ROLE OF MAGNESIUM TO ALLEVIATE DAMAGING EFFECT OF SALINITY ON DEVELOPMENT AND YIELD PERFORMANCE OF RICE PLANT (*Oryza sativa* L.)

A THESIS

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CERTIFICATE

This is to certify that the thesis entitled, ***"ROLE OF MAGNESIUM TO ALLEVIATE DAMAGING EFFECT OF SALINITY ON DEVELOPMENT AND YIELD PERFORMANCE OF RICE PLANT (Oryza sativa L.)"*** *submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE IN AGRICULTURAL BOTANY,*** *embodies the results of a piece of bonafide research work carried out by* ***FAISAL MHAMUD*** *Registration No.* ***11-04403*** *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.

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ABSTRACT

A pot experiment was conducted at the net house of the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka-1207, during *Boro* rice cropping season of the year of 2017-2018 to investigate the role of magnesium to alleviate damaging effect of salt stress on development and yield performance of rice plant (*Oryza sativa* L.). The experiment was conducted using two salinity levels with magnesium viz. S_0= Control, S_1= 4 dSm^{-1} salt, S_1Mg_1= 4 dSm^{-1} salt + 80 ppm magnesium, S_1Mg_2 = 4 dSm^{-1} salt + 160 ppm magnesium, S_2 = 6 dSm^{-1} salt, S_2Mg_1 = 6 dSm^{-1} salt + 80 ppm magnesium, S_2Mg_2 = 6 dSm^{-1} salt + 160 ppm magnesium. The experiment was set in Randomized Complete Block Design **(**RCBD) having one factor with three replications. The results on the effect of morphological and yield contributing characters indicated that plant height; numbers of tillers, leaf length, leaf breath, and SPAD value, effective tiller, number of non effective tiller, panicle length and filled grain, unfilled grain, thousand seed weight grain yield were influenced by salinity and magnesium. Among the 3 salinity level (0,4 & 6dSm^{-1}), the damaging effect was found more in higher stress (6dSm^{-1} salt).But magnesium supplementation along with salt greatly reduced the damaging effect of salt. Out of 2 level of magnesium, 160 ppm magnesium. Significantly reduced the damaging effect of salt. Therefore, for cultivation of BRRI dhan67 under the saline condition magnesium application could be a better practice for getting higher yield.

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LIST OF ABBREVIATIONS

AEZ = Agro-Ecological Zone
BARI = Bangladesh Agricultural Research Institute
BBS = Bangladesh Bureau of Statistics
LAI = Leaf area index
ppm = Parts per million
et al. = And others
N = Nitrogen
TSP = Triple Super Phosphate
MP = Muriate of Potash
RCBD = Randomized complete block design
DAS = Days after sowing
ha^{-1} = Per hectare
g = gram (s)
Kg = Kilogram
µg = Micro gram
SAU = Sher-e-Bangla Agricultural University
SRDI = Soil Resources and Development Institute
HI = Harvest Index
No. = Number
Wt. = Weight
LSD = Least Significant Difference
^{0}C = Degree Celsius
mm = Millimeter
Max = Maximum
Min = Minimum
% = Percent
cv. = Cultivar
NPK = Nitrogen, Phosphorus and Potassium
CV% = Percentage of coefficient of variance
Hr = Hour
T = Ton
viz. = Videlicet (namely)

CHAPTER I

INTRODUCTION

Rice(*Oryza sativa* L.) is the staple food for more than half of the world's population. In humid and sub-humid Asia,rice is the single most important source of employment and income for rural people and it provides 50%-80% of the calories consumed for more than three billion Asians (Hossain and Fischer, 1995;Khush, 2005). However, rice is very sensitive to salinity stress and is currently listed as the most salt sensitive cereal crop with a threshold of 3 dSm^{-1} for most cultivated varieties (USDA, 2016)**,** whereas, generally, a soil is only considered saline (salt-affected) if it has an ECe (electrical conductivity of saturation extract)about above (Rengasamy, 2006).Even at ECe as low as 3.5 dSm^{-1}, rice loses about 10% of its yield, and 50% yield loss was recorded for rice at ECe 7. 2 dSm^{-1}. Asia accounts for 90% of the world's production and consumption of rice but "sea level rise is already increasing rice growing areas of the world" (Dayton, 2014).

Salinity is a general term used to describe the presence of elevated levels of different salts such as sodium chloride, magnesium and calcium sulphates and bicarbonates in soil and water (Hoang *et al.* 2015). With more than 830 million hectares (ha) of salt-affected land globally (Mannus, *et al*. 2005) and approximately two million hectare of land uncultivable due to excessive salinity added each year (Umali, 1993), salinity is a growing worldwide problem. Irrigation and extensive clearing of vegetation, which bring the groundwater with soluble salts to, or close to, the soil surface, are the two major human activities that accelerate salinity. Of the 230 million hectare of the world's irrigated land, 45 million hectare (20%) has been salt-affected (Shrivastava and Kumar, 2015). When growing on salt-affected soils, crops must compete with salts in the soils for water as well as to cope with ion toxification, nutritional disorders and poor soil physical conditions to survive, therefore, their productivity was reduced (Shrivastava and Kumar, 2015, Munns and Tester, 2005). By 2050, the world's population is predicted to reach 9.6 billion people and food production needs to increase approximately 70% by 2050 or 44 million metric tons annually to provide sufficient food for this population (FAO, 2009, 2012; United Nations Population Fund, 2016). This is a challenge because there is very little potential for future expansion of arable lands, whereas environmental stresses affecting crop production are increasing (Tester and Langridge, 2010; Eckardt, 2009, Cominelli, *et al.* 2013). Salinity and water deficit were listed as the two most critical factors that limit global crop production (Munns, 2011). To help sustain the increasing population, crops with enhanced salinity tolerance must be developed to increase productivity on salt-affected lands.

Salinity is one of the most brutal environmental stresses that adversely influenced the capability of plant to uptake water, and this quickly causes reduction in growth rate, along with a suite of metabolic changes (Munns, 2002, Vaidyanathan *et al.* 2003). It seriously limits agricultural productivity with significant crop loss through worldwide (Munns and Tester 2008). Now more than 800 million hectares of land throughout the world are salt affected which is 6% of the world's total land area (FAO 2008) and this area is increasing day by day because of global warming with consequent rise in sea level and increase in tidal surges, particularly in coastal areas in the globe (Wassmann *et al*. 2004). In Bangladesh, about 1.06 million hectares out of 2.85 million hectares of coastal and off-shores land is affected by different degrees of salinity (Murshed, 2008).

