EFFECTS OF CALCIUM SUPPLEMENTATION ON GROWTH, YIELD AND NUTRIENT CONTENT OF TWO RICE CULTIVARS UNDER DIFFERENT SALINE CONDITIONS

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CERTIFICATE

This is to certify that the thesis entitled "EFFECTS OF CALCIUM SUPPLEMENTATION ON GROWTH, YIELD AND NUTRIENT CONTENT OF TWO RICE CULTIVARS UNDER DIFFERENT SALINE CONDITIONS" submitted to the DEPARTMENT OF AGRICULTURAL CHEMISTRY, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (M.S.) in AGRICULTURAL CHEMISTRY, embodies the results of a piece of bona fide research work carried out by PARVEZ AHMED, Registration. No. 07-02562, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

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

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DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

A pot culture experiment was conducted from January to June, 2015 at the net house of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the effect of supplemental calcium (Ca) for amelioration of salinity and improve the growth of rice. The three factorial experiment composed of Factor A: two selected rice varieties (Binadhan-8 and BRRI dhan29), Factor B: 4 salinity levels (0, 4, 8 and 12 dSm^{-1}) and Factor C: 3 levels of Ca supplement (0, 5 and 10 mM). Due to varietal effect; highest panicle length (24.34 cm), 1000-grain weight (20.09 g) and grain yield $hill^{-1}$ (22.74 g) were found in Binadhan-8. Plant height, number of total tiller $hill^{-1}$, panicle length, number of spikelet $panicle^{-1}$, number of filled grains $panicle^{-1}$, root dry weight, shoot dry weight, total dry weight, 1000-grain weight and grain yield $hill^{-1}$ increased up to 4 dSm^{-1} and then decreased afterwards.1000-grain weight and grain yield $hill^{-1}$ increased with increasing calcium (Ca) supplement while non-effective tiller $hill^{-1}$ and unfilled grains $panicle^{-1}$ decreased. With the increase of salinity, parameters showed negative trend in most of the cases in both varieties. Reduction of yield (from control salinity) at highest salinity level is higher in BRRI dhan29 (26.51 to 8.109 g $hill^{-1}$) than Binadhan-8 (25.78 to 11.28 g $hill^{-1}$). As the Ca level increased, 1000-grain weight and grain yield $hill^{-1}$ increased but non-effective tiller $hill^{-1}$ and unfilled grains $panicle^{-1}$ decreased in both varieties. At every salinity level, 1000-grain weight and grain yield $hill^{-1}$ increased with the increase of Ca while non-effective tiller $hill^{-1}$ and unfilled grains $panicle^{-1}$ decreased. Interaction of variety, salinity and calcium significantly affected all the parameters studied. Each of the variety showed significant reduction in growth and yield parameters including 1000-grain weight and grain yield $hill^{-1}$ due to higher salinity level (except at 4 dSm^{-1}) while Ca supplementation had significant positive effects on these parameters at every salinity level. Binadhan-8 showed highest yield (13.48 g $hill^{-1}$) in maximum salinity level with 10 mM calcium (Ca) supplementation compared to BRRI dhan29 (10.11 g $hill^{-1}$). In each variety, at every salinity level, K and Ca content in shoot increased with increasing calcium (Ca) supplement while Na content decreased. But Binadhan-8 showed higher K (1.52%) and lower Na (1.29%) content in highest salinity level with 10 mM calcium (Ca) supplement compared to BRRI dhan29 (0.73% K and 2.45% Na, respectively).

