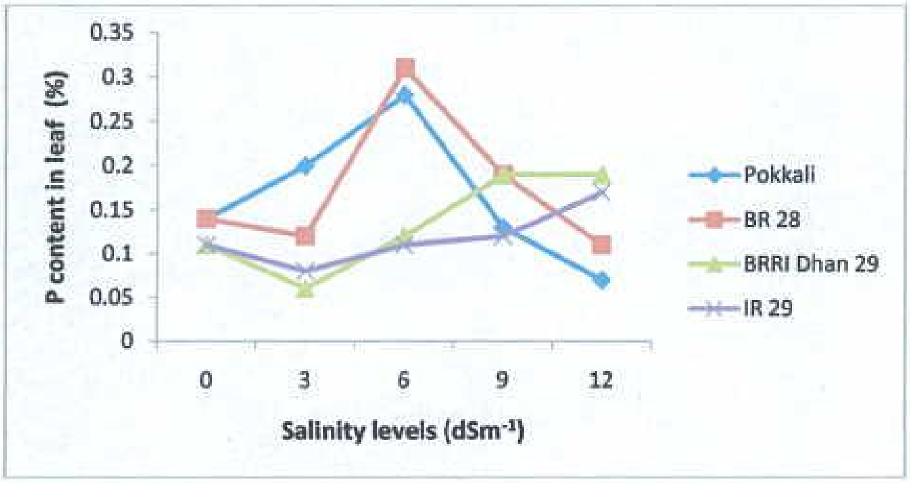
4.2.3 Interaction effect of variety and salinity

The interactions between salinity levels and cultivars, had significant influence on P content in leaf of all rice cultivars. The P content increased in stem of BRRI Dhan 29 upto the highest salinity and in case of Pokkali, IR 29 and BR 28, this increasing tendency found upto 6 dSm^{-1} salinity; thereafter decreased (Figure 4). In case of leaf, the % P content increased in the cultivar BRRI Dhan 29 and BR 28 upto 9 dSm^{-1} salinity level and then it decrease; whereas in the variety Pokkali and IR 29 % P content decreased upto 6 dSm^{-1} salinity level and thereafter increased upto highest salinity level {Figure 4 (A)}.

The % P content in stem of rice was highest (0.32 %) in IR 29 at 12 dSm^{-1} salinity and it was lowest (0.10 %) in BR 28 at 0 dSm^{-1} level of salinity. In leaf of rice, the % P content was highest (0.31 %) in BR 28 at 6 dSm^{-1} salinity and it was lowest (0.06 %) in BRRI Dhan 29 at 3 dSm^{-1} level of salinity (Appendix 4).



(A)



(B)

Figure 4. Interaction effect of variety and salinity on (A) P content in stem and (B) P content in leaf of four rice cultivars

Similar opinion also expressed by Mohiuddin *et al.* (1998) and Sarfraz *et al.* (2002). Yaduvanshi (2002) observed that continuous use of P fertilizer, green manuring and farmyard manure in gypsum amended sodic soils significantly enhanced the yields of rice and wheat and improved the available P status of the soil. Zhu *et al.* (2001) observed that F_3 populations exhibited higher concentration of Ca, P and lower Na accumulation in shoots in the presence of NaCl than the parental populations after 42 days of salt exposure. Khan *et al.* (1992b) observed that application of gypsum and Zn in coastal saline soil decreased Na and P concentrations in rice plant.

4.3 Potassium

4.3.1 Effects of variety

It appears from the results presented in Table 3 that there was a significant variation in potassium (K) content in four selected rice cultivars under different salinity levels. The highest K content in stem and leaf was found in Pokkali (0.24 % and 0.19%) and that was lowest (0.21% and 0.17 %) in IR 29 in case of stem and in BR 28 in case of leaf respectively .

Table 3. Effects of variety on the % K content of stem & leaf of rice plant (mean of 5 salinity levels)

Variety	K in stem	K in leaf
Pokkali	0.24 a	0.19 a
BR 28	0.23 ab	0.17 c
BRRI Dhan 29	0..24 a	0.18 b
IR 29	0.21 b	0.18 b
Significant level	**	**
$LSD_{0.05}$	**0.022**	**0.023**
CV (%)	**10.91**	**4.31**

** 1% level of significance

4.3.2 Effects of salinity

The Potassium (K) contents in stem and leaf of rice also significantly varied due to the effect of different salinity levels; where the K content decreased with the increasing level of salinity in both stem and leaf (Figure 5). The highest K content in leaf and stem (0.25 and 0.32 %) was recorded in 0 dSm^{-1} and it was lowest (0.13 and 0.15 %) in 12 dSm^{-1} salinity level respectively (Appendix-5).

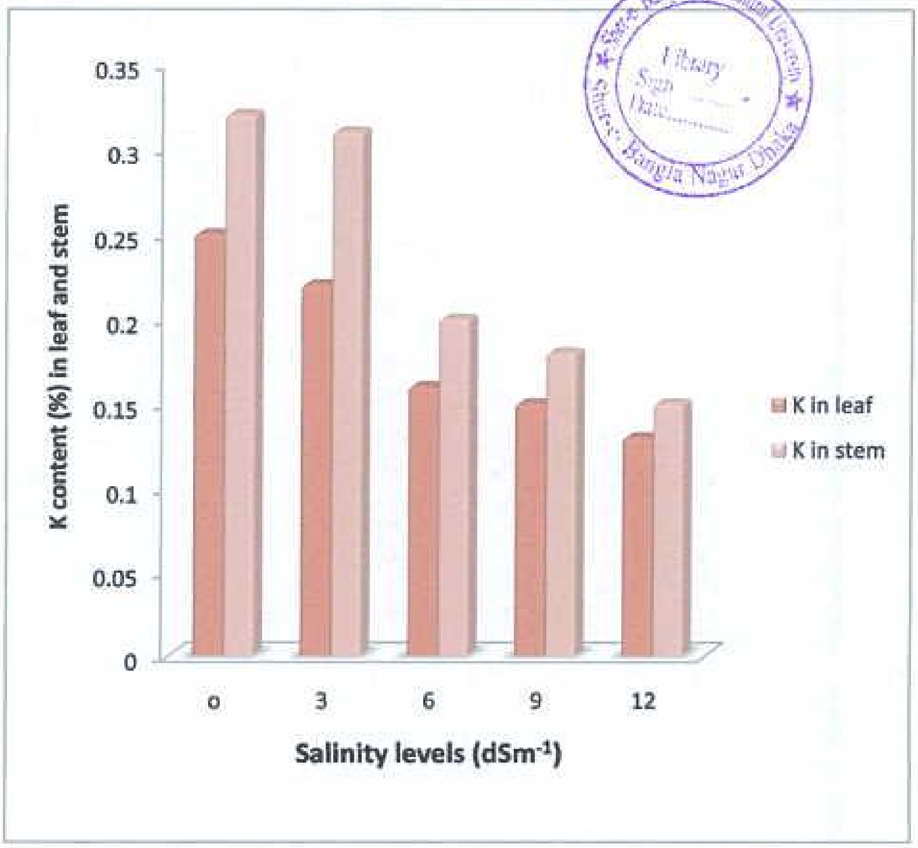
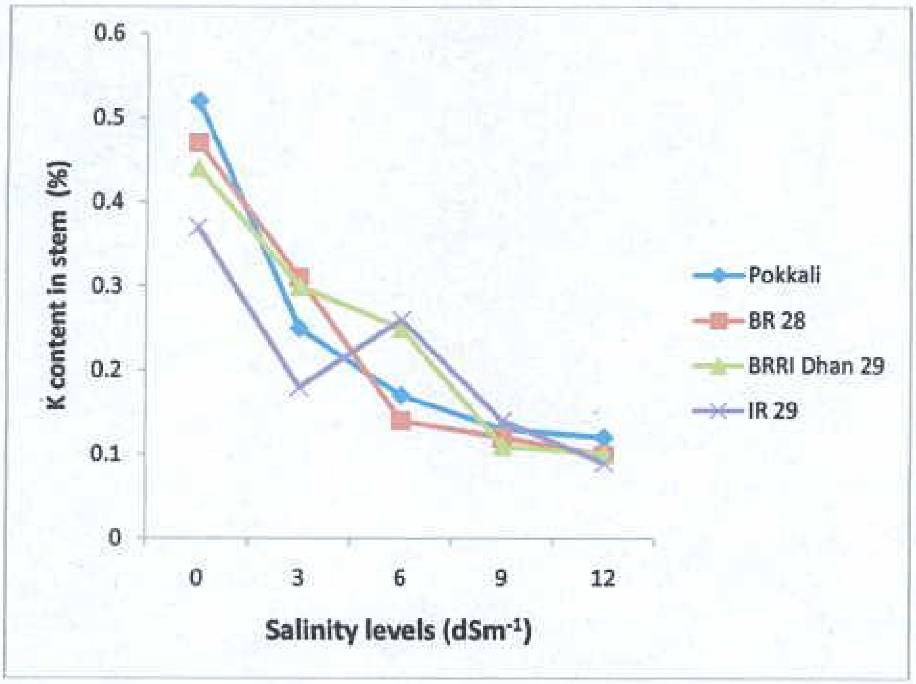