Magnesium (Mg) is one of the essential mineral nutrients for the growth and development of plants. Apart from being a central atom of the chlorophyll molecule, Mg also acts as activator or regulator of many key enzymes in plant physiological processes (Marschner *et al*. 1995, Shaul, 2002). Both Mg deficiency and over supply have detrimental effects on plant photosynthesis (Shabala and Y. Hariadi, 2005) consequently resulting in abnormal or restricted growth of plants (Shaul, 2002).The cation competitive effects frequently lead to Mg deficiency in the field (Mengel and Kirkby, 1987).Mg deficiency in plants occurs worldwide influencing productivity and quality in agriculture (Hermans, 2005). Magnesium (Mg) is major plant macro-nutrient that plays important roles in stomatal movement, osmoregulation, enzyme activity, cell expansion, neutralization of non-diffusible negatively charged ions, and membrane polarization.Application of magnesium can complete with sodium ion and reduce the salt stress. Because salt stress mainly occurs due to salt toxicity in plant. Metabolic toxicity of Na is largely due to its ability to compete with Mg for binding site essential for cellular function effects of salt stress.

Therefore, it is crucial to enhance rice tolerance to salinity stress to enable this staple crop to provide enough food for rice consuming communities. Although some success has been reported for enhanced salinity stress tolerance in rice, the achievements so far are quite modest.

Therefore, the present work has been designed and planes with the following objectives:

- To study the growth, development, yield contributing characters and yield of rice plant under salt stress
- To observe the roles of Mg in alleviating adverse effect of salt stress on vegetative and yield performance of rice plant

CHAPTER II

REVIEW OF LITERATURE

Sivasankaramoorthy (2014) studied under pot experiments 2008. Results indicated that significant increases were recorded in percentage of germination, seedling fresh and dry weights, seedling length, water content, catalase activity and photosynthetic pigments (chlorophyll a, b and total chlorophylls as well as carotenoids) under the low level concentration (20 mM) of NaCl or $CaCl_2$ and their combination (1:1). On other hand increasing salt concentration in nutrient solution caused significant decrease in all of these parameters. The great reduction occurred under high salinity level of NaCl (50 mM). Meanwhile, peroxidase activity increased significantly with increasing salinity levels from 20 mM to 50 mM of both applied salinity types. Besides, peroxidase activity under NaCl salinity showed a marked increase followed by NaCl + $CaCl_2$ (1:1) and $CaCl_2$ at 50 mM.

The successful establishment of crop mainly depends on good quality seed which germinate rapidly, uniformly and able to withstand under environmental adversity after sowing. Laboratory experiment was conducted by Yousof (2013) at Seed Technology Unit, Mansoura, Egypt to evaluate the effect of rice seed priming (c.v. Giza 177) with CaCl2 at osmotic potentials (- 0.75, -1.00 , -1.25 , -1.50 MPa and distilled water) for 6 , 12, 24 , 36 and 48 hours on seed germination, seed and seedling vigor under normal and salinity stress. The obtained results of this study indicated that salinity levels (9 dSm^{-1}) delayed germination, seed and seedling vigor characters compared with normal salinity (0.3 dSm^{-1}). Rice seed priming with $CaCl_2$ at (-1.00

MPa) followed by (-1.25 MPa) gave the highest values of germination percentage, speed of germination index, germination rate, germination co-efficient, germination energy %,seedlings length, seedlings dry weight, water uptake % and decreasing mean germination time as well as time to 50 % germination compared with control (distilled water) under salinity stress. Whereas, priming seed with distilled water (control) resulted in the lowest germination characters under salinity stress. Priming duration 24 h showed its superiority in improving germination characters comparing with other priming durations. It could be concluded that, priming rice seed (c.v. Giza 177) with osmotic potential (-1.00 MPa) for 24 h can reduce the injurious effects of salinity stress.

Wu and Wang (2012) conducted to investigate the effects of Ca^{2+} on cation accumulation and K^+/Na^+ selectivity, in this study, two-week-old rice (*Oryza sativa* L.) plants were exposed to 25 or 125 $mmolL^{-1}$ NaCl with or without 10 $mmolL^{-1}$ $CaCl_2$. At low salinity (25 $mmolL^{-1}$ NaCl), Ca^{2+} significantly decreased Na^+ accumulation in roots, increased K^+ accumulation in shoots, and maintained higher K^+/Na^+ ratios in both roots and shoots of rice plants. At high salinity (125 $mmolL^{-1}$ NaCl), however, Ca^{2+} did not have any effects on Na^+, K^+ accumulation and K^+/Na^+ ratios in plants. Further analysis showed that, at low salinity, the addition of Ca^{2+}significantly enhanced the selective absorption and transport capacity for K^+ over Na^+ in rice. Although Na^+ efflux and Na^+ influx was remarkably reduced by Ca^{2+} under both low and high salt stresses, their ratio was lowered only under low salt stress. In summary, these results suggest that Ca^{2+} could regulate K^+/Na^+ homeostasis in rice at low salinity by enhancing the selectivity for K^+ over Na^+, reducing the Na^+ influx and efflux, and lowering the futile cycling of Na^+.

Suriyan Cha-um *et al.* (2012) evaluate its role in regulating physiological and biochemical process in response to salt-induced stress. Two rice genotypes, Pokkali salt tolerant and IR29 salt susceptible, grown on liquid Murashige and Skoog medium (MS) supplied by 1.98 mM $CaCl_2$ (control) were compared to 2 (3.96 mM), 4 (7.92 mM) and 8 (15.84 mM) folds exogenous $CaCl_2$ pretreatment subsequently exposed to 200 mM NaCl salt stress. Thus, the present investigation evaluated the potential of exogenous calcium chloride ($CaCl_2$) supply in improving the growth performance and photosynthetic ability in salt stressed rice. In IR29 salt susceptible rice, leaf area of salt-stressed seedling was significantly recovered by exogenous application of 7.92 mM $CaCl_2$, which was greater by 1.38-folds over that in 1.98 mM $CaCl_2$ application. Exogenous $CaCl_2$ (7.92 mM) enhanced proline accumulation in both Pokkali (3.26 mmol g-1FW) and IR29 (4.37 mol g-1FW) genotypes, and reduced relative electrolyte leakage thereby indicating its positive role in membrane stability. Treatment of 7.92 mM $CaCl_2$ significantly enhanced the photosynthetic abilities, including maximum quantum yield of PSII (Fv/Fm), photon yield of PSII (PSII), photochemical quenching (qP) and net photosynthetic rate (Pn), in two genotypes of salt-stressed rice seedlings, especially in salt susceptible IR29 genotypes. The study concludes that an exogenous application of 7.92mM $CaCl_2$ significantly enhanced the photosynthetic abilities and overall growth performances in the photoautotrophic growth of salt-stressed rice seedlings. Exogenous calcium in the culture media may absorb by root tissues, transfer to whole plant and function as salt defense mechanisms including calcium signaling in the abscisic acid (ABA) regulation system and calcium sensing in stomatal closure when plant subjected to salt stress.