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A pot culture experiment was conducted from January to June, 2015 at the net house of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the effect of supplemental calcium (Ca) for amelioration of salinity and improve the growth of rice. The three factorial experiment composed of Factor A: two selected rice varieties (Binadhan-8 and BRRI dhan29), Factor B: 4 salinity levels (0, 4, 8 and 12 dSm^{-1}) and Factor C: 3 levels of Ca supplement (0, 5 and 10 mM). Due to varietal effect; highest panicle length (24.34 cm), 1000-grain weight (20.09 g) and grain yield $hill^{-1}$ (22.74 g) were found in Binadhan-8. Plant height, number of total tiller $hill^{-1}$, panicle length, number of spikelet $panicle^{-1}$, number of filled grains $panicle^{-1}$, root dry weight, shoot dry weight, total dry weight, 1000-grain weight and grain yield $hill^{-1}$ increased up to 4 dSm^{-1} and then decreased afterwards.1000-grain weight and grain yield $hill^{-1}$ increased with increasing calcium (Ca) supplement while non-effective tiller $hill^{-1}$ and unfilled grains $panicle^{-1}$ decreased. With the increase of salinity, parameters showed negative trend in most of the cases in both varieties. Reduction of yield (from control salinity) at highest salinity level is higher in BRRI dhan29 (26.51 to 8.109 g $hill^{-1}$) than Binadhan-8 (25.78 to 11.28 g $hill^{-1}$). As the Ca level increased, 1000-grain weight and grain yield $hill^{-1}$ increased but non-effective tiller $hill^{-1}$ and unfilled grains $panicle^{-1}$ decreased in both varieties. At every salinity level, 1000-grain weight and grain yield $hill^{-1}$ increased with the increase of Ca while non-effective tiller $hill^{-1}$ and unfilled grains $panicle^{-1}$ decreased. Interaction of variety, salinity and calcium significantly affected all the parameters studied. Each of the variety showed significant reduction in growth and yield parameters including 1000-grain weight and grain yield $hill^{-1}$ due to higher salinity level (except at 4 dSm^{-1}) while Ca supplementation had significant positive effects on these parameters at every salinity level. Binadhan-8 showed highest yield (13.48 g $hill^{-1}$) in maximum salinity level with 10 mM calcium (Ca) supplementation compared to BRRI dhan29 (10.11 g $hill^{-1}$). In each variety, at every salinity level, K and Ca content in shoot increased with increasing calcium (Ca) supplement while Na content decreased. But Binadhan-8 showed higher K (1.52%) and lower Na (1.29%) content in highest salinity level with 10 mM calcium (Ca) supplement compared to BRRI dhan29 (0.73% K and 2.45% Na, respectively).

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LIST OF ACCRONYMS AND ABBREVIATION

AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
Anon.	Anonymous
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
cm	Centi-meter
CV	Coefficient of Variance
DMRT	Duncan's Multiple Range Test
dSm^{-1}	Deci semence per mol
mM	Milli mole
ECsw	Electrical conductivity soil water
ECe	Electrical conductivity extract
Environ.	Environmental
g	Gram (s)
mg	Milligram
Sci.	Science
$hill^{-1}$	Per hill
i.e.	*id est* (L), that is
j.	Journal
kg	Kilogram (s)
m^2	Meter squares
Res.	Research
SE	Standard Error
$t\ ha^{-1}$	Ton per hectare
UNDP	United Nations Development Programme
viz	Namely
%	Percentage

Chapter 1
Introduction

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important crop in the world after wheat, with more than 90% currently grown in Asia. Rice is the grain that has shaped the cultures, diets and economies of billions of Asians. For them, rice is more than food; rice is life. About 120,000 varieties are grown across the world in an extensive range of climatic soil and water condition. It is grown on an area of 149.151 million hectares (ha) yielding 550.193 million tons of paddy with a yield of 3689 kg ha^{-1} (Alam *et al*., 2001). 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 introduction of irrigation with saline waters. In Bangladesh, there are approximately 2.85 million ha of coastal soils (Ponnamperuma, 1977) which occur in the southern parts of the Ganges tidal floodplain, in the young Meghna estuarine floodplain and in tidal areas of the Chittagong coastal plain and offshore islands (Brammer, 1978). About one million ha of land of these coastal and offshore areas are affected by varying degrees of salinity.

The majority of the saline land (0.65 million ha) exists in the districts of Satkhira, Khulna, Bagerhat, Barguna, Patuakhali, Pirojpur and Bhola on the western coast and a smaller portion (0.18 million ha) in the districts of Chittagong, Cox's Bazar, Noakhali, Lakshmipur, Feni and Chandpur. According to the report of the Soil Resource Development Institute (SRDI, 2007) of Bangladesh, about 0.203 million ha of land is very slightly (2-4 dSm^{-1}), 0.492 million ha is slightly (4 -8 dSm^{-1}), 0.461 million ha is moderate (8-12 dSm^{-1}) and 0.490 million ha is strong (>12 dSm^{-1}) salt affected soils in southwestern part of the coastal area of Bangladesh.

