EFFECTS OF SALINITY ON MORPHOLOGY AND MINERAL CONTENTS IN SHOOTS OF SOME LOCAL AND MODERN RICE (*Oryza sativa* L.) CULTIVARS

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CERTIFICATE

This is to certify that the thesis entitled, *"EFFECTS OF SALINITY ON MORPHOLOGY AND MINERAL CONTENTS IN SHOOTS OF SOME LOCAL AND MODERN RICE (Oryza sativa L.) CULTIVARS"* submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of *MASTER OF SCIENCE (M.S.) IN AGRICULTURAL CHEMISTRY*, embodies the result of a piece of *bona fide* research work carried out by *BISHAWNATH SUTRADHAR, Registration No. 05-01803* under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated:

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Dedicated to
My
Beloved Parents

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The Author

EFFECTS OF SALINITY ON MORPHOLOGY AND MINERAL CONTENTS IN SHOOTS OF SOME LOCAL AND MODERN RICE (*Oryza sativa* L.) CULTIVARS

ABSTRACT

An experiment was conducted at the net house of the department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207 under pot-culture during the Boro season (December-June) of the year 2010-11 to study the effects of salinity on morphology and mineral content in shoots of some rice cultivar. The experiment was completed using five varieties (Jatabalam, Chapsal, Kolar-mocha, BINA dhan 8 and BRRI dhan41) and five salinity levels (0, 3, 6, 9 and 12 dSm^{-1}). The experiment was set in Completely Randomized Design (CRD) having two factors with three replications. The plant height, total tiller number, shoot dry weight, root dry weight, effective tiller, grain weight were highest in genotypes BRRI dhan41but Kolar-mocha showed the lowest performance under different salinity levels. The highest concentration of Na^{+}, $Ca^{2+}$and Mg^{2+} was in Kolar-mocha and it was lowest in BRRI dhan41. The shoot of BRRI dhan41 contained the highest concentration of K^{+}. Conversely, Kolar-mocha contained the lowest amount of K^{+}. The plant height, total tiller number, shoot dry weight, root dry weight, effective tiller, filled grain, grain weight were highest in0 dSm^{-1} level of salinity. The highest K content in shoot (1.64%) was recorded in 0 dSm^{-1}. The highest Na content in shoot (1.584%) was recorded in 12 dSm^{-1} level of salinity. The Ca content recorded in shoot was highest (1.07 %) in 6dSm^{-1}. The lowest Mg (0.35%) content was in the shoot in 0 dSm^{-1}. The highest panicle length and filled grain $panicle^{-1}$ was recorded in BRRI dhan41 at 0 dSm^{-1} level of salinity. The minimum number of unfilled grain $panicle^{-1}$ was found in BRRI dhan41 at 0 dSm^{-1}. The highest grain yield $hill^{-1}$ (5.00 g) was found in BRRI dhan41 at 0 dSm^{-1} salinity level. The lowest Na content (0.78%), Ca content (0.75%) and Mg content (0.33%) in shoot was found in the cultivar BRRI dhan41 at the 0 dSm^{-1} salinity level. Considering the above results cultivar BRRI dhan41 and BINA dhan 8 were salt tolerant, Chapsal as moderately tolerant and Kolar-mocha and Jatabalam as susceptible cultivar.

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LIST OF ACRONYMS

AEZ	=	Agro- Ecological Zone
BARC	=	Bangladesh Agricultural Research Council
BBS	=	Bangladesh Bureau of Statistics
BINA	=	Bangladesh Institute of Nuclear Agriculture
BRRI	=	Bangladesh Rice Research Institute
cm	=	Centi-meter
cv.	=	Cultivar
DAT	=	Days after transplanting
^{0}C	=	Degree Centigrade
DF	=	Degree of freedom
EC	=	Electrical Conductivity
et al.	=	and others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram
HI	=	Harvest Index
HYV	=	High yielding cultivar
hr	=	hour
IRRI	=	International Rice Research Institute
Kg	=	kilogram
LV	=	Local cultivar
LYV	=	Low yielding varieties
LSD	=	Least significant difference
m	=	Meter
m^2	=	meter squares
MPCU	=	Mussorie phos-coated urea
MV	=	Modern cultivar
mm	=	Millimeter
viz.	=	namely
N	=	Nitrogen
ns	=	Non significant
%	=	Percent
CV %	=	Percentage of Coefficient of Variance
P	=	Phosphorus
K	=	Potassium
ppm	=	Parts per million
PU	=	Prilled urea
SAU	=	Sher-e- Bangla Agricultural University
S	=	Sulphur
SCU	=	Sulphur coated urea
t ha^{-1}	=	Tons per hectare
UNDP	=	United Nations Development Program
USG	=	Urea supergranules
Zn	=	Zinc

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa*) is one of the most important cereal crops in Bangladesh. It is a major source of food for more than 2.7 billion people on a daily basis and is cultivated on about one-tenth of the earth's arable land (El-Refaee*et al.*, 2006). Over half of the world's population depends on rice as a staple food.In Asia, rice supplies 30 - 80% of the daily consumed calories (Narciso and Hossain, 2002).The green revolution of the 1970's resulted in remarkable increases in rice production. Rice is the most suited crop for saline soils because it can tolerate standing water, which is necessary for reclamation of saline soils. Soils are considered saline if they contain soluble salts in quantities sufficient to interfere with the growth of most crop species. Salinity is a major threat to crop productivity in the Southern and South-Western part of Bangladesh, where it is developed due to frequent flood by sea water of the Bay of Bengal and on the other hand introduction of irrigation with saline waters. Saline soil covers our earth's surface, estimated to be from 400 to 950 million ha (Lin *et al.*, 1998).

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). The total saline area forms one third of the 9 million hectares of total national cultivated area in Bangladesh (ABSPII, 2006). Saline soils can be managed by large scale irrigation and drainage schemes and by chemical treatments of soil, but the scale of the problem renders these solutions too costly (Gregorio *et al.*, 2002).One of such efforts is to cultivate rice with elevated level of salt tolerance on salt affected marginal lands. Today, the most economic and sustained way to overcome the problem of salt stress is to develop salt tolerant varieties.

Salinity in soil or water is one of the major stresses which can severely limit crop production (Shannon, 1998). 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; Marschner,1995). All these cause adverse pleiotropic effects on plant growth and development at physiological and biochemical levels (Munns, 2002) and also at molecular level (Mansour, 2000). It is often not possible to assess the relative contribution of these major constraints to growth inhibition at high substrate salinity, as many factors are involved. These include ion concentration, duration of exposure, plant species, cultivar and root stock (excluder and includer), and stage of plant development, plant organ and environmental conditions. So, to cope with the above constraints, salt stressed plants mainly adopt three mechanisms for salt tolerance such as (i) osmotic adjustment, (ii) salt inclusion/ exclusion and (iii) ion discrimination (Volkmar*et al.*, 1998).

The physiological mechanisms governing salinity tolerance are salt exclusion, root-shoot translocation, leaf to leaf compartmentation, tissue tolerance and dilution effects (Yeo and flowers, 1984). All these mechanisms lead to low Na content in the functional tissue, thus finally leading to low Na/K ratio in the shoot. High Na concentration in the shoot is correlated with susceptibility to salinity. However, it remains unclear whether this is the cause or the result of growth reduction at high salinity. Although appreciable progress has been made in general understanding of the physiology of the plant soil relationships but lack of a standard and effective measure of salt damage and resistance limits the application of the physiological information to breeding (Shannon, 1980).

Promising results have been obtained in field trials on the performance of modern salt tolerant rice cultivars of 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 $4dSm^{-1}$.

The present study aims to investigate the effect of different levels of salinity on the growth, yield and mineral nutrient contents of some local and modern rice cultivars of Bangladesh.

Considering above constraints the specific objectives of this experiment are as follows:

i. to study the effect of salinity on growth and yield of local and modern rice cultivars.

ii. to study the mineral contents in shoots of selected rice cultivars under different salinity levels, and

iii. to isolate suitable rice cultivars for saline areas.

CHAPTER 2

REVIEW OF LITERATURE

Rice is the staple food in many parts of the world. It is sensitive to various environmental factors *viz.* variety, soil, nutrient availability, temperature, salinity, light intensity and moisture for proper growth and yield. Many researches have been conducted on various aspects of rice in different countries. Literature regarding the studies on 'Effects of Salinity on Morphology and Mineral Contents in Shoots of Some Local and Modern Rice Cultivars'. The available literatures related to the present study are reviewed here.

Salinity is one of the major obstacles to increasing production in rice growing areas worldwide. It is one of the important constraints to rice production in coastal region of Bangladesh. Salinity of soil and water is caused by the presence of excess amount of soluble salts.

Saline soils have a high concentration of soluble salts. They are classed as saline when the EC $\geq$ 4 dS m^{-1}. This definition of salinity derives from the EC that would reduce yield of most crops. However, many crops are affected by an EC $<$ 4 dS m^{-1}. Osmotic and salt specific components inhibit root and shoot growth EC is the electrical conductivity of the saturated paste extract, and reflects the concentration of salts in saturated soil. A conductivity of 4 dS m^{-1} is quivalent to 40 mM NaCl.

Sodic soils have a low concentration of soluble salts, but a high exchangeable Na^{+} percentage (ESP). They are classed as sodic when the ESP is 15. This definition of sodicity derives from the ESP that causes degradation of the structure of clay soils, caused by Na^+ displacing divalent cations bound to negative charges on the clay particles. Poor soil structure inhibits root growth at high ESP. The soil drains poorly and becomes waterlogged when wet. It also becomes very hard when dry.

Zeng and Shannon (2000) studied on salinity effects on seedling growth and yield components of rice. They used cultivar M-202 rice and irrigated with nutrient solutions of control and treatments amended with NaCl and $CaCl_2$ (2:1 molar concentration) at 1.9, 3.4, 4.5, 6.1, 7.9, and 11.5 dS m^{-1} electrical conductivity. They found seedling growth was significantly reduced by salinity at the lowest salinity treatment, 1.9 dS m^{-1}. At 1.9 and 3.4 dS m^{-1}, significant reduction of seedling growth occurred at longer cumulative thermal time than at higher salt levels. Seedling survival was significantly reduced when salinity was 3.40 dS m^{-1} and higher. Tiller number per plant and spikelet number per panicle contributed the most variation in grain weight per plant under salinity. Reductions in seedling survival, tiller number per plant, and spikelet number per panicle were the major causes of yield loss in M-202 under salinity.

Fifteen rice cultivars were subjected to salt stress by Thirumeni *et al.* (2001). They used different salt concentrations of 0, 4, 8 and 12 dS m^{-1}. The 15 cultivars were Pokkali, Dasal, Damodar, Vytilla 3, Vytilla 4, Vytilla 5, Panvel 1, USAR 2, CO 43, IR 28, MI 48, Improved White Ponni, CSR 10, SR 26 B and Canning 7. The germination percentage and seedling growth decreased with increasing salt concentration in all the cultivars. Among the cultivars, Pokkali and SR 26 B were the most tolerant to salt stress with respect to seed germination and seedling vigour, while improved White Ponni and IR 28 were the most susceptible.