Kazemi and Eskandari (2011) carried out in 2009, in order to investigate the effects of salt stress (S_1= 0.0, S_2= 2.0, S_3= 4.0, S_4= 6.0 and S_5= 8.0 ds.m^{-2} Nacl) on germination and seedling properties of three rice cultivars (Anbar, LD and Hamar). Experiment was arranged as split-plot based on randomized complete block design in three replications, with the salinity levels in main plots and rice cultivars in subplots. The results indicate that all traits were significantly ($P \leq 0.05$) affected by salt stress, where germination, plumule and radicle length and weight were decreased with increasing in salt concentration. The extent of these reductions was related with the variationsin rice cultivar under different salt stress condition. By increasing NaCl concentration, seed germination delayed and decreased in all cultivars. Regarding the relationship between speed of germination and seed vigor, salt stress decreased seed vigor of rice cultivars LD a superior cultivar under all salt stress which can be suggested for cultivation under salinity condition.

Ashraf *et al.* (2010) conducted a hydroponics experiment to evaluate the role of potassium (K) and silicon (Si) in mitigating the deleterious effects of NaCl on rice cultivars differing in salt tolerance. Two salt-sensitive (CPF 243 and SPF 213) and two salt-tolerant (HSF 240 and CP 77-400) rice cultivars were grown for six weeks in ½ strength Johnson's nutrient solution. The nutrient solution was salinized by two

NaCl levels (0 and 100 mmol L^{-1} NaCl) and supplied with two levels of K (0 and 3 mmol L^{-1}) and Si (0 and 2 mmol L^{-1}). Applied NaCl enhanced Na^+ concentration in plant tissues and significantly ($P \leq 0.05$) reduced shoot and root dry matter in four rice cultivars. However, the magnitude of reduction was much greater in salt-sensitive cultivars than salt-tolerant cultivars. The salts interfered with the absorption of K^+ and Ca^{2+} and significantly ($P \leq 0.05$) decreased their uptake in rice cultivars. Addition of K and Si either alone or in combination significantly ($P \leq 0.05$) inhibited the uptake and transport of Na^+ from roots to shoots and improved dry matter yields under NaCl conditions. Potassium uptake, K^+/Na^+ ratios, and Ca^{2+} and Si uptake were also significantly ($P \leq 0.05$) increased by the addition of K and/or Si to the root medium. In this study, K and Si-enhanced salt tolerance in rice cultivars was ascribed to decreased Na^+ concentration and increased K^+ with a resultant improvement in K^+/Na^+ ratio, which is a good indicator to assess plant tolerance to salt stress.

Zafar *et al.* (2004) investigated the response of rice cultivars Basmati-370 (salt-sensitive) and IR6 (salt-tolerant) to 2 salinity levels (4.0 (control) and 10 dSm^{-1}) in a pot experiment in a wire-house. They took four harvests at an interval of 10 days each after imposition of salinity treatment, and growth and chemical analyses of plant samples were carried out. Plant biomass showed an inverse relationship with increasing salinity levels. A general trend of decrease in dry weight of plant with salinity was noted in both cultivars. The mean values for dry weight were higher in Basmati-370 in the control condition. Analysis of variance showed a significant increase in Na^+ and Cl^- uptake with increasing salinity. Varietal means were highly significant and the maximum increase in Na^+ uptake (18.69%) was recorded in Basmati-370. Harvest means showed that Na^+ uptake increased with the passage of time. However, at maturity there was a decline in Na^+ content in both cultivars. Cl^- increased with increasing salinity levels. Cultivar x treatment interaction revealed an increase in Na^+ and Cl^- uptake over the control in both cultivars. However, it was less in IR-6. The cultivars differed significantly for K^+, Ca^{2+}, P and N uptake. K^+ and Ca^{2+} uptake increased with the passage of time. Basmati-370 and IR-6 showed 45.20 and 15.55% decrease in Ca^{2+} over the control. P and N uptake increased with increasing salinity levels. An increase of 23.21% P uptake was recorded in Basmati-370 compared to IR-6. However, IR-6 accumulated higher (22.16%) N compared to Basmati-370 under the control and saline conditions.

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). 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 2005cultivars 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).

Baba and Fujiyama (2003) investigated short-term (72 h) responses of the water and nutritional status to Na-salinization in rice (*Oryza sativa* L. cv. Koshihikari) and tomato (*Lycopersicon esculentum* Mill cv. Saturn) using pot experiments. The short-term effect of supplemental K and Ca to the nutrient solution on the water status and absorption and transport of ions in the plants was also investigated. In both species, Na salinity resulted in the deterioration of the water status of tops and in nutritional imbalance. However, in rice, it was possible to prevent the deterioration of the nutrient status by enhancing the transport of cations, especially K, while tomato could maintain an adequate water status by inhibiting the water loss associated with transpiration. On the other hand, the water status in rice and the nutritional status in tomato markedly deteriorated by high Na level in the solution. Supplemental K and Ca could not ameliorate the water status in both species, and even worsened the status in rice. In rice, a close relationship was observed between the osmotic potential (OP) of the solution, water uptake and water content. The water status of rice, therefore, seemed to depend on OP of the solution. Supplemental K and Ca, on the other hand, were effective in the amelioration of the nutritional status. In tomato, supplemental Ca could improve the nutritional balance by suppressing the transport of Na and enhancing that of the other cations in avoidably the deterioration of the water status. Thus, the differences in the responses of the water and nutritional status of rice and tomato to high Na salinization and to supplemental K and Ca were evident in a short-term study and supported a similar tendency observed in a long-term study.

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 among the 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.

Din *et al.* (2001) used artificially salinized soils to see the effect of foliar and soil application of K on rice. Results indicated that the number of tillers plant^{-1}, paddy and straw yield and grains to straw ratio significantly decreased with the increase in salinity. All K application methods increased the above parameters significantly at all salinity levels over distilled water spray. Increasing levels of salinity decreased K concentration in shoots and straw, which was increased significantly by foliar and soil application. Both methods of K application remained at par with each other. Sodium concentration increased with increase in salinity in both shoots and straw and decreased by foliar and soil application of K. Foliar application of K proved better than soil application in this respect. The K/Na ratio decreased significantly by the increase of salinity, while this ratio increased significantly by the foliar and soil application of K.