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. Thus, the criterion for distinguishing saline from non-saline soils is arbitrary (Marschner, 1995). The possibility of increasing food production by increasing land area is quite out of question in Bangladesh. The only feasible alternative is to increase the cultivable land areas by bringing salt affected soils under cultivation with high yielding salt tolerant rice cultivars. The lack of an effective evaluation method for salt tolerance in the screening of genotypes is one of the reasons for the limited success in conventional salt tolerant breeding. Two yield parameters, tiller number per plant and spikelet number per panicle, have proved most sensitive to salinity and are highly significantly correlated to final seed yield in rice cultivar under salt stress (Zeng and Shannon, 2000).

Plant growth was seriously affected due to salinity which reduced turgor in expanding tissues and osmoregulation (Steponkus, 1984). Alam *et al.* (2001) stated that the critical EC level of salinity for seedling growth was about 5 dSm^{-1}. They observed that dry matter, seedling height, root length and emergence of new roots of rice decreased significantly at an electrical conductivity value of 5-6 dSm^{-1} and during the early seedling stage, higher salinity caused rolling and withering of leaves, browning of leaf tips and ultimately death of seedlings. They speculated that both osmotic imbalance and Cl^- was responsible for suppress of the growth. These authors maintained that the shoot growth was more suppressed than that of root and salt injury was more severe at high temperature (35°C) and low humidity (64%) due to increased transpiration and uptake of water and salt by rice plants. At the reproductive stage, salinity depressed grain yield much more than that at the vegetative growth stage (Alam *et al.*, 2001).

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 and Kinraide, 1998).

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.

Keeping the above ideas, in mind, the present work has therefore, been designed and planned with the following objectives:

- Investigating the effect of salinity on growth and yield aspects as well as mineral content in shoot (K , Na, Ca) of two rice varieties,
- The ameliorative effects of calcium nutrition on growth, yield and mineral-uptake of salt-stressed two rice varieties.

Chapter 2

Review of literature

CHAPTER II

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, humidity, light intensity and moisture for proper growth and yield. Many researchers have been conducted on various aspects of rice in different countries. A lot of work has been done on calcium (Ca) effects on different crops in normal soils, but a little information is available regarding Ca fertilization effects paddy yield in salt affected soils. Literature regarding the studies on 'Effect of ca supplementation on growth, yield and nutrient content of two rice cultivars under different saline condition' are also scanty in Bangladesh. The available literatures related to the present study are reviewed here.

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 calcium (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.

Khattak *et al.* (2007) conducted a pot experiment to evaluate the effect of various doses of gypsum on the yield of crops and properties of salt affected soils at Agricultural Research Institute (ARI), Tarnab, Peshawar during 2000-2001. Sodic soil in bulk was collected from Nowshera area and homogenized after grinding. Earthen pots eighteen (18) in number were filled with this soil. There were six treatments comprising of gypsum @ 0, 25, 50, 75, 100 and 200% of the gypsum requirement (G.R.). Each treatment was replicated three times. Rice seedlings were transplanted in the pots having been added the required amount of gypsum. pH, electrical conductivity (EC), and sodium adsorption ratio (SAR) were monitored in the first 9 leachates, received after irrigations. After the harvest of rice, every pot soil was analyzed for pH, EC and G.R. Then every pot soil was remixed and wheat was grown in it at field capacity without further addition of gypsum. Initial 5 leachates of drained water of all the pots were collected after respective irrigations and checked for the same characteristics, which were done during rice crop. The results showed that pH, EC, and SAR of the leachate samples were decreased with increasing level of gypsum and with the number of leachates. EC and SAR decreased considerably relative to pH. Gypsum application in different doses increased yield of rice by 9.8 to 25.3% and that of wheat crop by 10-80% over control treatment. Maximum increase occurred with the application rate of 200% of G.R. in both the cases. The data further indicated that soils were also improved with gypsum application especially with respect to pH and SAR. It was found that pH of soils was decreased considerably with increasing level of gypsum. G.R. of the gypsum treated pots after rice crop decreased by 40-89%, while after wheat crop they showed nil requirement of gypsum.