Figure 5. Effects of different salinity levels on K content(%) in leaf and stem

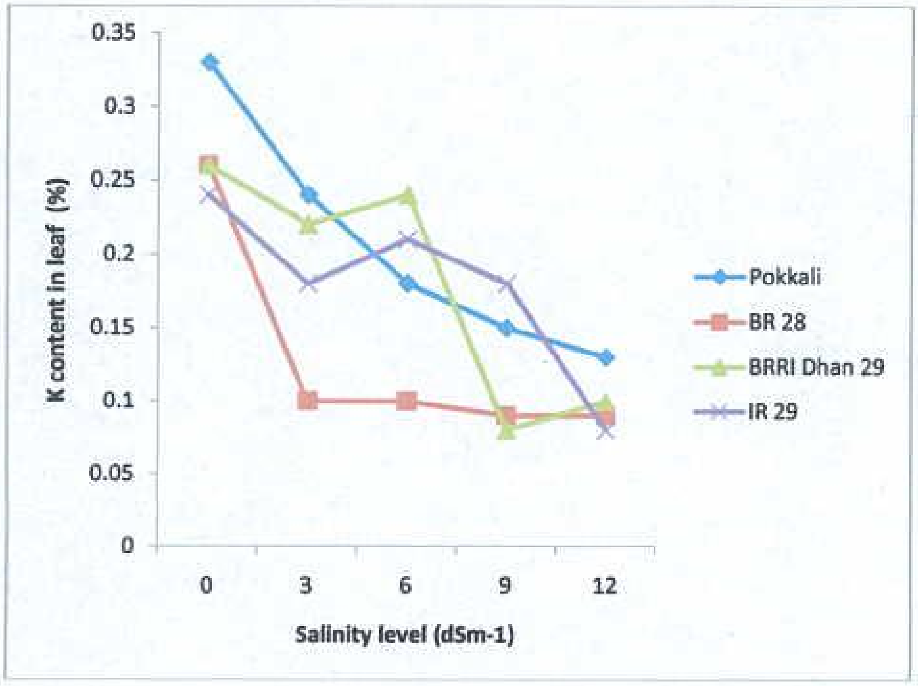
4.3.3 Interaction effect of variety and salinity

The combined effect of salinity and cultivar on content of K (%) in stem and leaf was found decreased significantly. The content of K in both stem and leaf of all the selected cultivars progressively decreased with increasing the salinity levels where this decreasing pattern was very sharp in BR 28 than those of other Cultivars (Figure 6). The highest K content (0.52%) in stem was found in Pokkali at 0 dSm^{-1} and it was lowest (0.09%) in the IR 29 cultivar at the 12 dSm^{-1} salinity level. The results in Appendix 6 show that the highest K content (0.33%) was in the leaves of Pokkali at 0 dSm^{-1} and it was lowest (0.08%) in the IR 29 cultivar at 12 dSm^{-1} salinity level.

These findings are in agreement with the observation of Feagley and Fenn (1998), Khan *et al.* (1992b), Pua *et al.* (2001), Aslam *et al.* (2001), Yaduvanshi (2002), Baba and Fujiyama (2003). The addition of supplemental Ca to the root environment has been suggested as a mean of enhancing plant tolerance to salt stress (Rengel, 1992; Epstein, 1998). Under salt stress conditions, Ca^{2+}/ Na^{+} ratio decreased in root environment which might have affected membrane properties due to displacement of membrane- associated Ca^{2+} by Na^{+}, leading to disruption of membrane integrity and ion selectivity (Cramer *et al.*, 1985; Kinraide, 1998). The disruption in membrane integrity of cells that would accentuate and change enzyme activity, disturbance in K^{+} uptake and partitioning in the cells throughout the plant might even affect stomatal opening (Epstein, 1998). This author also mentioned that the addition of Ca^{2+} to the root environment of salt stressed plants maintained or enhanced the selective absorption of K^{+} at high Na^{+} concentrations and prevented the deleterious effects of the excess of Na^{+}.



(A)



(B)

Figure 6. Interaction effect of variety and salinity on (A) K content in stem and (B) K content in leaf

4.4 Sodium

4.4.1 Effects of variety

The percent content of Na in leaf and stem of all the four selected rice cultivars varied significantly grown at different levels of salinity. Its content in leaf was highest (0.062 %) in BR 28 and lowest (0.041 %) in Pokkali. In stem the content of Na was highest (0.098 %) in IR 29 and lowest (0.062 %) in Pokkali **(Table 4)**

Table 4. Effects of variety on the Na content (%) in stem & leaf of rice plant (mean of 5 salinity levels)

Variety	Na in stem	Na in leaf
Pokkali	0.062 d	0.041 d
BR 28	0.085 b	0.062 a
BRRI Dhan 29	0.073 c	0.054 b
IR 29	0.098 a	0.045 c
Significant level	**	**
$LSD_{0.05}$	**0.012**	**0.023**
CV (%)	**14.65**	**11.47**

** 1% level of significance

4.4.2 Effects of salinity

The sodium (Na) content in stem and leaf of rice significantly varied due to the effect of different salinity levels; where the Na content increased with the increasing level of salinity in both stem and leaf (Figure 7). The highest Na content in stem and leaf (0.098 and 0.063%) were recorded in 12 dSm^{-1} level of salinity which were statistically identical with 9 dSm^{-1} level of salinity and then were lowest (0.045 and 0.037 %) in 0 dSm^{-1} respectively (Appendix-7).