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 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 grains.

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.

Aslam *et al.* (2001) conducted in solution and soil cultures and in naturally salt-affected field. In the case of solution culture, Ca at the rate of 5, 10, 20, 40, 80 and 160 µg Ca mL^{-1} was applied in the presence (80 mol m^{-3}) and absence (0 mol m-3) of NaCl salinity; whereas, in case of soil culture, Ca at the rate of 0, 50, 100 and 200 kg ha-1was applied to artificially prepared saline (ECe 9 dSm^{-1}, SAR 5.46, pHs7.8), saline sodic (ECe9 dSm^{-1}, SAR 28.2, pHs 8.2) soils and in naturally salt affected field (ECe 6 dSm^{-1}, SAR 16.1, pHs 8.2). Three cultivars of differential salinity tolerance used to investigate the ameliorative nutritional aspects of Ca were: KS-282 (salt tolerant), BG 402-4 (mixed behavior) and IR-28 (salt sensitive). Application of Caimproved all growth characteristics (tillering capacity, shoot and root lengths, shoot and root weights) because of external Ca supply @ 20-40 µg Ca mL^{-1} in solution culture in the presence of NaCl salinity. Shoot Na^+ and Cl^- decreased; whereas, K^+ concentration and K^+: Na^+ ratio improved because of Ca supply to saline medium. Paddy and straw yields, plant height and panicle length were significantly higher in saline as compared to saline sodic soil. Application of 200 kg Ca ha-1proved statistically superior to control in respect of panicle length, number of tillers, paddy and straw yield under both saline and saline sodic soils as well as in naturally salt affected field. The ameliorative effect of Ca was due to reduced shoot Na+ and Cl^- concentration and better ratio of K^+ to Na^+ in shoot. Seed setting was improved in all the three cultivars because of external Ca supply to saline and saline sodic soils.

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 dSm^{-1} electrical conductivity. They found seedling growth was significantly reduced by salinity at the lowest salinity treatment, 1.9 dSm^{-1}. At 1.9 and 3.4 dSm^{-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 dSm^{-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.

Most of Bangladesh’s coastal region lies on the southwest coastal region of the country. Approximately 30% of the crops land of Bangladesh is located in this region (Mondal et al., 2001) and continuous to support crops productivity and GDP growth. But in the recent past, the contribution of crops to GDP has decreased because of salinity. In total, 52.8% of the cultivable land in the coastal region of Bangladesh was affected by salinity in 1990 (Karim et al., 1990) and the salt affected area has increased by 14600 ha per year (SRDI, 2001). SRDI had made a comparative study of the salt affected area between 1973 to 2009 and showed that about 0.223 million ha (26.7%) of new land has been affected by varying degrees of salinity during the last four decades and that has badly hampered the agro-biodiversity (SRDI, 2010). Farmers mostly cultivate low yielding, traditional rice varieties. Most of the land kept fallow in the summer or pre-monsoon hot season (March-early June) and autumn or post-monsoon season (October- February) because of soil salinity, lack of god quality irrigation water and late draining condition. In the recent past, with the changing degree of salinity of southwest coastal region of Bangladesh, crop production becomes very risky and crop yields, cropping intensity, production levels of crop and people's quality of livelihood are much lower than that in the other parts of the country. Cropping intensity in saline area of Bangladesh is relatively low, mostly 170% ranging from 62% in Chittagong coastal region to 114% in Patuakhali coastal region (FAO, 2007).

In most of the cases, the negative effects of salinity have been attributed to increase in Na^+ and Cl^- ions in different plants hence these ions produce the critical conditions for plant survival by intercepting different plant mechanisms. Although both Na^+ and Cl^- are the major ions produce many physiological disorders in plant, Cl^- is the most dangerous (Tavakkoli *et al*., 2010). Salinity at higher levels causes both hyper ionic and hyper osmotic stress and can lead to plant demise. The outcome of these effects may cause membrane damage, nutrient imbalance, altered levels of growth regulators, enzymatic inhibition and metabolic dysfunction, including photosynthesis which ultimately leading to plant death (Mahajan and Tuteja, 2005; Hasanuzzaman *et al.*, 2012).

The available literature revealed the effects of salinity on the seed germination of various crops like Oryza sativa (Xu *et al.*, 2011), *Triticum aestivum* (Akbarimoghaddam *et al.*, 2011), Zea mays , Brassica spp. and Helianthus annuus It is well established that salt stress has negative correlation with seed germination and vigor. Higher level of salt stress inhibits the germination of seeds while lower level of salinity induces a state of dormancy.

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.

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).

Bohra and Doerffling (1993) grew a salt-tolerant (Pokkali) and a salt-sensitive (IR28) variety of rice (*Oryza sativa* L.) in a phytotron to investigate the effect of K (0, 25, 50 and 75 mg K kg^{-1} soil) application on their salt tolerance. Potassium application significantly increased potential photosynthetic activity (Rfd value), percentage of filled spikelets, yield and K concentration in straw. At the same time, it also significantly reduced Na and Mg concentrations and consequently improved the K/Na, K/Mg and K/Ca ratios. IR28 responded better to K application than Pokkali. Split application of K failed to exert any beneficial effect over basal application.

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. Aslam *et al*. (2003) 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, numbers 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 maintained 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.

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).

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experiment period, site description, climate condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, intercultural operation, data collection and statistical analysis.

3.1 Experiment location

The experiment was conducted at the experimental shed of the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka during the period from December, 2017-April, 2018

3.2 Soil condition

The soil of experimental area situated to the Modhupur Tract (UNDP, 1988) under the AEZ no. 28 and Tejgoan soil series (FAO, 1988). The soil was sandy loam in texture with pH 5.47 - 5.63. The physical and chemical characteristics of the soil have been presented in Appendix I.

3.3 Climatic condition

The experimental area was under the sub-tropical climate that is characterized by less rainfall associated with moderately low temperature during Boro season, (October-March) and high temperature, high humidity and heavy rainfall with occasional gusty winds during Aus season (April-September).

3.4 Selection of cultivars

BRRI dhan67 is a salt tolerant variety which was, used as the test crop in this experiment. It can tolerant salinity 12-14 dS/m (upto 3 weeks) during seedlings stage and 8 dSm^{-1} during maturity stage.