Puteh and Mondal (2013) conducted an experiment with four levels of sodium chloride induced salinity levels, 0, 6, 9 and 12 p^{-1} were imposed at 25 days after planting of six rice mutants. Results indicated that morphological parameters such as plant height and leaf area, dry mass production in different plant parts such as root, stem, leaf and grain yield $hill^{-1}$, physiological characters such as biological yield and harvest index, yield attributes such as number of effective tillers $hill^{-1}$, number of grains $panicle^{-1}$ and 1000-grain weight, mineral ions in leaves such as potassium and calcium were decreased with gradual increasing of salinity levels while number of non-effective tillers $hill^{-1}$ and Na content of leaves were increased with increasing soil salinity. The highest value of the above parameters was observed in control and the lowest values of them were observed at 12 dSm^{-1}. Generally genotypes having ability to exclude Na from leaves were found salt tolerant in respect of dry mass production in different plant parts and vice versa. Among the genotypes, the dry matter production and yield loss due to salinity was less in RM250-170 and RM250-2080 than that in the others, which further revealed that RM250-170 and RM250-2080 had a greater tolerance to salinity than RM350-130, RM300-280, RM250-1080 and IRATOM. The rank of salinity tolerance was: RM250-2080 > RM250-170 > RM250-1080 > IRATOM >RM300-280 > RM350-130.

Aslam *et al.* (2001) conducted an experiment investigations on the nutritional aspects of Ca in improving rice growth and yield were 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^{-1} was applied to artificially prepared saline (ECe 9 dSm^{-1}, SAR 5.46, pHs 7.8), saline sodic (ECe 9 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 Ca improved all growth characteristics (tillering capacity, shoot and root lengths, shoot and root weights) because of external Calcium (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^{-1} proved 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

Zhang *et al.* (2015) conducted an experiment was well established that both salt and reactive oxygen species (ROS) stresses are able to increase the concentration of cytosolic free Ca^{2+}($[Ca^{2+}]$i), which is caused by the flux of calcium (Ca^{2+}). However, the differences between these two processes are largely unknown. Here, they introduced recombinant aequorin into rice (*Oryza sativa*) and examined the change in $[Ca^{2+}]$ in response to salt and ROS stresses. The transgenic rice harbouringa equorin showed strong luminescence in roots when treated with exogenous Ca^{2+}. Considering the histological differences in roots between rice and *Arabidopsis*, they reappraised the discharging solution, and suggested that the percentage of ethanol should be 25%. Different concentrations of NaCl induced immediate ([Ca^{2+}]i) spikes with the same durations and phases. In contrast, H_2O_2 induced delayed ([Ca^{2+}]i) spikes with different peaks according to the concentrations of H_2O_2. According to the Ca^{2+} inhibitor research, we also showed that the sources of Ca^{2+} induced by NaCl and H_2O_2 are different. Furthermore, we evaluated the contribution of [Ca^{2+}] responses in the NaCl and H_2O_2 induced gene expressions respectively, and present a Ca^{2+} and H_2O_2 mediated molecular signaling model for the initial response to NaCl in rice.

Naeem and Qureshi (2005) conducted an experiment with decrease in yield of crop may be related to the imbalance of essential plant nutrients within the plant which may be controlled by the composition in the rooting medium, therefore, some experiments were conducted to determine whether some appropriate external ratios of ions help to maintain the suitable internal ionic composition and thus improve rice growth in the saline conditions. Hence, different ratios were established in the saline substrate involving two rice lines, *i.e.* NIAB 6 (salt tolerant) and BG 402-4 (less salt tolerant). Results showed that higher Ca^{2+}:Na^+ ratios in the external medium did help in improving the shoot and root growth as well as they reduced the Na^+ accumulation and improved K^+:Na^+ ratio and K^+ selectivity in both lines. It is confirmed that an adequate amount of Ca^{2+} in proportion to Na^+ must be present in the system to improve and/or maintain better K^+ selectivity (S K^+ Na^+).