Six hundred and fifty seven *japonica* rice from different countries like China, Japan, Indonesia, Egypt, Philippines, Korea and Senegal were collected for screening salinity tolerance at the seedling stage (Lee and Senadhira, 1996). Among the cultivars 19 tolerant and 197 moderately tolerant *japonica* rice were identified. The tolerance of Pokkali was higher than that found in the *japonica* set. They reported that Pokkali absorbed significantly less Na and much higher amounts of K than any *japonica* variety.

Gregorio *et al.* (2002) collected 250 traditional cultivars from Orissa and Tamil Nadu in India. They conducted an experiment at IRRI. From the experiment they identified some tolerant germplasms NV, Pat, Solla and DH, which found similar to Pokkali. They conducted another study of coastal rice cultivars of Indonesia, Thailand and Vietnum and identified three highly tolerant types: Ketumber from Indonesia, Khao Seetha from Thiland and Soc Nau from Vietnum. The cultivars like Pat, Ketumber and Soc Nau have better grain quality and performances than Pokkali. They also collected some wild rice genotypes (*Oryza rufipogon*) from Sri Lanka which shows salinity tolerance at seedling stage. Salt tolerant *indica* rice cultivars seem to have originated or been selected in coastal areas of India; examples are Pokkali, Nonabokra, Cheriviruppu and SRB26. It appeared there are sources of salt tolerance germplasm distributed among the rice growing countries. It appeared there are sources of salt tolerance germplasm distributed among the rice growing countries.

Alam *et al.* (2002) conducted an experiment with two varieties of rice (*Oryza sativa* L.) (BR-11 and Pokkali) with varying degrees of salt tolerance. From their study they found that concentrations of nitrogen (N), phosphorus (P), potassium (K), and Ca in shoots and roots of two varieties of rice plants decreased with increasing salinity levels, while results obtained with Na and magnesium (Mg) were opposite.

Salinity might directly or indirectly inhibit cell division and enlargement in the vegetative growing period of plant. Salinity caused reduced shoot growth in growing tissues (Munns *et al.*, 1982). They also found that salinity might not effect on photosynthetic tissues. Salinity affected plants become stunted.

Muhling and Lauchli (2001) observed that Na^+ accumulation in leaves, particularly in the leaf apoplast, could be responsible for Na^+ toxicity in maize leaves. Lower Na^+ concentrations were found in leaves of a more salt tolerant maize cultivar (Pioneer 3769) compared to a salt-sensitive maize cultivar (Pioneer 3751). They also found that the Na^+ concentration in the leaf apoplast of Pioneer 3751 significantly increased with higher Na^+ supply. They concluded that the Na^+ concentration in the leaf apoplast was not high enough to be responsible for the decline in leaf growth. The K^+ and Ca^{2+} concentrations in whole leaves decreased with salt treatment, while K^+ increased and Ca^{2+} remained constant in leaf apoplasts under salt stress.

Growth and yield responses of rice (*Oryza sativa* L.) to soil salinity were studied in 6 varieties differing in tolerance at the seedling stage (Makihara *et al.*, 1999). They grew plants in 4 litre pots containing soil treated with sodium chloride at 5, 10 and 15 g/pot.

They used tolerant varieties at the seedling stage (Kala Rata 1-24 and IR4595-4-1-13) under salinity, but in other tolerant varieties (Nona Bokra and Pokkali) leaf emergence, tillering and plant length were suppressed by salinity to a similar degree as in the sensitive varieties (IR 28 and Mangasa). The decrease in yield was more obvious in IR 28, Mangasa and Pokkali than in the other 3 varieties. Yield components responsible for the yield reduction varied: small number of spikelets in IR 28 and Pokkali, and high sterility induced by white heads in Mangasa.

The effects of salinity at 50 mM NaCl on floral characteristics, yield components, and biochemical and physiological attributes of the sensitive rice variety IR-28 under controlled conditions to determine the causes of sterility in seed set under salinity stress were studied by Abdullah *et al.* (2001). They found that significant decreases in panicle weight, panicle length, primary branches panicle^{-1}, filled seeds panicle^{-1}, unfilled seeds panicle^{-1}, total seeds panicle^{-1}, total seed weight panicle^{-1}, 1000-seed weight and total seed weight plant^{-1} with the increase of salinity.

A field experiment was conducted and showed that an average seasonal salinity of the field water in excess of 1.9 dS m^{-1} can reduce rice grain yields, which was quite lower than current guidelines indicating that salinity affects rice yield at or above 3.0 dS m^{-1} (Grattan *et al.*, 2002). They found that salinity had negative impacts on a number of yield components, including stand establishment, numbers of panicles, tillers and spikelets per plant, floret sterility, individual grain size and heading. The emergence and early seedling growth stages were most sensitive to salinity, as was the three-leaf to panicle-initiation stages.

Munns and Termat (1986) explained that even at low salinity levels, external salt concentration is much greater than that of nutrient ions, so that a considerable concentration of ions may reach the xylem. Being the actively transpiring parts of the plant, the leaves accumulate salt, which leads to their premature death.

Salt stress affects many aspects of plant metabolism and as a result growth is reduced. Excess salt in the soil solution may adversely affect plant growth either through osmotic inhibition (Bernstein and Hayward, 1958) of water uptake by roots or by specific ion effects. Specific ion effects may cause direct toxicity or, alternatively, the insolubility or competitive absorption of ions may affect the plant's nutritional balance. These effects may be associated with enzyme activity, hormonal imbalance or morphological modifications.

Photosynthesis is reduced because it is affected by leaf expansion rate, leaf area and leaf duration, as well as by photosynthesis and respiration per unit leaf area. Growth may be indirectly affected given that salt decreases the amount of photosynthesis, water and other growth factors reaching the growing region. This decrease may be due to stomatal closure or the direct effect of salt on the photosynthetic apparatus. Transport of photosynthates in the phloem may also be inhibited (Munns, 2002).

The general effect of salinity is to reduce the growth rate resulting in smaller leaves, shorter stature, and sometimes fewer leaves. The initial and primary effect of salinity, especially at low to moderate concentrations is due to its osmotic effects (Munns and Termaat, 1986). Roots are also reduced in length and mass but may become thinner or thicker.

Salt stress can be ascribed to two salts calcium salts and sodium salts, although most of the salt stresses in nature are due to Na salts, particularly NaCl. Salinity effects can be classified as osmotic, toxic or nutritional. Salt stress causing toxicity could be termed primary salt injury and that causing osmotic stress and nutritional stress (including deficiency of other nutrients) is secondary salt-induced stress (Manneh, 2004).

Typical symptoms of salt injury in rice are stunted growth, leaf rolling, white leaf tip, white blotches in the leaf blade, drying of the older leaves, and poor root growth (Ponnamperuma and Bandyopadhya, 1980).

Some researchers found that low salinity at the early developmental stages can have a stimulatory effect on plant growth. However, high salinity levels at any growth stage will inhibit the growth and yield of rice (Flowers and Yeo, 1981; Khatun and Flowers, 1995a, 1995b). High salinity is detrimental to plant growth as it causes

1) nutritional disorders by decreasing the uptake of cations, such as potassium and calcium, but also of anions such as phosphorus and nitrate (Asch *et al.*, 2000)

2) ion cytotoxicity mainly due to elevated concentrations of Na^+, Cl^-, plus $SO_4^{=}$. and

3) osmotic stress (Zhu, 2001).

The combined effects of ion toxicity, osmotic stress, and nutritional disorders may lead to a metabolic imbalance, resulting in oxidative stress.

Vegetative growth of rice in salt-affected soils is generally better during the wet than during the dry season, mainly the result of a lower vapor pressure deficit and, hence, reduced transpiration rates. Most rice cultivars are severely injured in flooded soils at 8-10 dS m^{-1}. Sensitive cultivars suffer damage already at 2 dS m^{-1}. Salt injury is usually less severe in neutral and alkaline soils than in acid soils, and less severe at 20°C than at 35°C. Rice, which is tolerant during germination, can become highly sensitive during the early seedling stage. Cultivars with a high level of salt tolerance during the vegetative growth can become temporarily salt-sensitive during pollination and fertilization before again increasing the tolerance level at maturity. Salinity during the reproductive stage depresses grain yield much more than salinity during the vegetative growth stage (Akbar and Ponnamperuma, 1982; Castillo *et al.*, 2003).

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). 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).

Salinity affected rice during pollination, decreased seed setting and grain yield (Maloo, 1993). 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, and primary branches per panicle, filled and unfilled grain, 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 grain.

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 genotypes to combat the adverse effect of salinity.

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).

CHAPTER 3

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 Nethouseof Department of Genetics and Plant Breeding and Laboratory of Agricultural Chemistry Department,Sher-e-Bangla Agricultural University, Dhaka.

3.2 Experimental period

The experiment was conducted in pots during *Boro* rice cropping season (December to June) of the year of 2010- 11.

3.3 Selection of cultivars

There were five rice cultivars of which 3 local cultivars (Jatabalam,ChapsalandKolar-mocha) and 2 modern cultivars (BINAdhan8 and BRRI dhan41)used for the study. They were collected from the saline prone area in Bangladesh,Bangladesh Rice Research Institute (BRRI)and Bangladesh Institute ofNuclear Agriculture (BINA).

3.4 Experimental design

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

Factor 1: Cultivars- five (V_1-Jatabalam, V_2-Chapsal, V_3-Kolar-mocha,V_4-BINAdhan8and V_5-BRRI Dhan41).

Factor 2: Salinity levels - 5 (0, 3, 6, 9 and 12 dSm^{-1})

Replication: 3

The fivecultivars in combination with five salinity levels were randomly assigned to 75(5×5×3) experimental unit/ Pot.

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 was maintained using distilled water only.

3.6 Collection and preparation of soil

The soils of the experiment were collected from Sher-e-Bangla Agricultural University (SAU) farm. The soil was non-calcarious Red Brown Terrace soil with loamy texture belonging to the AEZ 28 (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

The 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 at the rate of 100, 80 and 60 $kgha^{-1}$ 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 chemical fertilizers *i.e.*, Urea, Triple Supper Phosphate (TSP), Muriate of Potash (MOP) and Gypsum were added for N, P, K and S in all the pot soils at the rate of 100 kg N, 80 kg P_2O_5, 60 kg K_2O and 20 kg S ha^{-1}, respectively. The whole amount of TSP, MOP, Gypsum and $1/3^{rd}$ of urea were applied before the final preparation of the pots. Thereafterthe pots containing soil were moistened with water. Five weeks old seedlings of selected rice cultivars were transplanted in the respective pots. There were two hills in each pot. 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 electrical conductivity (EC) of each pot was measured everyday with a EC meter and necessary adjustments were made by adding water. The remaining $2/3^{rd}$ urea were top dressed at two equal divisions after 25 and 50 days of transplanting.

3.11 Collection of data

3.11.1 Plant height

The plant height (cm) was measured from the surface level of the growth media to the tip of the longest leaf at harvesting by taking the average value of five random samples.

3.11.2 Total tiller

Total tiller number $hill^{-1}$ was counted at maturity stages. At the final harvest, the data on yield components like number of effective tillers $hill^{-1}$, filled grains $panicle^{-1}$,unfilled grains $panicle^{-1}$and grain yield $hill^{-1}$ were recorded.

3.11.3 Root dry weight

Roots were carefully cleaned with running tap water and finally washed with distilled water. Then the root samples were oven-dried to a constant weight at 70^0 C. The mean root dry weight $hill^{-1}$ was calculated for each treatment.