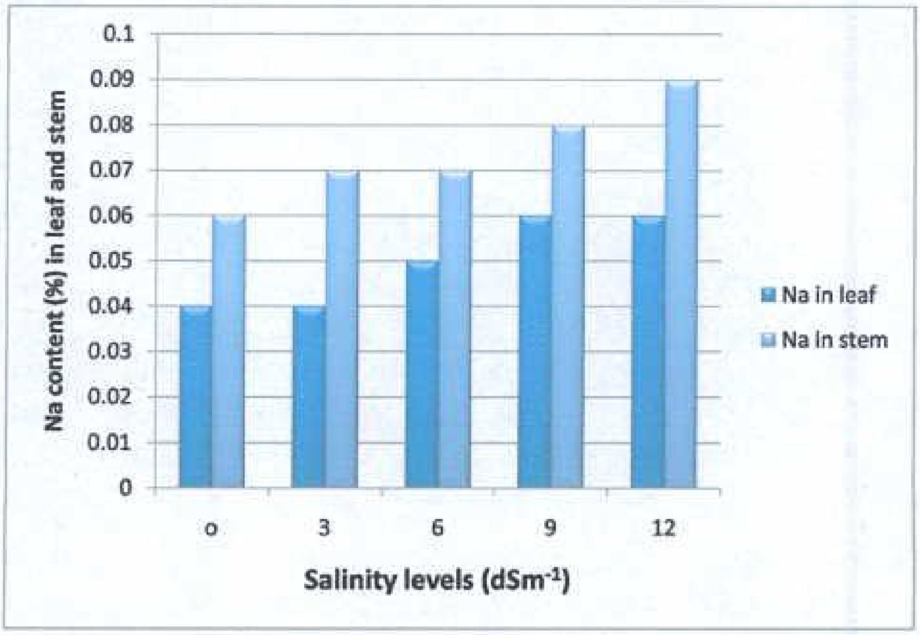
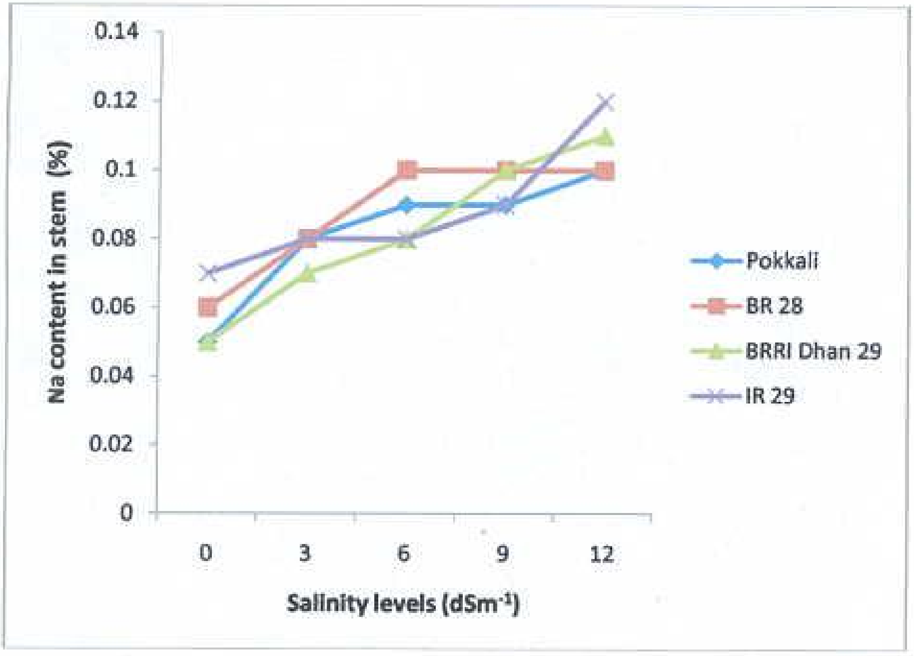


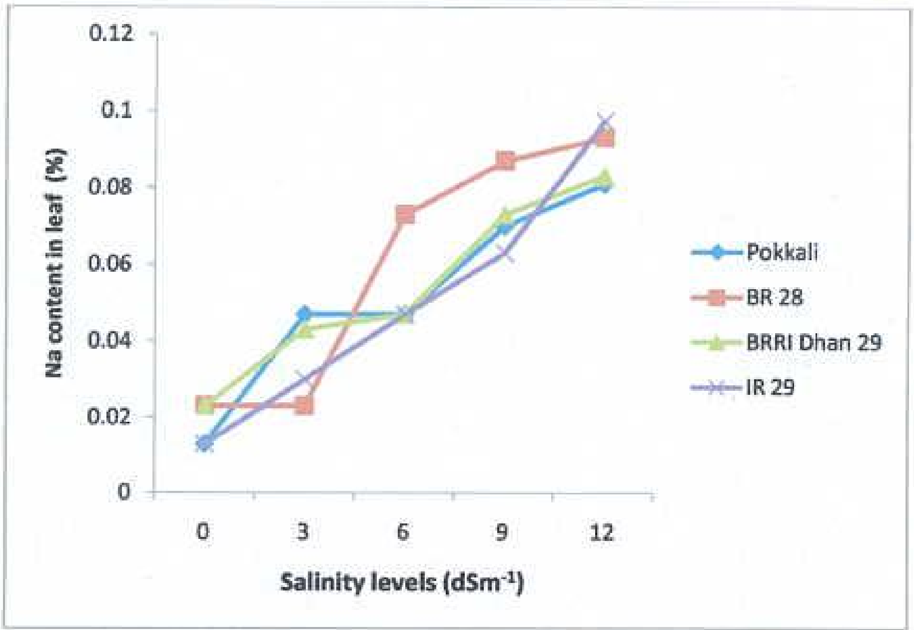
Figure 7 . Effects of different salinity levels on Na content in leaf and stem of rice plant (mean of 4 cultivars)

4.4.3 Interaction effect of variety and salinity

The combined effect of salinity and cultivar on content of % Na in stem and leaf was found significant. The Na content increased with the increasing level of salinity in both stem and leaf of all cultivars; where the increasing pattern were very sharp in both stem and leaf of cultivar BR 28 (Figure 8). The highest Na content (0.12 %) in stem was found in IR 29 at 12 dSm^{-1} and it was lowest (0.05%) in the cultivar Pokkali at the 0 dSm^{-1} salinity level. The results in Appendix 8 show that the highest Na content (0.97%) was in the leaves of IR 29 at 12 dSm^{-1} and it was lowest (0.013%) in the cultivar Pokkali at the 0 dSm^{-1} salinity level. Ashraf *et al.* (2001) found that applied NaCl enhanced Na^+ concentration in tissues of four rice varieties (two salt sensitive and two salt-tolerant). Cha-um *et al.* (2005) and Fageria (2003) also found similar results.