Hakim *et al.* (2014) conducted an experiment to assess the responses of salinity on the growth, nutrient accumulation and yield of rice varieties. Five Malaysian varieties (MR33, MR52, MR211, MR232 and MR219), two salt sensitive (BRRI dhan29 and IR20) and one salt tolerant varieties (Pokkali) were evaluated in four levels of salinity. Two factors complete randomized design (CRD) was used with four replications. Dry weight of root, shoot and yield significantly decreased with the increase of salinity levels, while MR232 and MR211 were less affected. Na^+

ions accumulations increased in the root and shoot with the increase of salinity, while the lowest accumulation was in MR211. Na^+/ K^+ ratio sharply increased in the root with increasing the salinity. Whereas, Ca^{2+}/Na^+ and Mg^{2+}/Ca^{2+} ratio showed decreasing trend with increasing salinity level. The maximum amount of nitrogen and phosphorous accumulation was observed in the shoot of MR211, while Na^+ in BRRI dhan29, K^+ in Pokkali. The highest accumulation of Na^+ and K^+ observed in the root of MR219. The maximum Ca^{2+} and Mg^{2+} were found in MR33 and MR211, respectively. Considering all, varieties MR211 and MR232 were found to be relatively tolerant to salt than the other varieties.

Gautam *et al.* (2015) was conducted an experiment with pot experiment was conducted at the Net House of Department of Crop Physiology at Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad during Kharif season in year 2011-12 and 2012-13 to investigate the effect of different levels of salinity on morphological and physiological traits of rice associated with salinity tolerance. Four rice variety *viz.,* Pokkali, Narendra Ushar Dhan 3, IR 28 and IR 29 were grown in various salinity levels i.e. normal soil, EC 6.0 and 10.0 dSm^{-1} three seedlings of 21 days old were transplanted. Results indicated that morpho-physiological characters such as plant height, number of tillers, dry biomass, chlorophyll, carbohydrate, catalase activity, seed yield per plant, and mineral ions in shoots, such as potassium and calcium were decreased with gradual increasing of salinity levels, whereas, sodium content in shoot was increased with increased respective salinity level in rice varieties. The lowest values of them were observed at EC 10.0 dSm^{-1}. Generally rice varieties having the ability to exclude Na^+ from shoot were found salt tolerant in respect of grain yield and in susceptible varieties vice-versa. Among the varieties, the yield loss due to salinity was less in Pokkali and Narendra Ushar Dhan 3 than in the IR 28 and IR 29. Pokkali and Narendra Ushar Dhan 3 had a greater tolerance to salinity than IR 28 and IR 29.

Wu and Wang (2012) was conducted an experiment 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 m mol/L NaCl with or without 10 m mol/L $CaCl_2$. At low salinity (25 m mol/L 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 m mol/L 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 were 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^+.

Hwang *et al.* (1989) and Kumar (1990) stated that the addition of gypsum increased the growth and tillering patterns of rice plants. Aslam *et al.* (2003) noted that when Ca (as gypsum) was applied in saline environment, a positive, improving and stimulative effect of Ca was observed in growth characteristics (shoot and root weights and tillering capacity) in both salt-tolerant and salt-sensitive rice cultivars. They further stated that the ameliorative effect of Ca was because of increased Ca: Na ratio in growth medium. Sarfraz *et al.* (2002) stated that the number of tillers, grain and straw yields significantly increased with the application of NPK + sulfur fertilizer as compared to that without sulfur fertilizer. Aslam *et al.* (2001) indicated that the application of 20-40 $\mu g\ ml^{-1}$ Ca in solution culture containing 80 mM NaCl improved all growth characteristics such as tillering capacity, shoot and root length and weights of both salt tolerant and susceptible cultivars.

Kumar (1990) observed that application of gypsum in sodic soil increased green forage growth and yields of crops. The ability of $CaSO_4$ to ameliorate the effect of salinity on the growth of IR 29 (salt sensitive rice variety) seedlings could be attributed to the environment of its Ca^{2+} in some regulatory mechanisms (Pua *et al*., 2001).

Islam *et al*. (1998) found that filled grains panicle^{-1} at maturity was higher in Binadhan-13 and Binadhan-19 at lower salinity levels (3.6-6.9 dSm^{-1}).