3.11.4 Shoot dry weight

After separation of roots, the samples of stem, leaf and panicle were oven-dried to a constant weight at 70^0 C. Then the shoot dry weight was calculated from the summation of leaf, stem and panicle.

3.11.5 Number of effective tillers

Effective tiller number $hill^{-1}$ was counted at harvesting. There were two hills in each pot. The effective tiller number $hill^{-1}$ was counted from the pot.

3.11.6 Number of non effective tillers

Number of sterile tillers was also counted by subtracting the number of effective tillers from the total tiller number $hill^{-1}$.

3.11.7 Panicle length

Average panicle length (cm) was calculated by taking the lengths of all the panicles $hill^{-1}$.

3.11.8 Number of filled grain

Average number of filled grain $panicle^{-1}$was calculated by counting the number of filled grain of 5 panicles $hill^{-1}$.

3.11.9 Number of unfilled grain

Number of unfilled grain panicle^{-1} was also counted.

3.11.10Grain yield

The grain yield of the hill which had effective tiller was recorded.

3.11.11 Analysis of different chemical constituents in shoot of rice plant samples

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

ii) Digestion

The ground plant sampleswere digested by Micro-Kjeldahl method (Thomas *et al.*, 1967).Exactly 0.25 g oven-dried shoot samples of rice seedlings were taken in kjeldahlflasks.About 5 mL of concentrated sulphuric acidand 1 mL H_2O_2 were taken in a digestion tube and left to stand for 20 minutes and then transferred to a digestion block and continued heating at 100°C. The temperature was increased to 365°C gradually to prevent frothing (50°C steps) and left to digest until yellowish color of the solution turned to whitish color.Then the digestion tubes were removed from the heating source and allowed to cool to room temperature. About 40 mL of de-ionised water was carefully added to the digestion tubes and the contents filtered through Whatman no. 40 filter paper into a 100 mL volumetric flask and the volume was made up to the mark with de-ionised water. The samples were stored at room temperature in clearly marked containers.After digestion, approximately 10 mL of each digest samples was stored in a plasticbottle for determination of the Na^+, K^+, Ca^{2+} and Mg^{2+}. Content of Na^+ and K^+ were determined by Flame photometer while Ca^{2+} and Mg^{2+} by atomic absorption spectrophotometer (Model-PERKIN- ELMER, 2380).

3.12 Statistical analysis

The collected data were analyzed statistically following CRD design by MSTAT-C computer package programme developed by Russel (1986). The treatment means were compared by Duncan's Multiple Range Test (DMRT) and regression analysis were performed as and where necessary.

CHAPTER 4

RESULTS AND DISCUSSION

Five rice cultivars (Jatabalam, Chapsal, Kolar-mouch, BINA dhan 8 and BRRI dhan41) have been selected for present experiment in order to study some growth yield parameters and Na, K, Ca and Mg contents under salinity.

The levels of salinity 0, 3, 6, 9 and 12 dSm^{-1} were chosen in order to get more frequency for having a precise effect of salinity levels. Although salinity starts from 4 dSm^{-1} and above, and there is a probability of increasing trend of salinity in the root zone and surface of the soil which could minimize by choosing more frequent interval of salinity.

4.1 Plant height

Plant heights of the cultivars were measured at maturity. It was evident from Figure 1 that the height of the plant was significantly influenced by cultivar. The tallest plant (99.06 cm) was found in cultivar BRRI dhan41 and the shortest (85.20cm) plant was in Kolar-mocha at harvest. Probably the genetic makeup of varieties was responsible for the variation in plant height. This confirms the reports of BINA (1992), BRRI (1991) and Shamsuddin *et al.* (1988) that plant height differed due to varietal variation.

The height of the plant was significantly influenced by salinity. At harvest of rice plant the highest (103.8cm) plant height were observed in 0 dSm^{-1} and the lowest (75.93cm) values were found in 12 dSm^{-1} (Fig. 2).

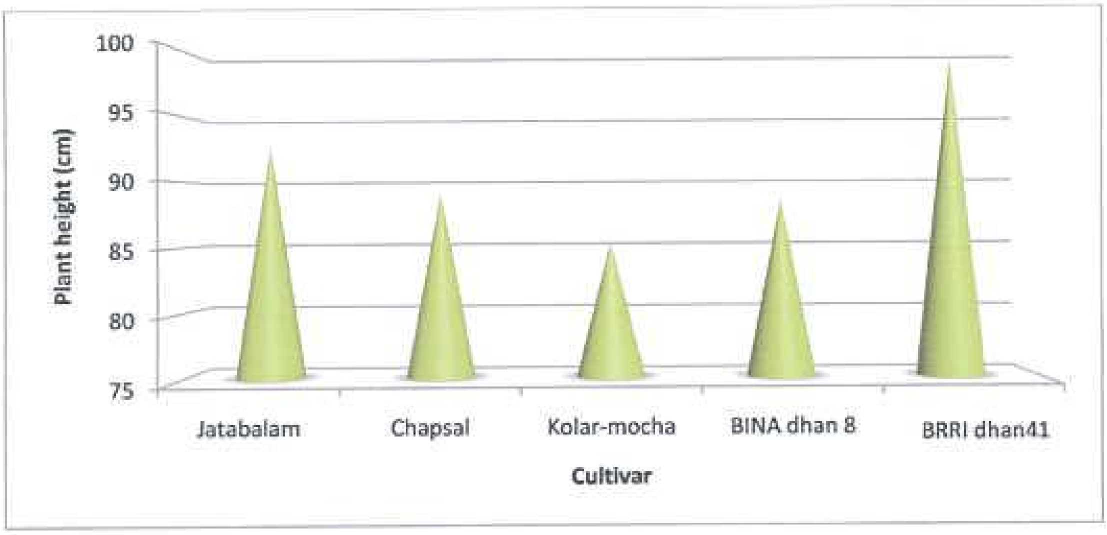

Fig. 1. Effect of cultivar on the plant height of rice (mean of 5 salinity levels)

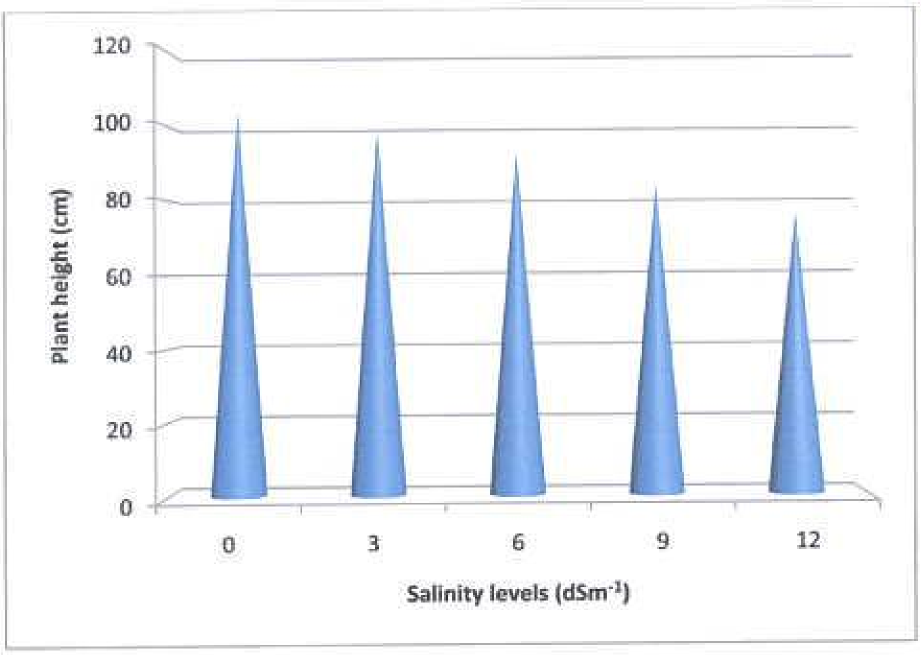

Fig. 2. Effect of different levels of salinity on the plant height of rice (mean of 5 cultivars)

In combination effect of cultivars and salinity levels was significantly influenced on plant height. The plant height of different rice cultivars significantly decreased with increasing the salinity levels (Table 1). The highest (111.30 cm) plant height was found in BRRI dhan41with 0 dSm^{-1}, which was statistically similar to 3 dSm^{-1} and the lowest (71.67 cm) plant height was found in Kolar-mocha with 12 dSm^{-1} levels of salinity.

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 cultivar 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).

4. 2 Number of total tillers $hill^{-1}$

The number of total tillers $hill^{-1}$ was significantly influenced by cultivar at all stages of crop growth. Varietal effects on the formation of total number of tillers are shown in Figure 3. BRRI dhan41 was achieved maximum tiller (10.33), where as the minimum tiller (6.73) production was observed in Jatabalam during harvest. The value decreased because some of the last emerged tillers died due to their failure in competing for light and nutrients as observed by Ishhizuka and Tanaka (1963). This revealed that during the reproductive and ripening phases the rate of tiller mortality exceeded the tiller production rate (Roy and Satter, 1992).

Table 1. Combined effect of cultivar and different salinity levels on the growth character of rice

Cultivar	Saliniy levels (dSm^{-1})	Plant height (cm)	No. of total tiller $hill^{-1}$	Root dry weight ($g\ hill^{-1}$)	Shoot dry weight ($g\ hill^{-1}$)	Effective tiller $hill^{-1}$	Non effective tiller $hill^{-1}$
Jatabalam	0	107.70 ab	9.33 f	3.382 d	11.490 c	7.83 ef	1.50 h
	3	104.30 bc	8.33 g	0.162 k	1.077 ijk	6.17 g	2.17 g
	6	96.67 d	6.50 i	0.144 k	0.965 ijk	3.17 i	3.33 ef
	9	79.00 ijk	5.67 ij	0.095 k	0.350 k	2.17 j	3.50 e
	12	75.00 kl	5.33 jk	0.840 g	0.154 k	1.17 k	4.17 d
Chapsal	0	101.30 c	16.33 a	4.517 b	14.190 b	12.17 b	4.17 d
	3	90.33 ef	10.33 e	0.644 gh	5.819 f	7.17 f	3.17 f
	6	88.67 fg	8.33 g	0.424 ij	3.040 gh	4.17 h	4.17 d
	9	85.00 gh	6.33 i	0.405 ij	2.290 hi	2.17 j	4.17 d
	12	79.67 ijk	4.50 kl	0.093 k	0.474 jk	0.00 l	4.50 c
Kolar-mocha	0	97.00 d	9.33 f	4.000 c	14.010 b	8.17 e	1.17 i
	3	93.33 de	8.33 g	0.416 ij	2.553 hi	6.17 g	2.17 g
	6	86.33 gh	7.33 h	0.301 ijk	2.001 hij	3.17 i	4.17 d
	9	77.67 jk	6.33 i	0.235 jk	1.477 h-k	0.00 l	6.33 a
	12	71.67 l	4.00 l	0.123 k	0.489 jk	0.00 l	4.00 d
BINA dhan 8	0	101.70 c	13.50 c	4.607 b	15.060 b	10.17 c	3.33 ef
	3	94.00 de	9.33 f	0.730 g	11.290 c	6.17 g	3.17 f
	6	88.00 fg	7.33 h	0.487 hi	8.529 de	3.17 i	4.17 d
	9	82.67 hi	5.33 jk	0.250 jk	4.500 fg	2.17 j	3.17 f
	12	76.00 jk	4.33 l	0.224 jk	2.139 hi	1.17 k	3.17 f
BRRI dhan41	0	111.30 a	15.33 b	6.333 a	23.140 a	14.17 a	1.17 i
	3	110.30 a	12.33 d	2.042 e	9.783 d	9.17 d	3.17 f
	6	101.70 c	10.33 e	1.282 f	9.112 d	6.17 g	4.17 d
	9	94.67 d	8.33 g	1.168 f	7.536 e	3.17 i	5.17 b
	12	77.33 jk	5.33 jk	0.761 g	4.530 fg	2.17 j	3.17 f
Significant level		**	**	**	**	**	**
$LSD_{(0.05)}$		3.61	0.79	0.194	1.418	0.72	0.23
CV(%)		5.42	5.78	11.7	13.84	9.06	16.33

** 5 % level of Significance

Variable effect of cultivar on number of total tillers $hill^{-1}$ was also reported by Hussain *et al.* (1989) who noticed that number of total tillers $hill^{-1}$ differed among the varieties.