(A)



(B)

Figure 8. Interaction effect of variety and salinity on (A) Na content in stem and (B) Na content in leaf

4.5 Calcium

4.5.1 Effects of variety

The results presented in Table 5 show that the calcium (Ca) content % in rice leaf and stem of the four selected cultivars had not significantly affected due to the mean effect of different salinity levels. The Ca content recorded in stem of Pokkali and IR 29 was same (0.02%) and it was lowest (0.018 %) in BRRI Dhan 29. The Ca content recorded in leaf of Pokkali and BRRI Dhan 29 were same (0.039%) and it was lowest (0.038 %) in BR 28 and the highest (0.041 %) amount was observed in IR 29 (**Table 5**).

Table 5. Effects of variety on the Ca content (%) in stem & leaf of rice plant (mean of 5 salinity levels)

Variety	Ca in stem	Ca in leaf
Pokkali	0.020	0.039
BR 28	0.019	0.038
BRRI Dhan 29	0.018	0.039
IR 29	0.020	0.041
Significant level	**NS**	**NS**
$LSD_{0.05}$	-	-
CV (%)	**12.58**	**14.65**

NS – Non-significant

4.5.2 Effects of salinity

The effect of different salinity levels on % Ca content in stem and leaf of rice plant did not differ significantly (Appendix 9). The Ca content recorded in stem were same (0.018 %) in 0, 6 & 9 dSm^{-1} and it was 0.021 % in 3 & 12 dSm^{-1}. The Ca content recorded in leaf was highest (0.045 %) in 0 dSm^{-1} and it was lowest (0.030 %) in 12 dSm^{-1} (Figure 9).

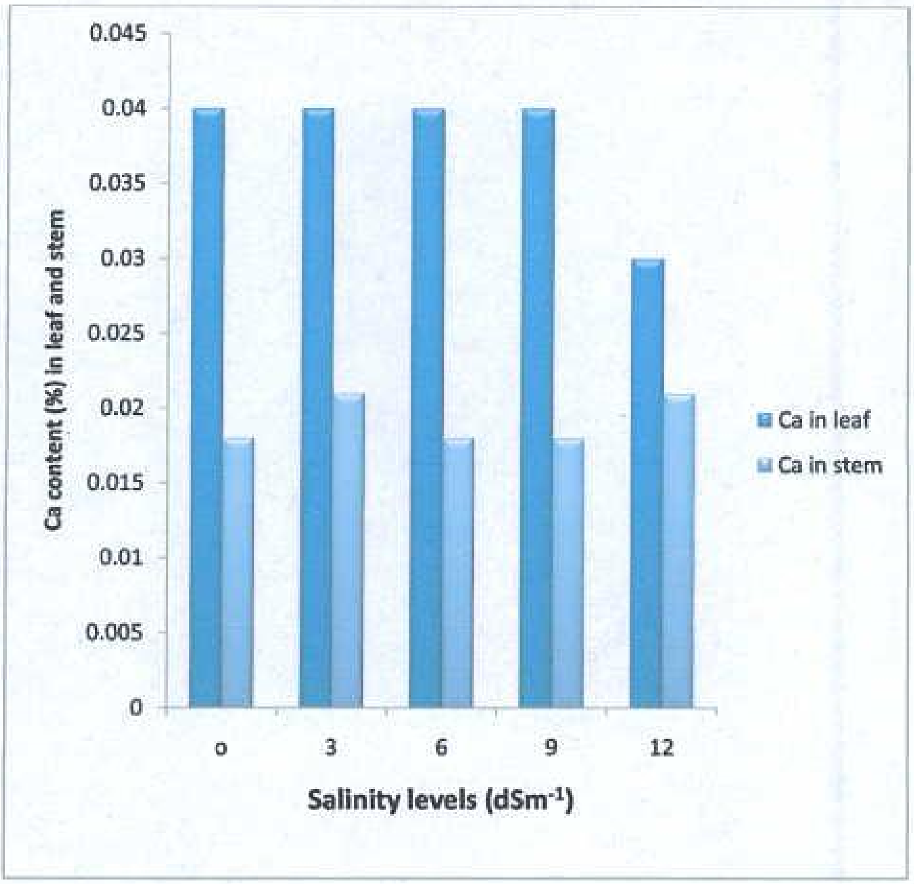


Figure 9. Effects of different salinity levels on Ca content in leaf and stem of rice plant

4.5.3 Interaction effect of variety and salinity

The combined effect of variety and salinity was found insignificant in case of Ca content (%) in stem and leaf (Table 6); where the highest Ca content (0.033 %) found in stem of Pokkali and IR 29 at 12 and 9 dSm^{-1} levels of salinity. In case of leaf, the highest (0.06 %) amount was found in Pokkali and IR 29 at 0 and 9 dSm^{-1} levels of salinity.

This is controverst to the findings of Qadar (1995) where he found that increasing sodicity stress decrease the Ca in shoots at 30 day after transplanting and at maturity.

Table 6. Effects of variety and salinity on the Ca content (%) in stem & leaf of rice plant

Variety	Salinity Level (dSm^{-1})	Ca in stem	Ca in leaf
Pokkali	0 dSm^{-1}	0.023	0.060
	3 dSm^{-1}	0.013	0.030
	6 dSm^{-1}	0.013	0.030
	9 dSm^{-1}	0.013	0.030
	12 dSm^{-1}	0.033	0.037
BR 28	0 dSm^{-1}	0.013	0.030
	3 dSm^{-1}	0.023	0.053
	6 dSm^{-1}	0.013	0.023
	9 dSm^{-1}	0.013	0.030
	12 dSm^{-1}	0.023	0.030
BRRI Dhan 29	0 dSm^{-1}	0.013	0.037
	3 dSm^{-1}	0.023	0.037
	6 dSm^{-1}	0.023	0.053
	9 dSm^{-1}	0.013	0.023
	12 dSm^{-1}	0.013	0.030
IR 29	0 dSm^{-1}	0.013	0.030
	3 dSm^{-1}	0.023	0.037
	6 dSm^{-1}	0.023	0.053
	9 dSm^{-1}	0.033	0.060
	12 dSm^{-1}	0.013	0.023
Significant level		**NS**	**NS**
LSD0.05		-	-
CV (%)		**12.58**	**14.65**

NS – Non-significant

4.6 Magnesium

4.6.1 Effects of variety

The concentration of magnesium % in the leaf and stem of the four selected rice cultivars differed significantly due to the mean effect of different salinity levels. The highest Mg content (0.23%) was found in the leaf of BRRI Dhan 29 and that was lowest (0.19%) in that of tolerant cultivar Pokkali due to the mean effect of different salinity levels. The highest Mg content (0.17%) in the stem was found in BRRI Dhan 29 which was statistically similar with BR 28 and IR 29 and that was lowest (0.13%) in cultivar Pokkali (Table 7).