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). They found that panicle number per unit area and percentage of ripened grain *i.e*. filled grain dramatically decreased in 0.5% saline water in the soil with low salinity level and in 0.1% saline water in soil with medium salinity level. The number of filled grains panicle^{-1} was less affected at 6 dSm^{-1} level of salinity in mutant variety Iratom24 which was in conformity with the findings of Baloch *et al*. (2003). They observed that the mutant variety of rice "Shua-92" maintained its superiority in various characteristics such as plant height, higher number of fertile panicles per plant and more fertile grains per panicle at 7.11- 8.0 dSm^{-1} level of salinity.

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.

The addition of supplemental Ca to the root environment has been suggested as a mean of enhancing plant tolerance to salt stress (Epstein, 1998). Under salt stress conditions, Ca^{2+}/ Na^{+} ratio decreased in root environment which might have affected membrane properties due to displacement of membrane- associated Ca^{2+} by Na^+, leading to disruption of membrane integrity and ion selectivity (Cramer *et al.*, 1985). 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 continued 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^+. The displacement of membrane- associated Ca^{2+} by Na^+ was the immediate increase of K efflux across the plasma membrane of salt stressed cotton roots at the salt concentrations above 100 mM NaCl, whereas supplemental Ca reduced this effect at concentrations above 150 mM NaCl (Cramer *et al.*, 1985).

Chapter 3
Materials and methods

CHAPTER III
MATERIALS AND METHODS

A pot culture experiment was conducted at the net house of Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the effect of supplemental Ca for amelioration of salinity and improve the growth of two selected rice varieties. The different plant parts were collected and analyzed at the laboratory of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, during the period from May to June, 2015. The soil collected from SAU Farm was used as growth medium.

3.1 Collection of pots

The required number of plastic pots having 24 cm top, 18 cm bottom diameter and 22 cm depth were collected from the local market and cleaned before use.

3.2 Selection of varieties

Two rice cultivars were used for comparative study between tolerant and susceptible variety.

Following two rice varieties were used in the study:

i) Binadhan-8 (Salt tolerant variety)

ii) BRRI dhan29 (Susceptible variety)

3.3 Sowing of seeds in seed bed

Previously collected seeds were soaked with water for 24 hours and then washed thoroughly in fresh water, and incubated for sprouting. These were sown in the wet seed bed. Required amount of fertilizers were applied one day prior to sowing of seeds in the seed bed.

3.4 Design of the experiment

The experiment was laid out in three factors CRD (Completely Randomized Design) with three replications.

Factor 1: Two varieties,

Factor 2: Salinity level- 4 (0, 4, 8, and 12 dSm^{-1})

Factor 3: Ca^{2+} level- 3 (0, 5, and 10 mM Ca)

Two varieties in combination with four salinity and three Ca^{2+} levels with three replications were randomly assigned in 72 experimental units/pots.

3.5 Preparation of pots for transplanting rice seedlings

The chemical fertilizers such as urea, triple superphosphate (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, 60 kg P_2O_5, 75 kg K_2O and 20 kg S ha^{-1}, respectively. The whole amount of TSP, MoP, gypsum and 1/3rd of urea were applied prior to final preparation of the pots. Gypsum was applied as supplemental Ca. According to treatment rate, the whole amount of supplemental Ca (as $CaSO_4.2H_2O$) was also added in the respective pots. Six weeks-old seedlings of selected rice varieties were transplanted in the respective pots. The four salinity treatement were 0 (control), 4, 8 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. At first, soil in pot was moistened with water and commercial NaCl salt was added to salinize pots to develop salinity up to the level of 3 dSm^{-1}. Two weeks after transplanting the remaining salt solutions were applied in each pot according to the treatments. To avoid osmotic shock, salt solutions were added in three equal installments every alternate day until the expected conductivity was reached. The electric conductivity (EC) of each pot was measured every day with a conductivity meter and necessary adjustments were made. The remaining 2/3rd urea were applied after 30 days of transplanting.