Total number of tillers per hill was significantly influenced by different salinity levels (Fig. 4). The maximum total number of tillers $hill^{-1}$ (12.73) was produced from 0 dSm^{-1} and the minimum total number of tillers $hill^{-1}$ (4.73) was produced from 12 dSm^{-1} treatment.

The combined effect of varieties and different salinity levels were statistically significant (Table 1). At harvest, the maximum total number of tillers $hill^{-1}$ (16.33) was found from Chapsal with 0 dSm^{-1} and minimum total number of tillers $hill^{-1}$ (4.00) from Kolar-mocha with 12 dSm^{-1}. Zeng and Shannon (2000) stated that tillers number $hill^{-1}$ and spikelet number per panicle contributed the most variation in grain yield $hill^{-1}$ under salinity. Choi *et al.* (2003) observed that tiller number of rice decreased in 0.5% saline water in the soil with low salinity level. Zeng *et al.* (2001) observed that reduction in tiller number per plant was significant only when plants were salinized for 20 days duration before panicle initiation (PI) of rice. The tiller number decreased significantly at 15.62 dSm^{-1} salinity level in BR11 rice (Gain *et al.*, 2004). Grattan *et al.* (2002) reported that salinity threshold for rice yield was the EC of 3.0 dSm^{-1} and tiller densities reduced by 40% as compared to control (0.4 dSm^{-1}).

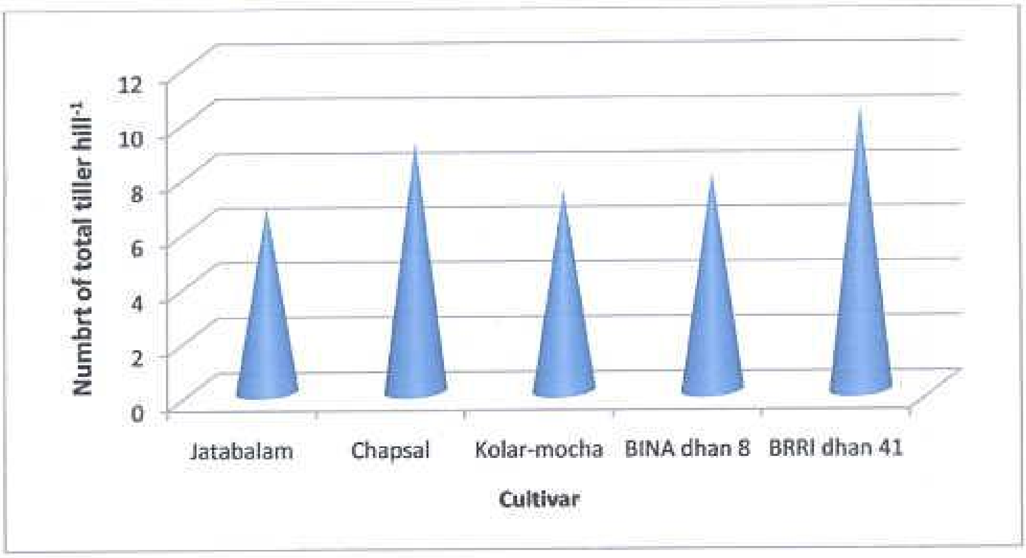

Fig. 3. Effect of cultivar on the number of total tillers of rice (mean of 5 salinity levels)

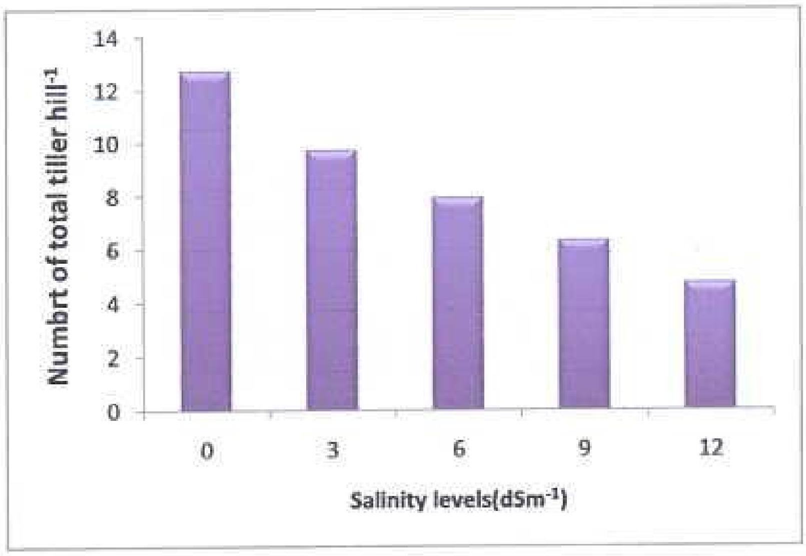

Fig. 4. Effect of different salinity levels on the number of total tillers of rice (mean of 5 cultivars)

4.3 Root dry weight

The root dry weight was significantly influenced by cultivar. Among the five rice cultivars the highest root dry weight (RDW) (2.317 gm $hill^{-1}$) was recorded in BRRI dhan41, whereas the lowest RDW (0.925 gm $hill^{-1}$) was in Jatabalam (Table 2).

The result presented in table 3 shows that the root dry weight was significantly influenced by the salinity levels. The root dry weight significantly decreased with increasing the salinity levels. The root dry weight was highest (4.568 g) at 0 dSm^{-1} and it was lowest (0.408 g) at 12 dSm^{-1} level of soil salinity (Table 3).

The effect of different salinity levels on root dry weight of selected rice cultivars differed significantly. The highest root dry weight (6.333 g) was found in BRRI dhan41 at 0 dSm^{-1} and the lowest value (0.093 g) was in Chapsal with 12 dSm^{-1} (Table 1). Roy *et al.* (2002) and Rodrigues *et al.* (2002) observed that the length and dry weight of rice shoots and roots, as well as the number of roots per plant decreased with increasing salinity levels which corroborate our results. Increasing concentrations of NaCl from 50 – 150 mM progressively decreased root growth (Lin and Kao 2001a) and increased both Na^+ and Cl^- concentrations in root (Lin and Kao 2001b). The reduction of root growth by NaCl was closely correlated with the increase in ionically bound peroxidase activity in roots of NaCl-stressed rice seedlings (Lin and Kao 1999).

Table 2. Effect of cultivar on the effective tiller, non-effective tiller, root dry weight and shoot dry weight of rice (mean of 5 salinity levels)

Cultivar	Root dry weight (g hill^{-1})	Shoot dry weight (g hill^{-1})	Effective tillers hill^{-1}	Non effective tillers hill^{-1}
Jatabalam	0.925 c	2.808 d	4.100 cd	2.933 c
Chapsal	1.217 b	5.163 c	5.133 b	4.033 a
Kolar-mocha	1.015 bc	4.107 cd	3.500 d	3.567 b
BINA dhan 8	1.260 b	8.303 b	4.567 bc	3.400 b
BRRI dhan41	2.317 a	10.82 a	6.967 a	3.367 b
Significant level	**	**	**	**
$LSD_{(0.05)}$	0.268	1.958	0.996	0.313
CV(%)	11.7	13.84	9.06	16.33

** 5 % level of Significance

Table 3. Effect of different salinity levels on the effective tiller, non effective tiller, root dry weight and shoot dry weight of rice (mean of 5 cultivars)

Salinity levels	Root dry weight (g hill^{-1})	Shoot dry weight (g hill^{-1})	Effective tillers hill^{-1}	Non effective tillers hill^{-1}
0	4.568 a	15.58 a	10.57 a	2.27 d
3	0.799 b	6.105 b	6.967 b	2.77 c
6	0.528 c	4.729 bc	3.967 c	4.00 b
9	0.431 c	3.231 cd	1.933 d	4.47 a
12	0.408 c	1.557 d	0.9 e	3.80 b
Significant level	**	**	**	**
$LSD_{(0.05)}$	0.268	1.958	0.946	0.31
CV (%)	11.7	13.84	9.06	16.33

** 5 % level of Significance

4.4 Shoot dry weight

Shoot dry weight (SDW) was evident from Table 2 that irrespective of cultivar significantly varied at harvest. Table 2 show that BRRI dhan41 had significant highest amount of shoot dry weight (SDW) (10.82 g). Lower amount of shoot dry weight (2.808) was produced from Jatabalam.

Statistically significant variation was recorded for shoot dry weight at harvest. The maximum shoot dry weight was obtained from (15.58 g) 0 dSm^{-1} while the minimum number was recorded from (1.56 g) 12 dSm^{-1} (Table 3).

The effect of cultivar and salinity on shoot dry weight was statistically significant at harvest (Table 1). The maximum shoot dry weight (23.14 g) was found from BRRI dhan41 with 0 dSm^{-1} and minimum shoot dry weight (0.154 g) from Jatablam at 12 dSm^{-1}. Salinity caused a substantial reduction in shoot and root dry weight, but the effect on root growth was proportionately less than that on shoot growth (Welfare *et al.*, 1996). But our results indicate that both root and shoot yield was equally affected by the increase in salinity levels. Zeng *et al.* (2001) observed that reduction in shoot dry weight of plants harvested at seed maturity was significant only when plants were salinized for 20 days duration before booting, but not after booting. Pushpam and Rangasamy (2002) observed that salinity induced general reduction in shoot and root length in susceptible cultivars (IR-20, IR-50) when compared to the tolerant cultivar (Pokkali). It was evident that tolerant rice genotypes maintained higher photosynthetic pigments which caused more photosynthetic efficiency and dry matter accumulation in shoot and roots under salt stress (Mandal and Singh 2001).

4.5 Number of effective tillers

The results in Table 2 revealed that the effective tillers $hill^{-1}$ of the selected rice cultivars varied significantly due to the mean effect of different salinity levels. The highest effective tillers $hill^{-1}$ (6.97) was found in BRRI dhan41 and the lowest (3.58) was in Kolar-mocha.

The number of effective tillers $hill^{-1}$ of selected rice cultivars was significantly influenced by different levels of salinity (Table3). The highest effective tillers $hill^{-1}$ (10.57) was recorded at 0 dSm^{-1} salinity level and the lowest (0.90) was found at 12 dSm^{-1} salinity level.