Table 7. Effects of Variety on the Mg content (%) in stem & leaf of rice plant

Variety	Mg in stem	Mg in leaf
Pokkali	0.13 b	0.19 b
BR 28	0.16 a	0.22 ab
BRRI Dhan 29	0.17 a	0.23 a
IR 29	0.16 a	0.21 ab
Significant level	**	**
$LSD_{0.05}$	**0.023**	**0.033**
CV (%)	**15.82**	**9.18**

** 1% level of significance

4.6.2 Effects of salinity

The percent Mg content in leaf and stem of rice significantly increased with increasing the salinity levels. The highest Mg (0.25%) content in the leaf was found at 12 dSm^{-1} level of salinity and that was lowest (0.17%) in 0 dSm^{-1}. The highest Mg (0.19%) content in the stem was found in 12 dSm^{-1} and that was lowest (0.13%) in 0 dSm^{-1}. (Figure 10 & Appendix 10)

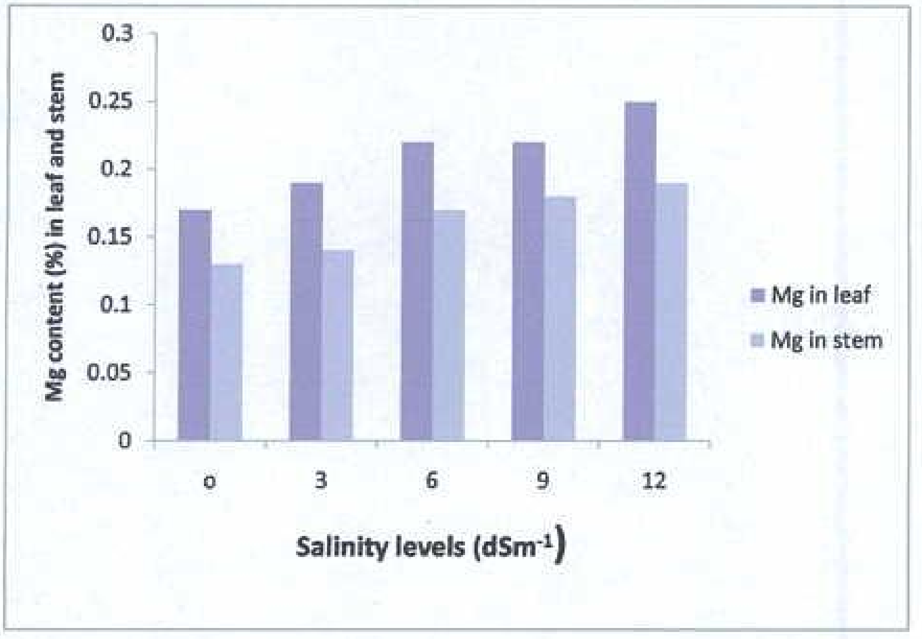
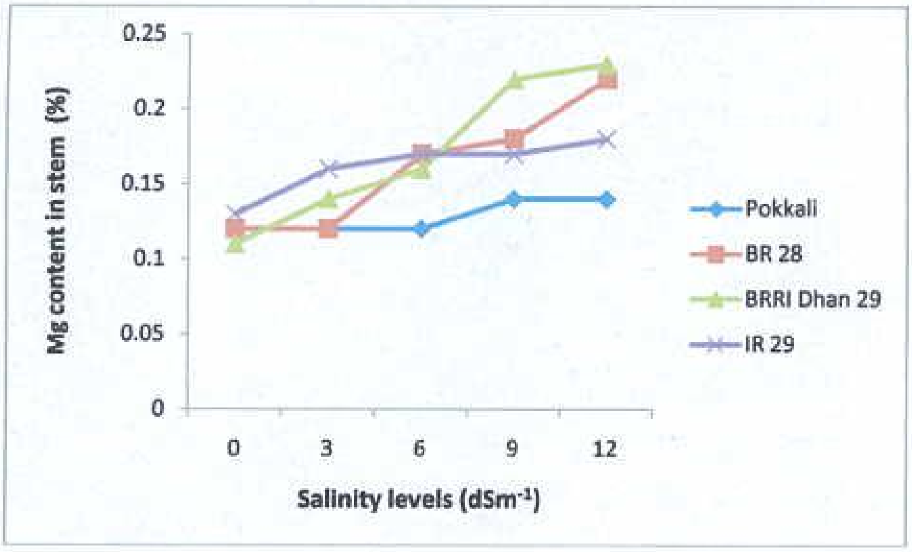


Figure 10. Effects of different salinity levels on Mg content (%) in leaf and stem of rice plant (mean of 4 cultivars)

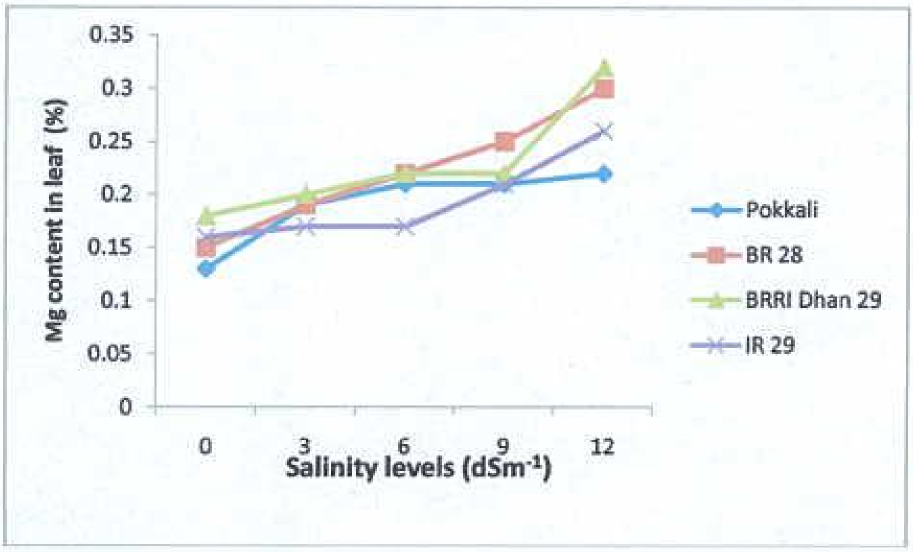
4.6.3 Interaction effect of variety and salinity

The combined effect of different salinity levels and four rice cultivars on Mg content (%) in stem and leaf differed significantly (Appendix 11). The Mg content increased with increasing level of salinity in both stem and leaf of all cultivars (Figure 11). In leaf the highest (0.32 %) Mg was found in BRRI Dhan 29 at 12 dSm^{-1} and it was lowest (0.13 %) in Pokkali at 3 dSm^{-1}. In stem the highest (0.23 %) Mg was found in BRRI Dhan 29 at 9 dSm^{-1} and it was lowest (0.11%) in BRRI Dhan 29 at 0 dSm^{-1} (Appendix 11).

Qadar (1995) found that Mg were slightly higher in the shoot in response to sodicity stress.