3.5 Experimental design

The experiment was set in Randomized Complete Block Design **(**RCBD) having one factor with three replications. The treatment combination of the experiment was assigned at random into 21 pots of each at 3 replications.

3.6 Treatments

The experiment consisted of one factors viz, Salinity level and Magnesium Concentration

1. S_0= Control
2. S_1= 4 dSm^{-1} salt
3. S_1Mg_1= 4 dSm^{-1} salt + 80 ppm Mg
4. S_1Mg_2= 4 dSm^{-1} salt + 160 ppm Mg
5. S_2= 6 dSm^{-1} salt
6. S_2Mg_1= 6 dSm^{-1} salt + 80 ppm Mg
7. S_2Mg_2= 6 dSm^{-1} salt + 160 ppm Mg

3.7 Collection and preparation of soil

The soils of the experiments 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 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.

3.8 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.

3.9 Sowing of seeds in seed bed

The sterilized seed 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.

3.10 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 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.

3.11 Seedling transplant in the pots:

The chemical fertilizers *i.e.*, Urea, Triple Supper Phosphate (TSP) ,Murate 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, 60 kg P_2O_5, and 20 kg S ha^{-1}, respectively. Magnesium Sulphate ($MgSO_4$) used as per treatment. The whole amount of TSP, MOP, Gypsum and 1/3rd of urea were applied before the final preparation of the pots. Thereafter the 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 electric conductivity (EC) of each pot was measured everyday with a EC meter and necessary adjustments were made by adding water. The remaining 2/3rd urea were top dressed at two equal divisions after 25 and 50 days of transplanting.

3.12 Collection of data

3.12.1 Plant height

The plant height (cm) was measured at different day after transplanting from the surface level of the growth media to the tip of the longest leaf at 20,35,50 and 65 days after transplanting by taking the average value of ten random samples. But the final height was measured from soil surface to the tip of the spikelet of longest panicle.

3.12.2 Total tiller hill^{-1}

Total tiller number hill^{-1} was counted at different days after transplanting.

3.12.3 Length and breadth of leaf

Length and breadth of leaf of each sample plant was recorded and sum total of them was divided by the total number of leaves of the sample plant.

3.12.4 SPAD value

Three leaves were randomly selected from each plant. The top and bottom of each leaves were measured with at LEAF as at LEAF value. Then it was averaged and total chlorophyll content was measured by the conversion of at LEAF value into SPAD units.

3.12.5 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.

3.12.6 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}.

3.12.7 Total dry matter

The total dry matter was recorded by drying the straw at 80 ± 2^{o}C for 48 hours and calculated from summation of leaves, stem, roots and panicle weight as observed in an electronic balance.

3.12.8 Panicle length

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

3.12.9 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}.

3.12.10 Number of unfilled grain

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

3.12.11 1000 grain weight

1000-seed were counted, which were taken from the seed sample of each plot separately, then weighed in an electrical balance and data were recorded.

3.12.12 Grain yield

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

3.13 Statistical analysis

The collected data were analyzed statistically following CRD design by MSTAT-C computer package program developed by Russel (1986). The treatment means were compared by Least Significant Test (LSD) and regression analysis were performed as and where necessary.

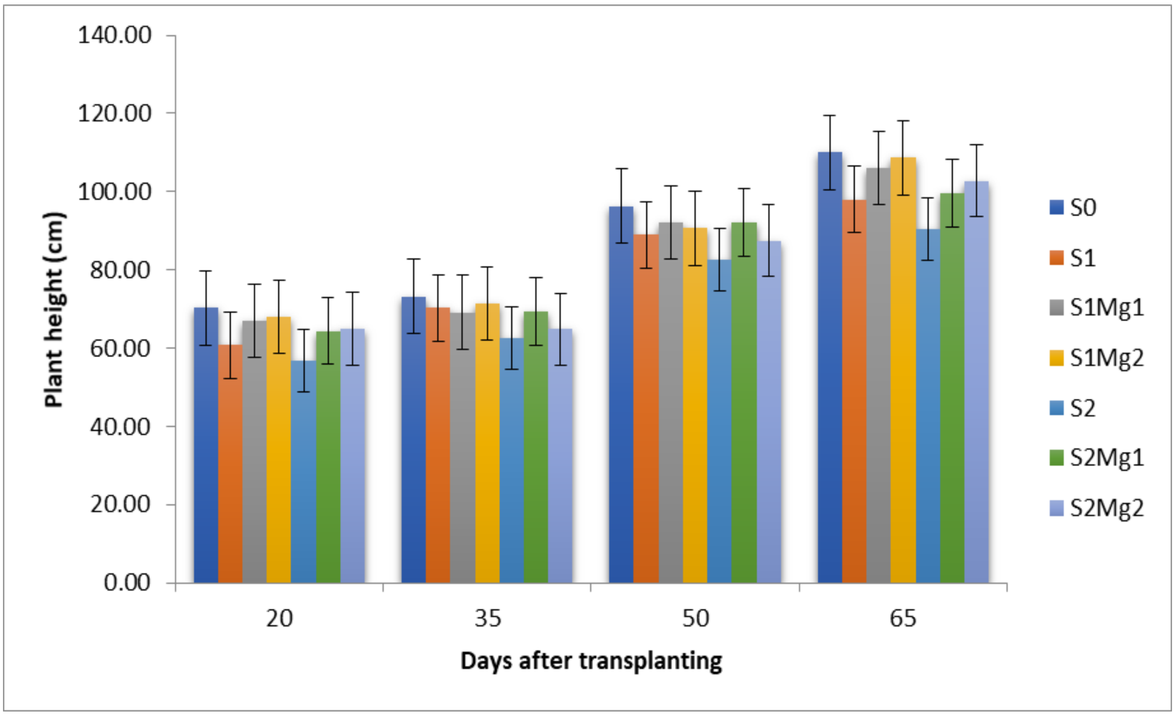
CHAPTER IV

RESULTS AND DISCUSSION

Result obtained from the present study have been presented and discussed in this chapter. The data have been presented in different tables and figures. The results have been presented and discussed, and possible interpretations are given under the following headings.

4.1 Plant height

The height of the plant was significantly influenced by salinity and magnesium at 20, 35, 50 and 65 DAT (Days after Transplanting) (fig. 1).The highest plant height (70.27, 73.13, 96.27, 110 cm at 20, 35, 50 and 65 DAT, respectively) was observed at control (S_0) treatment, which was statistically similar with S_1Mg_2 (67.97, 71.43, 90.70 and 108.70 cm at 20, 35, 50 and 65 DAT, respectively) and the lowest plant height (56.80, 62.50, 62.50, 82.73 and 90.33 cm at 20, 35, 50 and 65 DAT, respectively) was observed at S_2 (6 dSm^{-1} salt) treatment. 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).