Interaction effect of cultivar and different levels of salinity was significantly influenced on the number of effective tiller $hill^{-1}$ (Table 1). The maximum value of effective tillers $hill^{-1}$ (14.17) was found in BRRI dhan41 at 0 dSm^{-1} and the minimum (0.00) in Kolar-mocha at 12 dSm^{-1} level of salinity, which was statistically similar with Kolar-mocha at 9 dSm^{-1} and chapsal at 12 dSm^{-1}.

Bohra and Doerffling (1993) observed that plant height, number of tillers and shoot dry weight reduced under salinity stress in both salt tolerant and salt sensitive rice cultivars. They maintained that salinity stress wasted more energy in salt sensitive rice cultivars than that in salt tolerant ones. 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 per panicle, spikelet number per panicle, and tiller number per plant were reduced with increasing salinity (Zeng *et al.*, 2002). Our results also indicate that the percent effective tiller $hill^{-1}$ was badly affected at higher salinity levels.

4.6 Number of non-effective tillers

The mean effect of different salinity levels significantly influenced the number of non-effective tillers $hill^{-1}$ of five selected rice cultivars (Table 2). The highest number of non-effective tillers $hill^{-1}$ was observed in Chapsal (4.03) and it was least in Jatabalam (2.93).

The number of non-effective tillers $hill^{-1}$ of rice cultivars significantly differed to different levels of salinity. The highest non effective tillers $hill^{-1}$ (4.47) was recorded at 9 dSm^{-1} salinity level and it was the lowest (2.27) at 0 and 3 dSm^{-1} salinity levels (Table 3).

The number of non-effective tillers $hill^{-1}$ was statistically influenced by the interaction effect of cultivar and different salinity levels. The number of non-effective tillers $hill^{-1}$ was highest (6.33) in cultivar Kolar-mocha at 12 dSm^{-1} and the minimum value (1.67) of non-effective tillers $hill^{-1}$ was found in BRRI dhan41 with 0 dSm^{-1} levels of salinity (Table 1). Alam *et al.*, (2001) stated that the salinity at reproductive stage of rice depressed grain yield much more than that at the vegetative growth stage and at critical salinity levels it might give 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 florets and germination of pollen grains and hence caused an increase in number of sterile florets. The mutant cultivar maintained its superiority in various characteristics such as plant height, higher number of fertile panicles per plant (Baloch *et al.*, 2003).

4.7 Panicle length

The panicle length varied significantly due to cultivar shown in Table 4. The longest panicle length (17.92 cm) was obtained in cultivar BRRI dhan41 and the shortest panicle length (8.14 cm) was recorded in cultivar Kolar-mocha.

Length of panicle showed statistically significant differences due to the different levels of salinity. The longest panicle (19.56 cm) was found at 0 dSm^{-1} which is statistically similar to 3 dSm^{-1} salinity levels and the lowest panicle length (4.8 cm) was recorded at 12 dSm^{-1} level of salinity (Table 5).

The panicle length of selected five rice cultivars significantly decreased due to increasing the different salinity levels (Table 6). The highest panicle length (23.43 cm) was recorded in BRRI dhan41 at 0 dSm^{-1} level of salinity. However, the lowest panicle length (10.00) was recorded in Kolar-mocha at 6 dSm^{-1} level of salinity, whereas Kolar-mocha did not at all produce panicle at 9 & 12 dSm^{-1} levels of salinity. The cultivar Chapsal and BINA dhan 8 also did not produce any panicle at 12 dSm^{-1} level of salinity. Khatun *et al.* (1995) and Alam *et al.* (2001) reported that salinity severely reduces the panicle length, number of primary branches per panicle, number of spikelet per panicle, seed setting percentage and panicle weight, thereby reducing the grain yield. Marassi *et al.*, 1989 and Abdullah *et al.* (2001) observed that panicle length was significantly decreased due to salinity stress. Aslam *et al.* (2001) stated that panicle length of rice adversely affected by both saline and saline sodic soils. Salinity had a negative impact on a number of yield components including stand establishment, panicles, tillers and spikelets per panicle, floret sterility and individual grain size (Grattan *et al.*, 2002).

Table 4. Effect of cultivar on the yield and yield contributing character of rice (mean of 5 salinity levels)

Cultivar	Panicle length (cm)	No. of filled grain panicle^{-1}	No. of unfilled grain panicle^{-1}	Grain yield (g hill^{-1})
Jatabalam	16.02 ab	31.85 ab	8.816 abc	1.668 ab
Chapsal	12.7 bc	23.53 bc	9.366 ab	1.024 b
Kolar-mocha	8.14 c	5.282 d	11.45 a	0.852 b
BINA dhan 8	13.01 abc	20.35 c	7.612 bc	2.134 ab
BRRI dhan41	17.92 a	33.84 a	5.502 c	2.772 a
Significant level	**	**	**	**
$LSD_{(0.05)}$	4.832	8.598	3.239	1.392
CV(%)	15.73	16.51	16.71	16.32

** 5 % level of Significance

Table 5. Effect of different salinity levels on the yield and yield contributing character of rice (mean of 5 cultivars)

Salinity levels (dSm^{-1})	Panicle length (cm)	No. of filled grain panicle^{-1}	No. of unfilled grain panicle^{-1}	Grain yield (g hill^{-1})
0	19.56 a	38.23 a	2.4 c	3.996 a
3	17.58 a	37.05 a	5.532 c	2.754 a
6	14.82 ab	23.5 b	8.902 b	1.06 b
9	11.03 b	15.18 b	12.6 a	0.614 b
12	4.8 c	0.904 c	13.31 a	0.026 b
Significant level	**	**	**	**
$LSD_{(0.05)}$	4.832	8.598	3.239	1.392
CV (%)	15.73	16.51	16.71	16.32

** 5 % level of Significance

Table 6. Combined effect of cultivar and different salinity on the yield and yield contributing character of rice

Cultivar	Salinity levels (dSm^{-1})	Panicle length (cm)	No. of filled grain $panicle^{-1}$	No. of unfilled grain $panicle^{-1}$	Grain yield ($g\ hill^{-1}$)
Jatabalam	0	20.96 ab	47.00 a	2.67 klm	4.33 ab
	3	16.33 cd	51.00 a	6.33 ghi	2.62 cde
	6	16.00 cde	37.00 b	9.33 def	0.51 ghi
	9	14.80 cdef	34.21 bcd	12.67 c	0.39 hi
	12	12.00 efg	0.00 i	13.08 c	0.00 i
Chapsal	0	16.50 cd	35.50 bc	2.00 lm	3.00 c
	3	18.00 bc	45.50 a	5.33 hij	1.82 def
	6	16.00 cde	30.00 cde	8.50 defg	0.30 i
	9	13.00 defg	6.67 hi	17.00 b	0.00 i
	12	0.00 h	0.00 i	11.00 cd	0.00 i
Kolar-mocha	0	16.20 cd	11.21 fgh	5.00 hijk	2.83 cd
	3	14.50 cdef	15.20 fg	7.33 fghi	1.43 fgh
	6	10.00 g	0.00 i	12.37 c	0.00 i
	9	0.00 h	0.00 i	15.56 b	0.00 i
	12	0.00 h	0.00 i	20.00 a	0.00 i
BINA dhan 8	0	20.71 ab	46.20 a	1.33 lm	4.82 a
	3	18.20 bc	28.57 de	5.00 ijk	3.45 bc
	6	14.30 cdef	17.00 f	8.14 efg	1.79 def
	9	11.83 fg	10.00 gh	10.67 cde	1.10 fghi
	12	0.00 h	0.00 i	12.92 c	0.00 i
BRRI dhan41	0	23.43 a	51.23 a	1.00 m	5.00 a
	3	20.88 ab	45.00 a	3.67 jkl	4.45 ab
	6	17.82 bc	33.50 bcd	6.17 ghij	2.70 cd
	9	15.50 cdef	25.00 e	7.67 fgh	1.58 efg
	12	12.00 efg	4.52 hi	9.00 def	0.13 i
Significant level		**	**	**	**
$LSD_{(0.05)}$		3.50	6.23	2.35	1.01
CV(%)		15.73	16.51	16.71	16.32

** 5 % level of Significance

4.8 Number of filled grains

Different cultivars show significant variation in number of filled grain panicle^{-1}. The number of filled grains panicle^{-1} (33.84) was highest in BRRI dhan41 and that was lowest (5.28) in Kolar-mocha (Table 4). BRRI (1994) found that number of filled grains panicle^{-1} significantly differed due to cultivar.

The number of filled grains panicle^{-1} was significantly influenced by different salinity levels (Table 5). The highest number of filled grain panicle^{-1} (38.23) was recorded at 0 dSm^{-1} which is statistically similar with 3 dSm^{-1} level of salinity and the lowest (0.90) was found at 12 dSm^{-1} salinity level.

The effect of different salinity levels on filled grain panicle^{-1} of five rice cultivars significantly decreased with increase in salinity level. The filled grains panicle^{-1} of five selected rice genotypes was significantly influenced by different salinity levels (Table 6). At 0 dSm^{-1} level of salinity, the maximum filled grains panicle^{-1} (51.23) were found in BRRI dhan41 and that was minimum (4.52) also in BRRI dhan41 at 12 dSm^{-1}. The other cultivars did not produce any grain at 12 dSm^{-1} level of salinity and the cultivar Kolar-mocha produced grain upto 3 dSm^{-1} level of salinity. Choi *et al.* (2003) conducted two experiments, with low and medium soil salinity levels with four levels of salt solution mixed with seawater (0.1, 0.3, 0.5 and 0.7%) and control (tap water and 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. Khatun *et al.* (1995) investigated the effect of salinity on the reproductive physiology of rice genotypes by treatment from panicle initiation with sodium concentrations of 20, 35 or 50 mM in an "artificial seawater" and found that salinity delayed flowering, reduced the number of fertile florets per panicle and the grain yield. They further observed that the effect on grain yield was more severe than on vegetative growth which is also in conformity with our results.

4.9 Number of unfilled grain

Results showed that cultivar had significant effect in respect of the number of unfilled grains panicle^{-1} (Table 4). BRRI dhan41 produced minimum number (5.50) of unfilled grains panicle^{-1} and Kolar-mocha produced maximum number (11.45) of unfilled grains panicle^{-1}. This variation might be due to genetic characteristics. BINA (1993) and Chowdury *et al.* (1993) also reported differences in number of unfilled grains panicle^{-1} due to varietal differences.

It is revealed from the results that the number of unfilled grains panicle^{-1} differed significantly due to different salinity levels. The highest number of unfilled grain panicle^{-1} was recorded at 9 and 12 dSm^{-1} levels of salinity and it was the least at 0 and 3 dSm^{-1} levels of salinity (Table 5).

Interaction effect of varieties and different salinity levels showed significant response on unfilled grains panicle^{-1} (Table 6). The minimum number of unfilled grains panicle^{-1} (1.00) was found in BRRI dhan41 at 0 dSm^{-1} and the maximum number of unfilled grains panicle^{-1} (20.00) was recorded in Kolar-mocha at 12 dSm^{-1} level of salinity (Table 6). The sterility and significant reduction in seed setting in rice were assumed to be not merely due to reduction or inhibition of different biochemical constituents and physiological functions, but were also due to limitation of soluble carbohydrate translocation in primary and secondary spikelets, accumulation of more Na^+ and less K^+ in all the floral parts, and highly significant inhibition of specific activity of starch synthetase in developing rice grains (Abdullah *et al.*, 2001). Asch *et al.* (1999) observed that salinity was a major yield-reducing stress in many arid and/or coastal irrigation syshoots for rice. Arich *et al.* (1998) observed that number of unfilled grain per panicle increased with increasing salinity levels.