(A)



(B)

Figure 11. Interaction effect of variety and salinity on (A) Mg content in stem and (B) Mg content in leaf

4.7 Yield per hill

4.7.1 Effects of variety

The grain yield $hill^{-1}$ of four selected rice cultivars differed significantly due to the mean effect of different salinity treatments (Table 8). The highest grain yield $hill^{-1}$ (7.65 g) was found in cultivar Pokkali and the lowest yield (6.28 g) was recorded in IR 29. But intermediate and statistically identical results were found in cultivar BRRI Dhan 29 and BR 28.

Table 8. Effects of variety on Yield $hill^{-1}$ (g)

Treatments	Yield $hill^{-1}$ (g)
Pokkali	7.65 a
BR 28	6.40 b
BRRI Dhan 29	6.76 b
IR 29	6.28 c
Significance	**
$LSD_{0.05}$	0.1643
CV (%)	16.04

** 1% level of significance

4.7.2 Effects of salinity

A highly significant variation in grain yield $hill^{-1}$ of rice cultivars was observed due to the different salinity levels (Figure 12). The highest grain yield (14.53 g) $hill^{-1}$ was recorded at control treatment and it was lowest (0.52 g) at 12 dSm^{-1} level of salinity (Appendix 12).

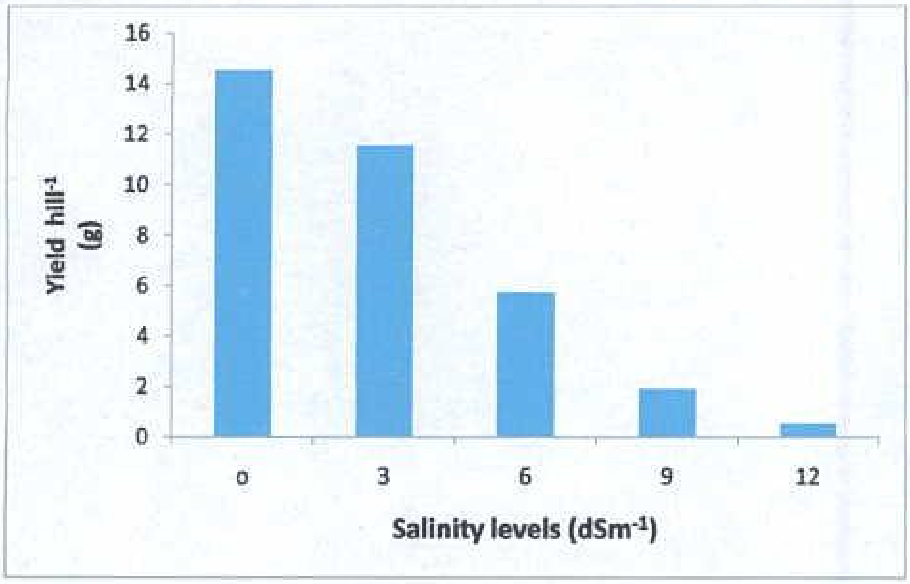


Figure 12. Yield hill^{-1} affected by various salinity levels

4.7.3 Interaction Effect of Variety and salinity

It appeared from the results that the variation in respect to grain yield hill^{-1} of selected four rice cultivars were decreased significantly due to different salinity levels (Figure 13). The highest grain yield hill^{-1} (16.75 g) was found in BRRI Dhan 29 at 0 dSm^{-1} salinity level and the lowest yield (0.12 g) was obtained in IR 29 at 12 dSm^{-1} level of salinity which was statistically identical with 9 dSm^{-1} level of salinity of that (IR 29) cultivar (Appendix 13).

Mishra *et al.* (1996) found that the reduction in grain yield was 28.9% in tolerant variety CSR10 while susceptible variety IR28 showed 98.2% yield reduction. Salinity reduced yield to nearly zero (Asch *et al.*, 2000). Grain yield is the function of number of panicles hill^{-1}, number of filled grain panicle^{-1} and 1000-grain weight. All the yield contributing characters contributed for the yield reduction hill^{-1} under saline conditions; contribution of the seriously affected number of unfilled grains panicle^{-1} was the highest (Grattan *et al.*, 2002).

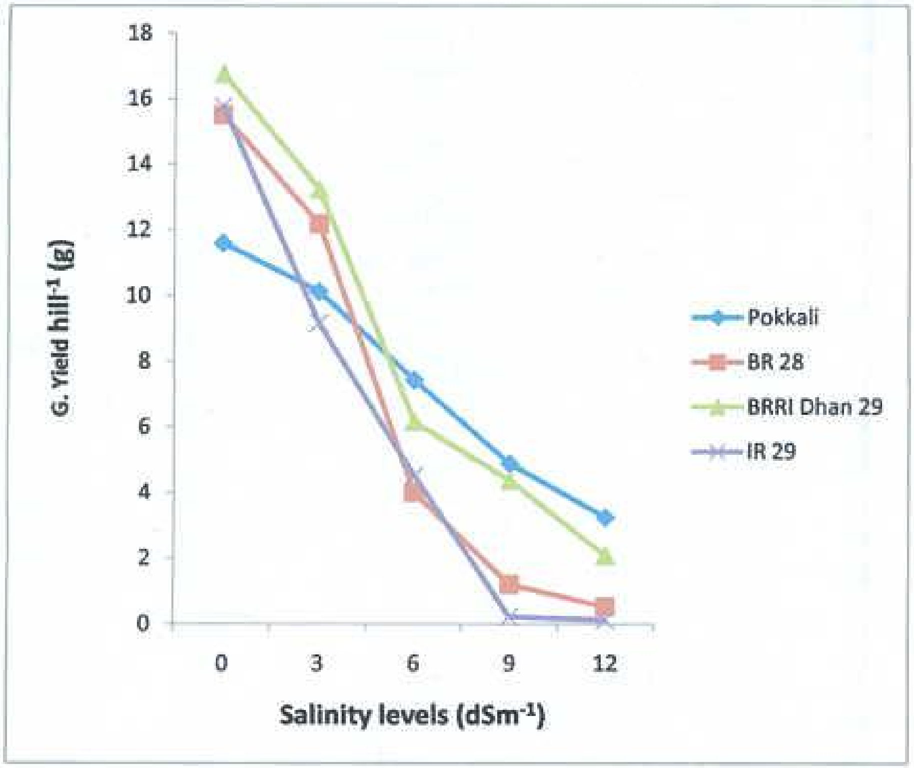


Figure 13. Interaction effect of variety and salinity on (A) Na content in stem and (B) Na content in leaf

They also reported that salinity affected rice yield at or above 3.0 dSm^{-1} level of salinity. The negative relationship between grain yield and salinity levels was also reported in rice (Khatun *et al.*, 1995; Arich *et al.*, 1998; Zeng and Shannon, 2000; Zeng *et al.*, 2001 and Zeng *et al.*, 2002). Starch synthetase activity in developing rice grains was inhibited very significantly under salinity stress and it was referred that sterility and significant reductions in seed setting in rice were not merely due to reduction or inhibition of different biochemical constituents and physiological functions, but were mainly due to limitation of soluble carbohydrate translocation in primary and secondary spikelets, accumulation of more Na^+ and less K^+ in all the floral parts, thus resulting in failure of seed set, thereby reducing the grain yield (Abdullah *et al.*, 2001 and Alam *et al.*, 2001).