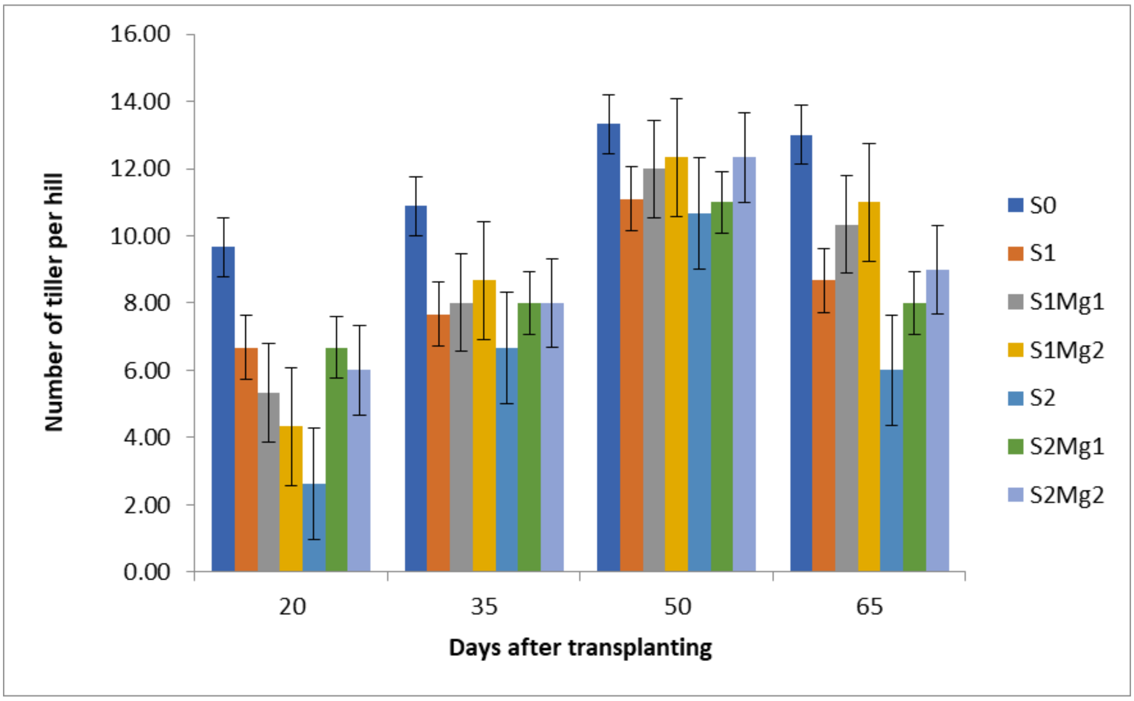


S_0= Control, S_1= 4 dSm^{-1} salt, S_1Mg_1= 4 dSm^{-1} salt + 80 ppm Mg , S_1Mg_2 = 4 dSm^{-1} salt + 160 ppm Mg, S_2= 6 dSm^{-1} salt, S_2Mg_1 = 6 dSm^{-1} salt + 80 ppm Mg, S_2Mg_2 = 6 dSm^{-1} salt + 160 ppm Mg

Fig.1. Effect of different levels of salinity and magnesium on the plant height of rice at different days after transplanting

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

Total number of tiller hill^{-1} was statistically influenced by different salinity level with magnesium at 20, 35, 50 and 65 DAT (Figure2). The maximum number of tiller hill^{-1} (9.67, 10.89, 13.33 and 13.00 at 20, 35, 50 and 65 DAT, respectively) was produced from control treatment (S_0) and the minimum number of tiller hill^{-1} (2.63, 6.67, 10.67, 6.00 at 20, 35, 50 and 65 DAT, respectively) was produced form S_2 treatment. Zeng and Shannon (2000) stated that tiller number hill^{-1} and spikelet number panicle^{-1} 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 (4dSm^{-1}).



Mg, S_0= Control, S_1= 4 dSm^{-1} salt, S_1Mg_1= 4 dSm^{-1} salt + 80 ppm Mg , S_1Mg_2 = 4 dSm^{-1} salt + 160 ppm S_2= 6 dSm^{-1} salt, S_2Mg_1 = 6 dSm^{-1} salt + 80 ppm Mg, S_2Mg_2 = 6 dSm^{-1} salt + 160 ppm Mg

Fig. 2. Effect of different salinity with magnesium on the number of tiller of rice at different days after transplanting

4.3 Leaf length

Length of leaf showed statistically significant differences due to the different levels of salinity with magnesium. The longest leaf (48.73 cm) was found at control treatment, which was statistically similar with S_1Mg_2, S_2Mg_1, S_1Mg_1, S_2Mg_2 and S_1 the lowest leaf length (37.17 cm) was recorded at S_2 treatment (Table 1).

4.4 Leaf breath

Breath of leaf showed statistically significant differences due to the different levels of salinity with magnesium. The maximum leaf breath (1.48 cm) was obtained at control treatment(S_0), which was followed by S_1Mg_1, S_2 Mg_1 and S_1Mg_2 and the minimum leaf breath (1.13 cm) was recorded at S_2 treatment (Table 1).

4.5 SPAD Value of leaf

Analysis of variance indicated that the effect of salinity with magnesium on rice on SPAD value of leaf was varied significantly (Table. 1). The maximum SPAD value (42.13) was found in S_2 treatment. The minimum SPAD value (30.53) was found from S_0 (Control) treatment, which was statistically similar with S_1Mg_2. Salachna and Zawadzińska, (2014) found that medium- and high-molecular-weight chitosan resulted in higher relative chlorophyll content (SPAD).

Table 1. Effect of salinity with magnesium on leaf length, leaf breath and SPAD value on rice

Treatment	Leaf length (cm)		Leaf Breath (cm)		SPAD value	
S_0	48.73	a	1.48	a	30.53	d
S_1	39.33	bc	1.18	ab	38.00	bc
S_1Mg_1	42.60	abc	1.30	ab	31.83	d
S_1Mg_2	46.00	a	1.23	ab	36.70	c
S_2	37.17	c	1.13	b	42.13	a
S_2Mg_1	44.00	ab	1.21	ab	40.37	ab
S_2Mg_2	46.83	a	1.18	ab	41.07	ab
LSD (0.05)	5.77		0.29		3.34	
CV (%)	5.04		7.46		10.03	

S_0= Control, S_1= 4 dSm^{-1} salt, S_1Mg_1= 4 dSm^{-1} salt + 80 ppm Mg , S_1Mg_2 = 4 dSm^{-1} salt + 160 ppm Mg, S_2= 6 dSm^{-1} salt, S_2Mg_1 = 6 dSm^{-1} salt + 80 ppm Mg, S_2Mg_2 = 6 dSm^{-1} salt + 160 ppm Mg

In a column figures having similar letter do not differ significantly whereas figures with dissimilar letter differ significantly as per LSD.