4.10 Grain yield

Grain yield is a function of interplay of various yield components such as number of productive tillers, grains panicle^{-1} and 1000-grain weight (Hassan *et al.*, 2003). The grain yield hill^{-1} of five selected rice cultivars differed significantly due to the mean effect of different salinity treatments (Table 4). The highest grain yield hill^{-1} (2.772 g) was found in cultivar BRRI dhan41 and the lowest yield (0.85 g) was recorded in Kolar-mocha. Grain yield differences due to varieties were reported by Suprithatno and Sutaryo (1992), Alam (1998) and IRRI (1978) who recorded variable grain yield among tested varieties.

A highly significant variation in grain yield hill^{-1} of rice cultivars was observed due to the different salinity levels (Table 5). The highest grain yield (3.996 g) hill^{-1} was recorded at control treatment and it was lowest (0.026 g) at 12 dSm^{-1} level of salinity (Table 5).

It was evident from the Table 6 that interaction of cultivar and different salinity levels significantly affected the grain yield. The highest grain yield hill^{-1} (5.00 g) was found in BRRI dhan41 at 0 dSm^{-1} salinity level, which was statistically similar with BINA dhan 8 and the lowest yield (0.00 g) was obtained in Kolar-mocha at 6, 9, 12 dSm^{-1} levels of salinity.

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). Baloch *et al.* (2003) observed that the mutant cultivar of rice "Shua-92" maintained its superiority to other varieties in various characteristics such as plant height, higher number of fertile panicles per plant, more fertile grains per panicle, heavy grain size and high plant yield at 7.11- 8.0 dSm^{-1} level of salinity.

4.11 Potassium

It appears from the results presented in Fig. 5 that there was a significant variation in potassium (K) content in five selected rice cultivars under mean effect of different salinity levels. The highest K content in shoot was found in BRRI dhan41(1.64%) and that was lowest (1.104%) in Kolar-mocha (Appendix IV).

The Potassium (K) contents in shoot 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 shoot (Figure 6). The highest K content in shoot (1.64%) was recorded in 0 dSm^{-1} and it was lowest (1.19%) in 12 dSm^{-1} salinity level respectively (Appendix IV).

The combined effects of salinity and cultivar on content of K (%) in shoot were differed significantly. The content of K in shoot of all the selected cultivars progressively decreased with increasing the salinity levels. The highest K content

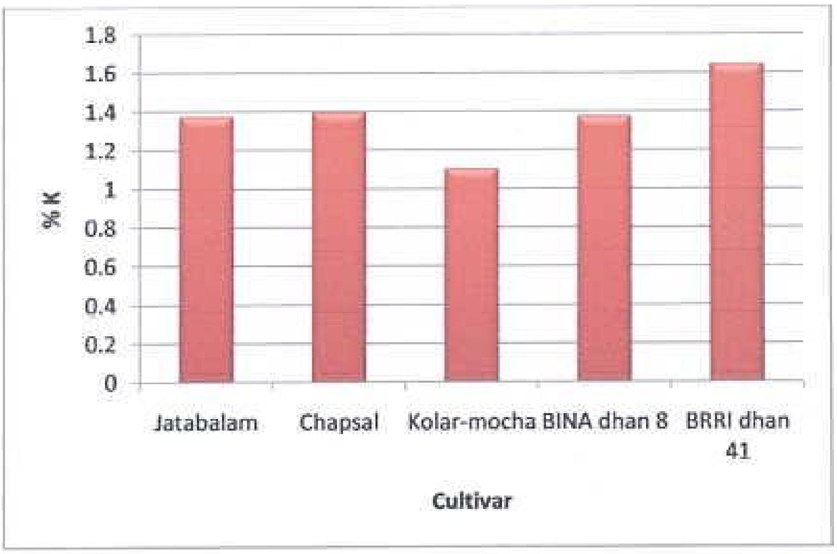

Figure 5 . Effects of different cultivars on K content in shoot of rice plant (mean of 5 salinity levels)

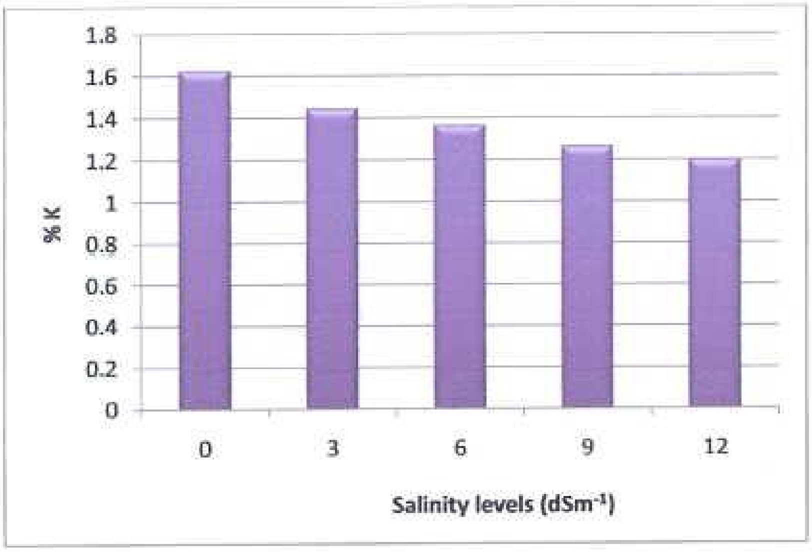

Figure 6 . Effects of different salinity levels on K content in shoot of rice plant (mean of 5 cultivars)

Table 7. Combined effect of cultivar and different salinity levels on the mineral content in shoot of rice

Cultivar	Salinity levels (dSm^{-1})	Na (%)		K (%)		Mg (%)		Ca (%)	
Jatabalam	0	1.27	efghi	1.4	cdef	0.33	a	0.91	efgh
	3	1.37	cdefg	1.36	cdef	0.34	a	0.96	cdefgh
	6	1.39	cdefg	1.34	defg	0.35	a	1.07	abc
	9	1.41	cdef	1.3	efgh	0.35	a	1.03	bcde
	12	1.47	bcdef	1.47	cde	0.35	a	1	bcdef
Chapsal	0	0.84	j	1.72	b	0.34	a	0.87	fghi
	3	0.98	hij	1.44	cde	0.34	a	0.85	ghi
	6	1.27	efghi	1.42	cdef	0.35	a	1.07	abc
	9	1.31	defg	1.24	fgh	0.35	a	0.96	cdefgh
	12	1.63	abcd	1.16	ghi	0.35	a	1.19	a
Kolar-mocha	0	1.27	efghi	1.34	defg	0.34	a	0.96	cdefgh
	3	1.51	bcdef	1.3	efgh	0.35	a	1.057	abcd
	6	1.59	bcde	1.14	hi	0.35	a	1.07	abc
	9	1.74	ab	0.9	jk	0.35	a	1.12	ab
	12	1.9	a	0.84	k	0.35	a	1.09	abc
BINA dhan 8	0	0.96	ij	1.74	b	0.33	a	0.93	defgh
	3	1.29	efgh	1.38	cdef	0.35	a	0.75	i
	6	1.35	cdefg	1.38	cdef	0.35	a	1.07	abc
	9	1.41	cdef	1.36	cdef	0.35	a	1.03	bcde
	12	1.67	abc	1.02	ij	0.35	a	0.98	cdefg
BRRI dhan41	0	0.78	j	1.92	a	0.33	a	0.87	fghi
	3	0.92	j	1.74	b	0.33	a	0.75	i
	6	1.08	ghij	1.54	c	0.33	a	1.05	bcd
	9	1.23	fghi	1.52	cd	0.35	a	0.91	efgh
	12	1.25	fghi	1.5	cd	0.35	a	0.84	hi
Significant levels		**		**		NS		**	
$LSD_{(0.05)}$		0.2747		0.1642		0.05191		0.1161	
CV(%)		12.82		7.11		8.40		7.25	

** 5 % level of Significance

NS- Non significant

(1.92%) in shoot was found in BRRI dhan41 at 0 dSm^{-1} and it was lowest (0.84%) in the Kolar-mocha cultivar at the 12 dSm^{-1} salinity level (Table 7). These findings are in agreement with the observation of Khan *et al.* (1992), Pua *et al.* (2001), Aslam *et al.* (2001), Yaduvanshi (2002), Baba and Fujiyama (2003). 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^+.

4.12 Sodium

The content of sodium (Na) in shoot of the entire fiver selected rice cultivars varied significantly grown at different levels of salinity. Its content in shoot was highest (1.602 %) in Kolar-mocha and lowest (1.052 %) in BRRI dhan-41 (Fig. 7 & Appendix IV).

The sodium (Na) content in shoot of rice significantly varied due to the effect of different salinity levels; where the Na content in shoot increased with the increasing level of salinity in shoot. The highest Na content (1.584%) in shoot was recorded in 12 dSm^{-1} level of salinity which is statistically identical with 9 dSm^{-1} level of salinity and then was lowest (1.02%) in 0 dSm^{-1} respectively (Fig. 8 & Appendix IV).

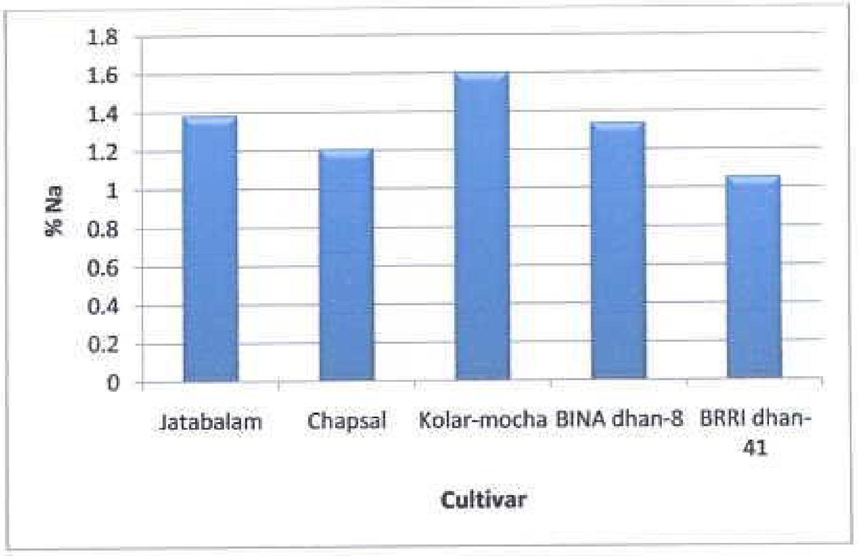

Figure 7 . Effect of cultivar on Na content in shoot of rice (mean of 5 salinity levels)

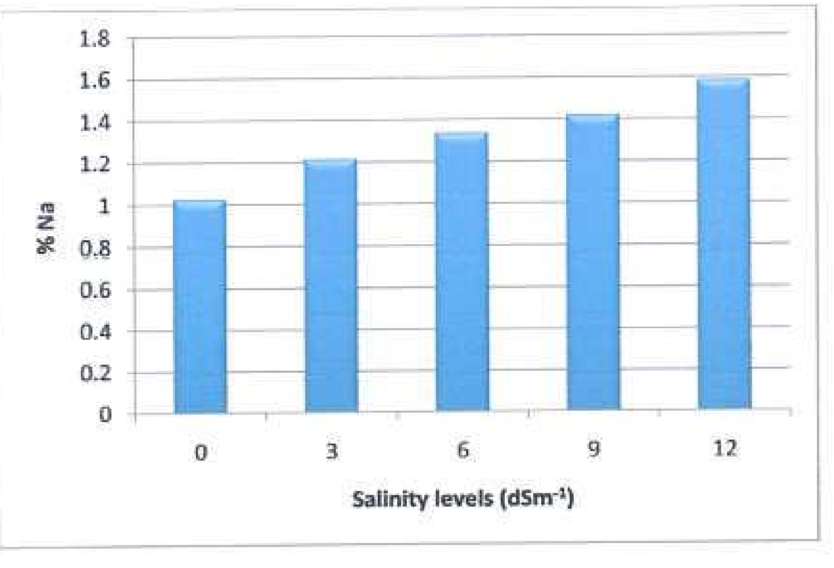

Figure 8. Effect of different salinity levels on Na content in shoot of rice (mean of 5 cultivars)

The combined effect of salinity and cultivar on content of Na in shoot was found significant. The Na content increased with the increasing levels of salinity in shoot of all cultivars; where the increasing pattern were very sharp in shoot of cultivar Kolar-mocha (table 8). The highest Na content (1.90 %) in shoot was found in Kolar-mocha at 12 dSm^{-1} and it was lowest (0.78%) in the cultivar BRRI dhan-41 at the 0 dSm^{-1} salinity level. Ashraf *et al.* (2004) 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.