Chapter V

SUMMARY AND CONCLUSION

A pot culture experiment was conducted to study the reclamation of salinity on yield and nutrient content of rice during the Boro season (December-June) of the year 2008-09 at Sher-e-Bangla Agricultural University, Dhaka-1207. The experiment was completed using four varieties namely Pokkali, BR 28, BRRI dhan 29 and IR 29; and five salinity levels (0, 3, 6, 9 and 12 dS m^{-1}).

In this study, the percent content of N, P, K, Na, Ca and Mg in stem and leaf and grain yield $hill^{-1}$ of the four selected cultivars were observed. Significant varietal differences were found in content of N, P, K, Na and Mg in stem and leaf . In stem N content was highest in Pokkali and lowest in BRRI Dhan 29. In leaf N content was highest in IR 29 and lowest in Pokkali. P content in stem was highest in Pokkali and lowest in IR 29 and in leaf it was highest in BR 28 and lowest in IR 29. In stem K content was highest in Pokkali and lowest in IR 29 and in leaf it was highest in Pokkali and lowest in BR 28. In stem Na content was highest in IR 29 and lowest in Pokkali and in leaf it was highest in BR 28 and lowest in Pokkali. Mg content was highest in BRRI Dhan 29 and lowest in Pokkali in both stem and leaf. Ca was found insignificant in both stem and leaf. Highest grain yield $hill^{-1}$ was obtained from Pokkali and lowest was in IR 29.

Almost all of the mineral elements showed significant changes due to the effect of salinity as well as grain yield $hill^{-1}$ except the element Ca. The content of N, Na and Mg increased gradually with the increasing level of salinity while K content decreased. P content increased upto 6 dS m^{-1} level of salinity and then decreased afterwards. In stem and leaf N was highest at 12 dSm^{-1} and lowest value in stem was found at 3 & 9 dSm^{-1} and in leaf it was at 0 dSm^{-1}. P content increased upto 6 dSm^{-1} in both stem and leaf and then decrease again but lowest values were obtained at 0 dSm^{-1}. Na content was highest at 12 dSm^{-1} and lowest at 0 dSm^{-1} in both leaf and stem. Mg content was also highest at 12 dSm^{-1} and lowest at 0 dSm^{-1} in both leaf and stem. Grain yield $hill^{-1}$ was highest at 0 dSm^{-1} and lowest at 12 dSm^{-1}.

Due to the interaction effect of variety and salinity the content of N, P, K, Na and Mg in stem and leaf and grain yield $hill^{-1}$ of the four selected cultivars varied significantly. The % N content in stem increased with increasing the salinity levels at cultivars Pokkali and BRRI Dhan 29 and in leaf N content increased in varieties BR 28 and BRRI Dhan 29 upto 9 dS m^{-1} level of salinity and then decreased. In case of P content in stem, it increased upto highest salinity at BRRI Dhan 29; whereas in leaf P content increased in BRRI Dhan 29 and BR 28 upto 9 dS m^{-1} level of salinity. The content of K decreased and Na and Mg contents increased in both stem and leaf of all rice cultivars with increase in salinity level.

It can be concluded that Pokkali is the best resistant cultivar among the four , BRRI Dhan 29 is moderate tolerant and IR 29 is susceptible to salinity.

Based on the results the following recommendations may be made -

- It may be possible to increase the rice production by cultivating Pokkali or other saline tolerant varieties in saline prone cultivable areas,.
- Plant Breeder may develop variety which is able to reduce the effect of salt stress and increase the yield.

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CHAPTER VII

Appendix

Appendix 1. Effects of different salinity levels on the %N content of stem & leaf of rice plant (mean of 4 cultivars)

Salinity Level(dSm^{-1})	N in stem	N in leaf
0	0.41 ab	0.31 d
3	0.39 b	0.37 c
6	0.41 ab	0.34 c
9	0.40 b	0.61 a
12	0.43 a	0.45 b
Significant level	**	**
$LSD_{0.05}$	**0.026**	**0.026**
CV(%)	**5.67**	**5.12**

Appendix 2. Effects of variety and salinity on the %N content of stem & leaf

Variety	Salinity Level (dSm^{-1})	%N in stem	%N in leaf
Pokkali	0	0.39 c-e	0.36 e
	3	0.42 bc	0.36 e
	6	0.42 bc	0.25 i
	9	0.45 ab	0.28 hi
	12	0.42 ab	0.36 e
BR 28	0	0.42 ab	0.31 f-h
	3	0.45 ab	0.34 e-g
	6	0.45 ab	0.42 d
	9	0.36 de	0.84 b
	12	0.36 de	0.28 hi
BRRI Dhan 29	0	0.39 c-e	0.30 g-i
	3	0.36 de	0.26 hi
	6	0.40 b-d	0.40 de
	9	0.40 b-d	0.98 a
	12	0.39 c-e	0.31 f-h
IR 29	0	0.42 bc	0.30 g-i
	3	0.34 e	0.50 c
	6	0.45 ab	0.31 f-h
	9	0.36 de	0.34 e-g
	12	0.48 a	0.84 b
Significant level		**	**
$LSD_{0.05}$		**0.052**	**0.052**
CV (%)		**5.67**	**5.12**

Values having same letter (s) in a column do not differ significantly at 5% level of probability

** —> Significant at 0.01 level of probability;

Appendix 3. Effects of different salinity level on the P content (%) of stem & leaf of rice plant (mean of 4 cultivars)

Salinity Level(dSm^{-1})	P in stem	P in leaf
0	0.17 d	0.12 c
3	0.19 cd	0.12 c
6	0.28 a	0.20 a
9	0.25 b	0.16 b
12	0.21 c	0.14 bc
Significant level	**	**
$LSD_{0.05}$	**0.026**	**0.026**
CV(%)	**11.22**	**9.74**

Appendix 4. Effects of variety and salinity on the P content % of stem & leaf of rice plant

Variety	Salinity Level (dSm^{-1})	%P in stem	% P in leaf
Pokkali	0	0.26 c	0.14 cd
	3	0.26 c	0.20 b
	6	0.28 a-c	0.28 a
	9	0.23 c	0.13 cd
	12	0.11 ef	0.07 ef
BR 28	0	0.10 f	0.14 cd
	3	0.17 d	0.12 de
	6	0.27 bc	0.31 a
	9	0.24 c	0.19 b
	12	0.15 d-f	0.11 d-f
BRRI Dhan 29	0	0.15 d-f	0.11 d-f
	3	0.16 de	0.06 f
	6	0.25 c	0.12 de
	9	0.25 c	0.19 b
	12	0.26 c	0.19 b
IR 29	0	0.17 d	0.11 d-f
	3	0.18 d	0.08 d-f
	6	0.31 ab	0.11 d-f
	9	0.25 c	0.12 de
	12	0.32 a	0.17 bc
Significant level		**	**
LSD0.05		**0.052**	**0.052**
CV (%)		**11.22**	**9.74**

Values having same letter (s) in a column do not differ significantly at 5% level of probability

** —> Significant at 0.01 level of probability;

Appendix 5. Effects of salinity on the K content (%) of stem & leaf of rice plant