4.6 Number of effective tillers

The number of effective tillers hill^{-1} of rice was significantly influenced by different levels of salinity with Magnesium (Table2). The highest number of effective tillers hill^{-1} (11.00) was recorded at control treatment and the lowest (3.00) was found at S_2 treatment. 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. However, Magnesium supplementation has mitigated to some extent by increasing effective tiller per hill. In both salinity treatment (4dSm^{-1} and 6dSm^{-1}) addition of 160 ppm magnesium has increased 1.3 effective tillers per hill (Table 2)

Table 2. Effect of salinity with magnesium on Number of effective tiller and Non-effective tiller hill^{-1} on rice

Treatment	Number of effective tiller hill^{-1}		Number of non-effective tiller hill^{-1}	
S_0	11.00	a	0.87	b
S_1	7.67	b	1.00	b
S_1Mg_1	9.67	ab	1.00	b
S_1Mg_2	9.00	ab	1.00	b
S_2	3.00	c	2.67	a
S_2Mg_1	7.00	b	1.33	b
S_2Mg_2	8.00	ab	1.00	b
LSD (0.05)	2.82		0.76	
CV (%)	12.04		10.18	

S_0= Control, S_1= 4 dSm^{-1} salt, S_1Mg_1= 4 dSm^{-1} salt + 80 ppm Mg , S_1Mg_2 = 4 dSm^{-1} salt + 160 ppm Mg, S_2= 6 dSm^{-1} salt, S_2Mg_1 = 6 dSm^{-1} salt + 80 ppm Mg, S_2Mg_2 = 6 dSm^{-1} salt + 160 ppm Mg

In a column figures having similar letter do not differ significantly whereas figures with dissimilar letter differ significantly as per LSD.

4.7 Number of non-effective tillers

The mean effect of different salinity levels with magnesium influenced the number of non-effective tillers hill^{-1}(Table 2). The highest number of non-effective tillers hill^{-1}(2.67) was observed in S_2 treatment and it was least in control treatment(0.87),The result that magnesium supplementation enhances panicle growth through minimizing toxicity effect of salinity. which was statistically similar with S_1, $S_1Mg_{1,}$ $S_1Mg_{2,}$ S_2Mg_1 and S_2Mg_2. 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 variety maintained its superiority in various characteristics such as plant height, higher number of fertile panicles per plant (Baloch *et al.*, 2003).

4.8 Panicle length

Length of panicle showed statistically significant differences due to the different levels of salinity with magnesium (Table 3). The longest panicle (24.30 cm) was found at control treatment and the lowest panicle length (21.97 cm) was recorded at S_2 treatment. Khatun *et al*. (1995) and Alam *et al*. (2001) reported that salinity severely reduces the panicle length, seed setting percentage and panicle weight. Similar to panicle bearing tillering in Magnesium supplemented salinity treatment, panicle length also recovered by Mg- supplementation, But the effective is more prominent in higher salinity level (6 dSm^{-1} salt) (Table 3).

4.9 Number of filled grain panicle^{-1}

The number of filled grain panicle^{-1} was significantly influenced by different salinity levels with magnesium (Table 3). The highest number of filled grain per panicle (165.90) was recorded at control treatment, which was followed by $S_1Mg_{1,}$ $S_1Mg_{2,}$ and $S_2Mg_1$and the lowest (106.90) was found at S_2 treatment. Primary branches per panicle was greatly affected in higher salinity stress (Table 3).However the mitigation effect of Magnesium was found better for low salinity level (4dSm^{-1} salt)

4.10 Number of unfilled grain panicle^{-1}

The number of unfilled grain panicle^{-1} was significantly influenced by different salinity levels with magnesium (Table 3). The highest number of unfilled grain per panicle (14.67) was recorded from S_2 treatment, the lowest (4.00) was found from control treatment.

4.11 Thousand seed weight

A highly significant variation in thousand seed weight of rice cultivars was observed due to the different salinity levels with magnesium (Table 3**).** The highest thousand seed weight (20.99g) was recorded at control treatment and it was lowest (16.23g) at S_2 treatment.Similar affect was observed for thousand grain weight i.e more reduction of 1000- grain weight was observed for higher salinity level but mitigation of reduction in 1000-grain weight was least in 4dSm^{-1} salinity with 1mM of $MgSO_4$

4.12 Grain yield hill^{-1}

A highly significant variation in grain yield hill^{-1} of rice cultivars (BRRI dhan67) was observed due to the different salinity levels with magnesium (Table 3)**.** The highest grain yield (26.57 g) was recorded at control treatment, which was followed by S_1Mg_2 and $S_1Mg_{1,}$ and it was lowest (15.67 g hill^{-1}) at S_2 treatment. In comparison to control (without salt), the reduction of grain yield was high in S_2 (6dSm^{-1}) salinity (47.28%) followed by S_1 (4dSm^{-1}) salinity (39.45%) (Table 3).But in both of the salt treatment, Magnesium supplementation greatly mitigated. The damaging effect of salinity thereby reducing grain yield reduction. However, the mitigation effect was more in less salinity stress (4dSm^{-1}), where yield reduction was 11.4% and 4.61% for 80 and 160 ppm magnesium, respectively. 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 variety 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.

Table 3. Effect of salinity with magnesium yield and yield contributing character of on rice

Treatment	Length of panicle	Number of filled grain panicle^{-1}	Number of unfilled grain panicle^{-1}	1000 seed weight (g)	Yield per plant (g)
S_0	24.30 a	165.90 a	4.00 b	20.99 a	26.57 a
S_1	22.50 ab	130.20 c	12.33 ab	17.60 c	16.34 d
S_1Mg_1	23.73 ab	141.40 b	5.33 ab	18.34 bc	23.40 b
S_1Mg_2	23.93 ab	149.60 b	5.47 ab	19.61 b	25.01 ab
S_2	21.97 b	106.90 d	14.67 a	16.23 d	15.67 e
S_2Mg_1	22.97 ab	140.80 b	11.13 ab	18.02 c	18.19 c
S_2Mg_2	23.93 ab	125.70 c	6.33 ab	17.16 cd	18.42 c
LSD $_{(0.05)}$	1.82	9.91	8.79	1.31	2.18
CV (%)	8.17	8.34	8.33	4.02	12.89

S_0= Control, S_1= 4 dSm^{-1} salt, S_1Mg_1= 4 dSm^{-1} salt + 80 ppm Mg , S_1Mg_2 = 4 dSm^{-1} salt + 160 ppm Mg, S_2= 6 dSm^{-1} salt, S_2Mg_1 = 6 dSm^{-1} salt + 80 ppm Mg, S_2Mg_2 = 6 dSm^{-1} salt + 160 ppm Mg

In a column figures having similar letter do not differ significantly whereas figures with dissimilar letter differ significantly as per LSD.