4.13 Calcium

The results presented in Fig 9 show that the calcium (Ca) content in rice shoot of the five selected cultivars had significantly affected due to the mean effect of different salinity levels. The highest Ca content (1.06%) recorded in shoot of Kolar-mocha and it was lowest (0.88 %) in BRRI Dhan-41 (Appendix IV).

The effect of different salinity levels on Ca content in shoot of rice plant differed significantly. The Ca content recorded in rice shoot was highest (1.07 %) in 6 dSm^{-1} and it was lowest (0.87 %) in 3 dSm^{-1} (Fig. 10).

The combined effect of cultivar and salinity was found significant in case of Ca content in shoot of rice plant (Table 7); where the highest Ca content (1.19 %) found in shoot of Chapsal at 12 levels of salinity and it was lowest (0.75 %) in BRRI dhan41 at 3 dSm^{-1}. This is controvert 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.

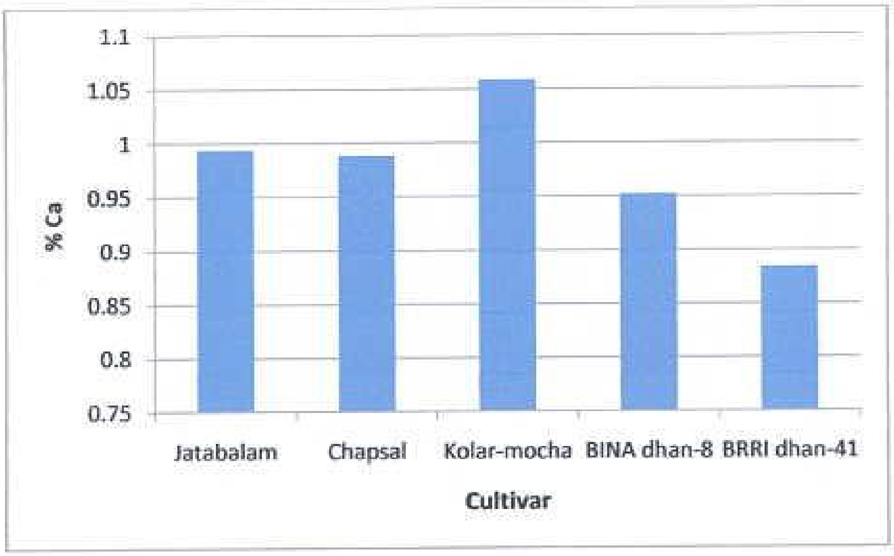

Figure 9 . Effects of cultivar on Ca content in shoot of rice (mean of 5 salinity levels)

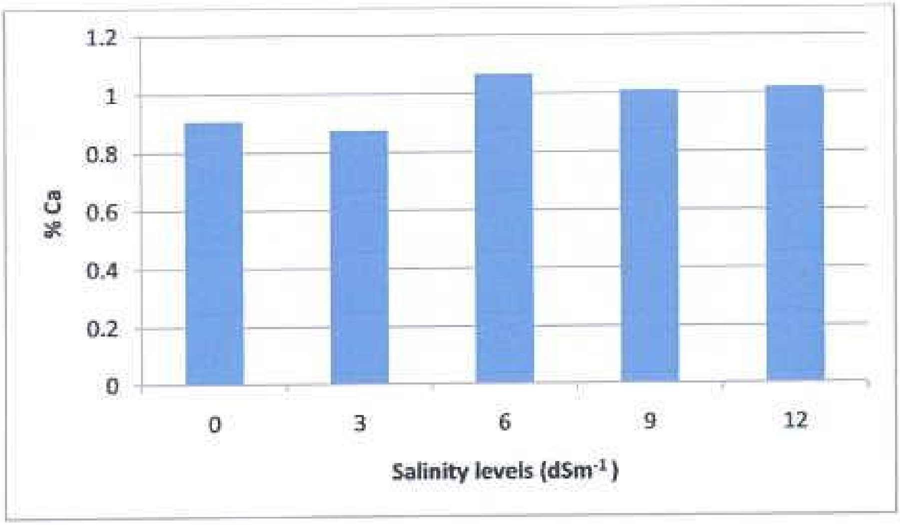

Figure 10 . Effects of different salinity levels on Ca content in shoot of rice (mean of 5 cultivars)

4.14 Magnesium

The concentration of magnesium (Mg) in the shoot of the five selected rice cultivars did not differ significantly due to the mean effect of different salinity levels. The highest Mg content (0.348%) in the shoot was found in Kolar-mocha and that it was lowest (0.338%) in cultivar BRRI dhan41 (Fig. 11 & Appendix IV).

The percent Mg content in shoot of rice did not significantly increase with increasing the salinity levels (Fig. 12). The highest Mg (0.350%) content in the shoot was found at 12 dSm^{-1} and that was lowest (0.334%) in 0 dSm^{-1} (Appendix IV).

The combined effect of different salinity levels and five rice cultivars on percent of Mg content in shoot did not differ significantly. However, the Mg content increased with increasing level of salinity in shoot and all cultivars (Table 7). In shoot the highest (0.350 %) Mg was found in Kolar-mocha at 12 dSm^{-1} and it was lowest (0.330%) in BRRI Dhan41at 0 dSm^{-1}. Qadar (1995) found that Mg were slightly higher in the shoot in response to sodicity stress.

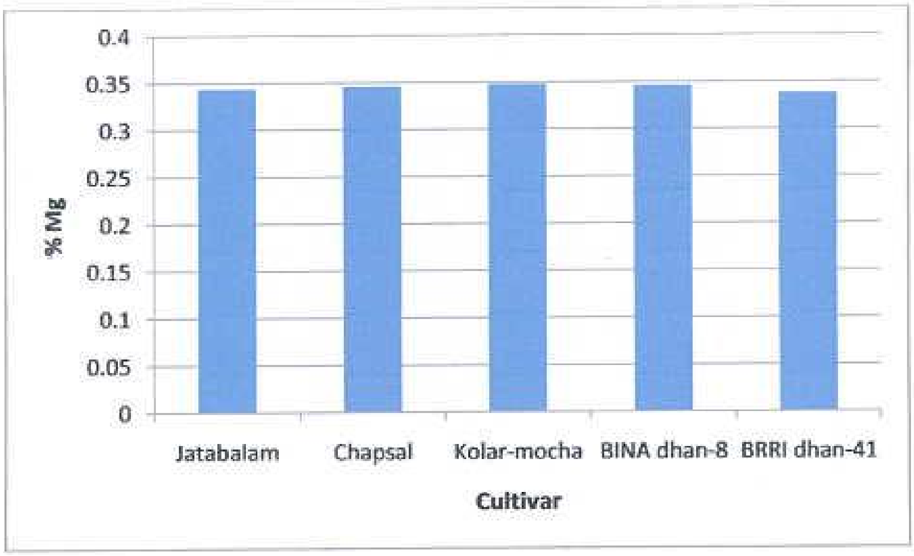

Figure 11 . Effects of cultivar on Mg content in shoot of rice (mean of 5 salinity levels)

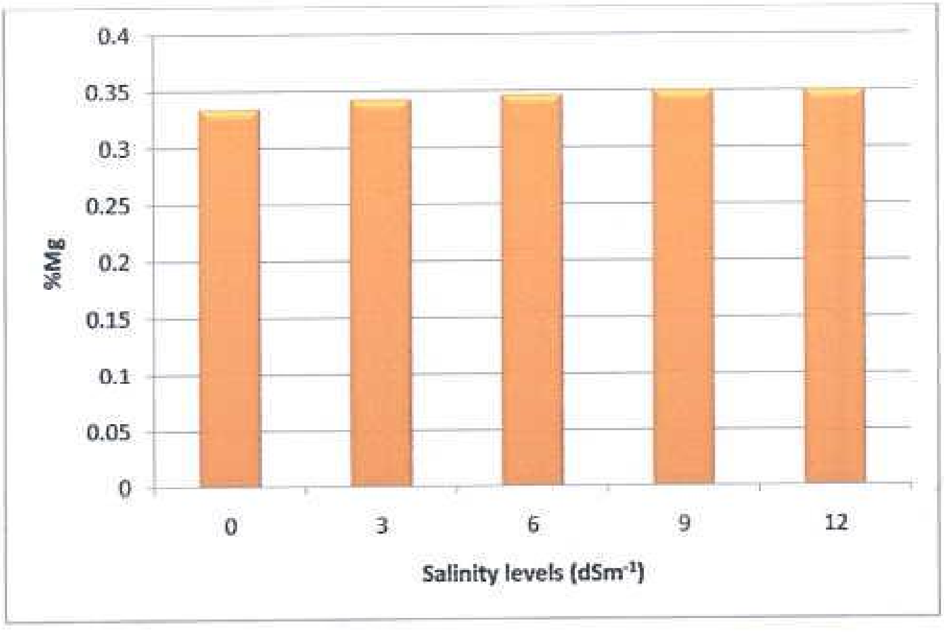

Figure 12 . Effects of different salinity levels on Mg content in shoot of rice (mean of 5 cultivars)

CHAPTER 5

SUMMARY AND CONCLUSIONS

An experiment was conducted at the net house of the department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207 under pot-culture during the Boro season (December-June) of the year 2010-11 to study the effect of salinity on morphology and mineral content in shoots of some local and modern rice cultivars. The experiment was completed using five varieties (Jatabalam, Chapsal, Kolar-mocha, BINA dhan 8 and BRRI dhan41) and five salinity levels (0, 3, 6, 9 and 12 dSm^{-1}). The experiment was set in Completely Randomized Design (CRD) having two factors with three replications.