Salinity Level(dSm^{-1})	%K in stem	%K in leaf
0	0.32 a	0.25 a
3	0.31 a	0.22 b
6	0.20 b	0.16 c
9	0.18 c	0.15 c
12	0.15 c	0.13 c
Significant level	**	**
$LSD_{0.05}$	**0.026**	**0.026**
CV(%)	**10.91**	**4.31**

Appendix 6. Effect of variety and salinity on the K content (%) of stem & leaf of rice plant(mean of 4 cultivars)

Variety	Salinity Level (dSm^{-1})	%K in stem	%K in leaf
Pokkali	0	0.52 a	0.33 a
	3	0.25 f	0.24 c
	6	0.17 gh	0.18 de
	9	0.13 hi	0.15 ef
	12	0.12 hi	0.31 ab
BR 28	0	0.47 ab	0.26 bc
	3	0.31 d	0.10 fg
	6	0.14 g-i	0.10 fg
	9	0.12 hi	0.09 g
	12	0.10 i	0.09 g
BRRI Dhan 29	0	0.44 b	0.26 bc
	3	0.30 de	0.22 cd
	6	0.25 ef	0.24 c
	9	0.11 i	0.08 g
	12	0.10 i	0.10 fg
IR 29	0	0.37 c	0.24 c
	3	0.18 g	0.18 de
	6	0.26 d-f	0.21 cd
	9	0.14 g-i	0.18 de
	12	0.09 i	0.08 g
Significant level		**	**
$LSD_{0.05}$		**0.052**	**0.052**
CV (%)		**10.91**	**4.31**

Values having same letter (s) in a column do not differ significantly at 5% level of probability

** —> Significant at 0.01 level of probability

Appendix 7. Effects of salinity on the Na content (%) of stem & leaf of rice plant(mean of 4 cultivars)

Salinity Level(dSm^{-1})	%Na in stem	%Na in leaf
0	0.045 d	0.037 c
3	0.061 c	0.046 b
6	0.084 b	0.049 b
9	0.092 a	0.059 a
12	0.098 a	0.063 a
Significant level	**	**
$LSD_{0.05}$	**0.013**	**0.026**
CV(%)	**14.65**	**11.47**

Appendix 8. Effects of variety and salinity on the Na content(%) of stem & leaf of rice plant

Variety	Salinity Level (dSm^{-1})	%Na in stem	%Na in leaf
Pokkali	0	0.05 d	0.013 d
	3	0.08 bc	0.047 a-d
	6	0.09 b	0.047 a-d
	9	0.09 b	0.070 a-c
	12	0.10 ab	0.081 ab
BR 28	0	0.06 cd	0.023 cd
	3	0.08 bc	0.023 cd
	6	0.10 ab	0.073 a-c
	9	0.10 ab	0.087 ab
	12	0.10 ab	0.093 ab
BRRI Dhan 29	0	0.05 de	0.023 cd
	3	0.07 c	0.043 b-d
	6	0.08 bc	0.047 a-d
	9	0.10 ab	0.073 a-c
	12	0.11 ab	0.083ab
IR 29	0	0.07 c	0.013 de
	3	0.08 bc	0.030 cd
	6	0.08 bc	0.047 a-d
	9	0.09 b	0.063 a-d
	12	0.12 a	0.0973 a
Significant level		**	**
LSD0.05		**0.023**	**0.052**
CV (%)		**14.65**	**11.47**

Values having same letter (s) in a column do not differ significantly at 5% level of probability

** —> Significant at 0.01 level of probability;

Appendix 9. Effects of salinity on the Ca content (%) of stem & leaf of rice plant(mean of 4 cultivars)

Salinity Level(dSm^{-1})	%Ca in stem	%Ca in leaf
0	0.018	0.045
3	0.021	0.039
6	0.018	0.040
9	0.018	0.036
12	0.021	0.030
Significant level	**NS**	**NS**
$LSD_{0.05}$	-	-
CV(%)	**12.58**	**14.65**

Appendix 10. Effects of salinity on the Mg content (%) of stem & leaf of rice(mean of 4 cultivars)

Salinity Level(dSm^{-1})	Mg in stem	Mg in leaf
0	0.13 c	0.17 c
3	0.14 bc	0.19 bc
6	0.17 ab	0.22 ab
9	0.18 a	0.22 ab
12	0.19 a	0.25 a
Significant level	**	**
$LSD_{0.05}$	**0.026**	**0.036**
CV(%)	**15.82**	**9.18**

Values having same letter (s) in a column do not differ significantly at 5% level of probability

** —> Significant at 0.01 level of probability;

NS—> Non-significant

Appendix 11. Effects of salinity and Variety on the Mg content (%) of stem & leaf of rice

Variety	Salinity Level (dSm^{-1})	Mg in stem	Mg in leaf
Pokkali	0	0.12 ef	0.13 g
	3	0.12 ef	0.19 c-g
	6	0.12 ef	0.21 c-f
	9	0.14 d-f	0.21 c-f
	12	0.14 d-f	0.22 c-f
BR 28	0	0.12 ef	0.15 fg
	3	0.12 ef	0.19 c-g
	6	0.17 c-e	0.22 c-f
	9	0.18 b-d	0.25 a-d
	12	0.22 a-c	0.30 ab
BRRI Dhan 29	0	0.11 f	0.18 d-g
	3	0.14 d-f	0.20 c-g
	6	0.16 de	0.22 c-f
	9	0.22 a-c	0.22 c-f
	12	0.23 a	0.32 a
IR 29	0	0.13 d-f	0.16 e-g
	3	0.16 de	0.17 d-f
	6	0.17 c-e	0.17 d-f
	9	0.17 c-e	0.21 c-f
	12	0.18 b-d	0.26 a-c
Significant level		**	**
LSD0.05		**0.052**	**0.073**
CV (%)		**15.82**	**9.18**

Values having same letter (s) in a column do not differ significantly at 5% level of probability

** —> Significant at 0.01 level of probability;

Appendix 12. Effects of salinity level on Yield hill^{-1}

Salinity Level(dSm^{-1})	Yield hill^{-1} (g)
0	14.53 a
3	11.55 b
6	5.747 c
9	1.913 d
12	0.5225 e
Significant level	**
$LSD_{0.05}$	0.1434
CV(%)	16.04

Appendix 13. Interaction effect of salinity level and variety on Yield hill^{-1} (g)

Variety	Salinity Level (dSm^{-1})	Yield hill^{-1} (gm)
Pokkali	0	12.93 e
	3	9.15 h
	6	6.93 i
	9	4.00 m
	12	1.27 o
BR 28	0	15.29 c
	3	12.12 f
	6	4.52 l
	9	1.080 p
	12	0.53 q
BRRI Dhan 29	0	17.01 a
	3	13.03 b
	6	6.16 j
	9	1.37 m
	12	0.23 r
IR 29	0	15.76 b
	3	11.60 g
	6	5.01 k
	9	1.20 o
	12	0.17 r
Significant level		**
LSD0.05		0.1045
CV (%)		**16.04**

Values having same letter (s) in a column do not differ significantly at 5% level of probability

** —> Significant at 0.01 level of probability;