CHAPTER V

SUMMARY AND CONCLUSION

A pot experiment was conducted at the net house of the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka-1207, during *Boro* rice growing season (December to April) of the year of 2017- 18 to observe the role of magnesium to alleviate damaging effect of salt stress on development and yield performance of rice plant (*Oryza sativa* L.). The experiment was conducted using seven salinity levels with magnesium viz. S_0 = Control, S_1= 4dSm^{-1} salt, S_1Mg_1= 4dSm^{-1} salt + 80 ppm Mg, S_1Mg_2 = 4dSm^{-1} salt + 160 ppm Mg, S_2= 6dSm^{-1} salt, S_2Mg_1 = 6dSm^{-1} salt + 80 ppm Mg, S_2Mg_2 = 6dSm^{-1} salt + 160 ppm Mg. The experiment was set in Randomized Complete Block Design **(**R**C**BD) having one factor with three replications.

The results on the effect of morphological characters indicated that plant height; numbers of tillers, leaf length, leaf breath, and SPAD value, effective tiller, number of non effective tiller, panicle length , filled grain, unfilled grain and thousand seed weight grain yield were significantly influenced by salinity and magnesium. All the measured morphological parameters were found highest in non saline control treatment .But the parameters gradually decline in 4 and 6 dSm^{-1} salt treatment. However, Magnesium supplementation greatly mitigated the damaging effect of salt for the growth, development and yield of BRRI dhan67. But the mitigation effect was more prominent at low salinity stress (4dSm^{-1}) compared to higher stress (6dSm^{-1}).

Moreover application of 160 ppm, showed better recovery compared to the 4dSm^{-1} salt stress.

Considering above facts, it could be concluded that, application of magnesium under salt stress condition could be a good option for obtaining better yield of salt tolerant varieties like BRRI dhan67. Further, research needed to get a concrete recommendation considering more varieties and a number of salt stress and magnesium level.

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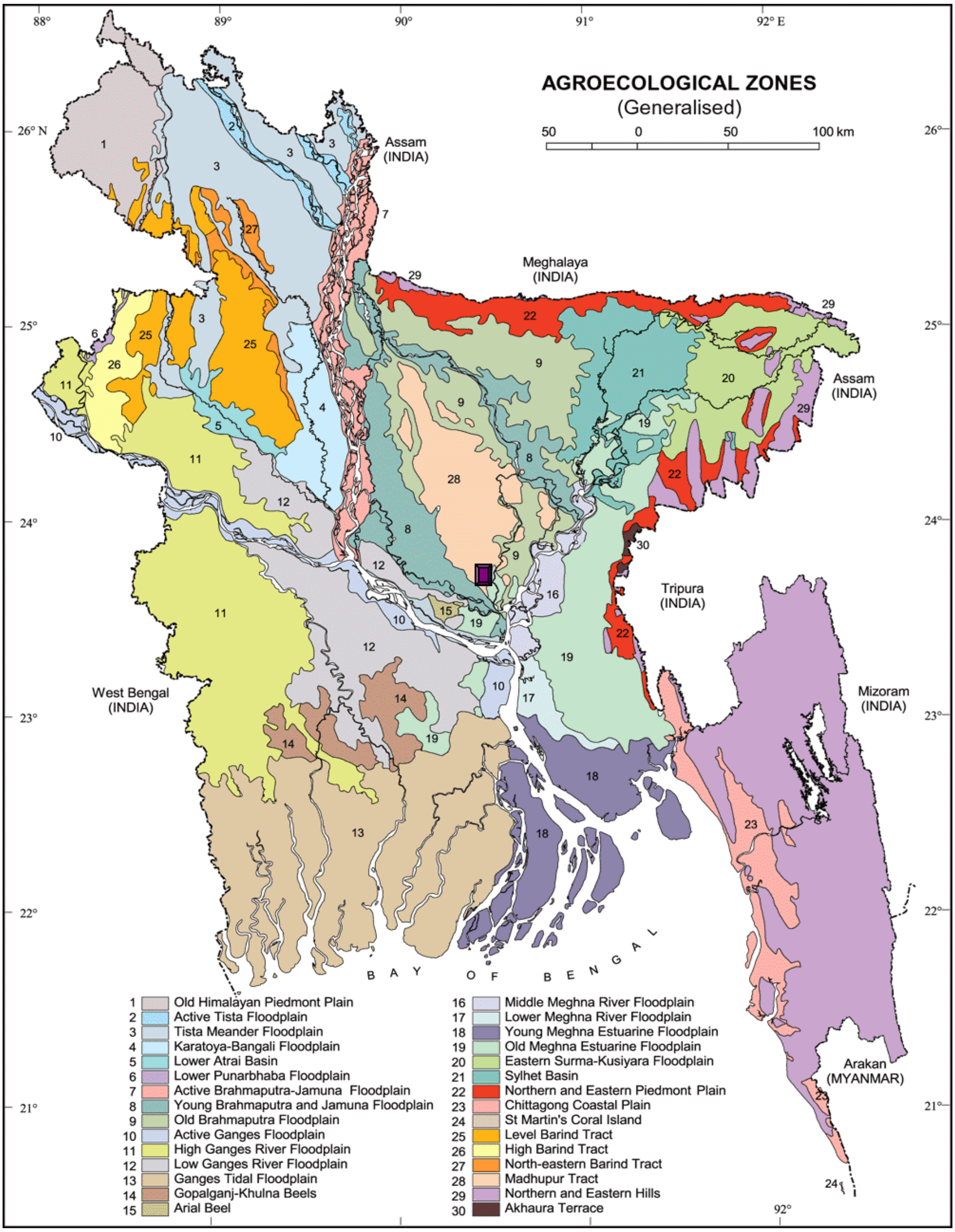
APPENDICES

Appendix I. Map showing the experimental sites under study



▮ **The experimental site under study**