The results on the effect of morphological characters indicated that plant height, total tillerss, effective tillers, number of non effective tillers, root dry weight, shoot dry weight, number of field grains, number of unfilled grains, panicle length and grains yield were significantly influenced by the variety. The tallest plant (99.06 cm) was found in cultivar BRRI dhan41. BRRI dhan41 was achieved maximum number of total tillers (10.33) and effective tillers (6.97) per hill. The highest root dry weight (RDW) (2.317 g $hill^{-1}$) and shoot dry weight (10.82 g $hill^{-1}$) were recorded in BRRI dhan41. The minimum number of non effective tillers (2.93 $hill^{-1}$) was observed in Jatabalam. The longest panicle length (17.92 cm) and the highest number of filled grains (33.84) $panicle^{-1}$ were obtained in cultivar BRRI dhan41. BRRI dhan41 produced minimum number (5.502) of unfilled grains $panicle^{-1}$. The highest grains yield $hill^{-1}$ (2.77 g) was found in cultivar BRRI dhan-41 and the lowest yield (0.85 g) was recorded in Kolar-mocha. There was a significant variation in potassium (K) content in five selected rice cultivars under different salinity levels. The highest K content in shoot was found in BRRI dhan41(1.64%). The Na, Ca and Mg content in shoot was minimum (1.052%, 0.88% and 0.338%, respectively) in BRRI dhan41.

All parameter was significantly influenced by different salinity levels. At harvest of rice plant the highest (103.8 cm) plant height were observed in 0 dSm^{-1}. The maximum total number of tillers $hill^{-1}$ (12.73), effective tillers $hill^{-1}$ (10.57), RDW (4.568 gm) and SDW (15.58 g $hill^{-1}$) were produced from 0 dSm^{-1}. The non effective tillers was the lowest (2.27) at 0 and 3 dSm^{-1} salinity levels. The longest panicle (19.56 cm) and number of filled grains $panicle^{-1}$ (38.23) was found at 0 dSm^{-1}. The minimum number of unfilled grains $panicle^{-1}$ (2.40) at 0 dSm^{-1}. The highest grains yield (3.99 g) $hill^{-1}$ was recorded at control treatment (dSm^{-1}) and it was lowest (0.026 g) at 12 dSm^{-1} level of salinity. The Potassium, Na and Ca contents in shoot of rice also significantly varied due to the effect of different salinity levels. The highest K content in shoot (1.64%) was recorded in 0 dSm^{-1}. The highest Na content in shoot (1.584%) was recorded in 12 dSm^{-1} level of salinity. The Ca content recorded in shoot of rice was highest (1.07 %) in 6 dSm^{-1}. The lowest Mg (0.35%) content in the shoot was in 0 dSm^{-1}.

In combination effect of cultivars and salinity levels was significantly influenced on all parameters. The highest (111.30 cm) plant height was found in BRRI dhan41with 0 dSm^{-1}. The maximum total number of tillers $hill^{-1}$ (16.33) was found from Chapsal with 0 dSm^{-1}. The highest root dry weight (6.33 g) and shoot dry weight (23.14 gm) $hill^{-1}$ was found in BRRI dhan41 at 0 dSm^{-1}. The maximum value of effective tillers $hill^{-1}$ (14.17) was found in BRRI dhan41 at 0 dSm^{-1}. The minimum value (1.67) of non-effective tillers hill^{-1} was found in BRRI dhan41 with 0 dSm^{-1} level of salinity. The highest panicle length (23.43 cm) and filled grains panicle^{-1} (51.23) were recorded in BRRI dhan41 at 0 dSm^{-1} level of salinity. The minimum number of unfilled grains panicle^{-1} (1.00) was found in BRRI dhan41 at 0 dSm^{-1}. The highest grains yield hill^{-1} (5.00 g) was found in BRRI dhan41 at 0 dSm^{-1} salinity level and the lowest or no yield (0.00 g) was obtained from Kolar-mocha at 6, 9, 12 dSm^{-1} levels of salinity. The highest K content (1.92%) in shoot was found in BRRI dhan41 at 0 dSm^{-1}. The lowest Na content (0.78%), Ca content (0.75%) and Mg content (0.33%) in shoot was found in the cultivar BRRI dhan41 at the 0 dSm^{-1} salinity level.

The effect of different salinity levels on Na^+, K^+, Ca^{2+}, Mg^{2+} contents in shoots of five rice cultivars significantly differed. Concentrations of Na^+, Ca^{2+}, Mg^{2+} in shoot of five rice cultivars showed significantly increased and the K^+ content significantly decreased with increase in salinity levels. The highest amount of Na^+, K^+, Ca^{2+} and Mg^{2+} were found in the shoots of rice cultivar Kolar-mocha and the lowest content of all these ions was obtained in BRRI dhan41. The cultivar Kolar-mocha showed the lowest amount of K^+ in shoot. On the other hand, the cultivar BRRI dhan41 contained the lowest concentration of Na^+, Ca^{2+}, Mg^{2+} and the highest amount of K^+ which might have diluted the Na^+ in plant system.

Based on the above results following conclusions and recommendation may be made -

- The cultivar BRRI dhan41 and BINA dhan 8 had better expression of morphological characters than those of Kolar-mocha and Jatabalam in all cases.

- Salinity increased the content of Na^+, Ca^{2+}, Mg^{2+} ¯, and decreased K^+ content in different plant tissues of the cultivars.
- Generally all the tolerant cultivars showed lower Na^+ concentration reflecting the dilution effect, the tolerance mechanism.
- based on the above conclusions plant breeder may adapt the technique of selection or screening the genotypes and develop salt tolerant rice cultivars.

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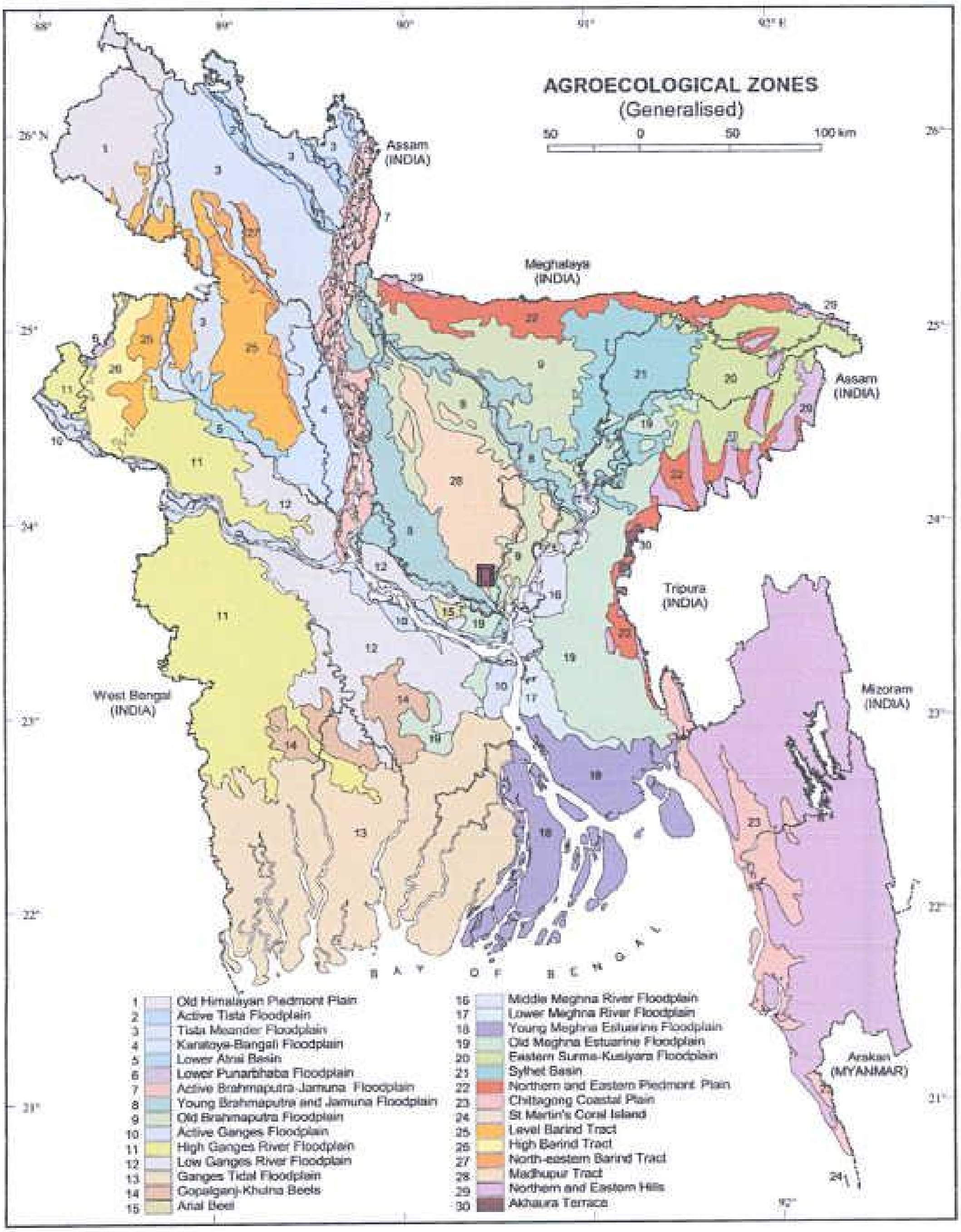
APPENDICES

Appendix I. Map showing the experimental sites under study



■ **The experimental site under study**

Appendix II. Analysis of variance of the data on the plant height, effective tiller, non effective tiller, root dry weight and shoot dry weight of rice

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm)	Root dry weight (g $hill^{-1}$)	Shoot dry weight (g $hill^{-1}$)	Effective tiller $hill^{-1}$	Non effective tiller $hill^{-1}$
Replication	2	784	158.333	5.336	10.943	30.653
Cultivar (A)	4	417.145*	31.32*	4.705*	160.215*	25.983*
Salinity level (B)	4	1873.744*	144.12*	49*	451.916*	232.683*
Interaction (A×B)	16	46.802*	5.445*	0.513*	8.862*	2.802*
Error	48	4.833	0.001	1.124	0.746	0.174

* Significant at 0.05 level of probability

Appendix III. Analysis of variance of the data on the yield and yield contributing character of rice

Source of variation	Degrees of freedom	Mean square			
		Panicle length (cm)	No. of filled grain $panicle^{-1}$	No. of unfilled grain $panicle^{-1}$	Grain yield (g $hill^{-1}$)
Replication	2	457.96	906.093	272.25	7.398
Cultivar (A)	4	208.158*	1939.053*	72.481*	9.428*
Salinity level (B)	4	513.431*	3671.669*	323.073*	40.398*
Interaction (A×B)	16	28.552*	199.455*	12.329*	0.899*
Error	48	4.543	14.385	2.042	0.377

* Significant at 0.05 level of probability

Appendix IV. Analysis of variance of the data on the mineral content in shoot of rice

Source of variation	Degrees of freedom	Mean square			
		Na	K	Mg	Ca
Replication	2	7.508	4.58	0.292	9.61
Cultivar (A)	4	0.631*	0.548*	0^{NS}	0.062
Salinity level (B)	4	0.67*	0.414*	0.001^{NS}	0.099
Interaction (A×B)	16	0.03*	0.047*	0^{NS}	0.017
Error	48	0.028	0.01	0.001	0.005

* Significant at 0.05 level of probability NS: Non significant