3.6 Intercultural operations

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

3.7 Collection of data

All the plant samples were collected from the pots at 60 days after transplanting (DAT) of the crop. After harvest, the plant samples were separated into roots and shoots.

a) Growth parameters

i) Plant height

The plant height (cm) was measured from the surface level of the growth media to the tip of the longest leaf.

ii) Number of total tillers

Total tillers number hill^{-1}, effective and non-effective tillers hill^{-1}were counted at harvesting time.

iii) Root dry weight

Roots were carefully cleaned with running tap water and finally washed with distilled water. Then the root samples were oven-dried at 70^0 C for 3 days to obtain constant weight. The mean root dry weight hill^{-1} was calculated for each treatment.

iv) Shoot dry weight

After separation of root, the shoot samples were oven-dried at 70^0C for 72 hrs. to achieve constant weight. Then the shoot dry weight hill^{-1} was calculated for each treatment.

v) Total dry matter

The total dry matter (TDM) was calculated from the summation of roots and shoots hill^{-1}.

b) Yield component

At the final harvest, the data on yield components like filled grains panicle^{-1}, unfilled grains panicle^{-1}, panicle length, spikelet number, grain yield hill^{-1} and 1000-grain weight were recorded.

c) Analyses of plant samples for estimating different elemental constituents

Rice plants were harvested at 60 days after transplanting. The plants were immediately separated into root and shoot and rinsed repeatedly with tap water and finally with distilled water. Rice shoot samples were analyzed for estimation of K, Na and Ca constituents through acid digestion techniques by micro-Kjeldahl digestion system (Thomas *et al*., 1967).

d) Procedure

For acid digestion, oven-dried ground plant shoot tissues (0.5 g) and 5 mL of concentrated sulphuric acid or 5 mL di-acid (HNO_3 and $HClO_4$) mixture and 1 mL H_2O_2 were taken in a digestion tube. This digestion tube were kept in a stand for 20 minutes and then transferred to a digestion block and continued heating at 100°C. The temperature was gradually increased by 50°C up to 365°C to prevent frothing 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. Content of K, Na and Ca were determined by Atomic Absorption Spectrophotometer (Model-PERKIN- ELMER, 2380).

3.8 Statistical analyses

The collected data were analyzed statistically by MSTAT-C computer package programme developed by Russel (1994). The mean differences were adjudged by Duncan's Multiple Range Test (DMRT) and regression lines were developed as and when required.

Chapter 4
Results and discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted under pot-culture at the net house of the department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207 to study the effect of supplemental Ca for amelioration of salinity and improve the growth and nutrients content of two selected rice varieties during Boro season (December-June) of the year 2014-15. The different growth, yield and mineral ion content parameters were studied including plant height, number of total tiller, number of effective tiller, number of non-effective tiller, panicle length, number of spikelet panicle^{-1}, number of filled and unfilled grain panicle^{-1}, root dry weight, shoot dry weight and total dry matter, grain yield hill $^{-1}$, thousand grain weight, sodium, calcium and potassium content of the shoots of the selected two rice cultivars in view to evaluate their response to calcium supplementation at different salinity levels. To evaluate the varietal performance the absolute (Dewey, 1960) values of different morphological characters and yield parameters have been taken into consideration and presented hereunder.

4.1 Plant height

4.1.1 Effect of variety

Effect of variety on plant height (cm) was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 1). The plant height was highest (92.65 cm) in BRRI dhan29 at harvest and the shortest (86.23 cm) was obtained in Binadhan-8.

4.1.2 Effect of salinity

The average plant height of the selected rice varieties decreased as the levels of salinity increased due to the mean effect of different supplemental Ca levels (Table 1). Plant height was highest (94.44 cm) at harvest in 0 dSm^{-1} and the shortest plant (78.89 cm) was obtained by 12 dSm^{-1}.

4.1.3 Effect of calcium

The plant height of two rice varieties increased with increasing the Ca levels over all the levels of salinity (Table 1). The plant height was highest (92.35 cm) at harvest by 10 mM Ca and the shortest plant (86.80 cm) was obtained from 0 mM Ca (Table1).

Table 1. Effect of variety, salinity and calcium on plant height, number of total tillers hill^{-1}, effective tillers hill^{-1} and non-effective tillers hill^{-1} of rice

Treatments	Plant height (cm)	Total tillers hill^{-1}	Effective tillers hill^{-1}	Non-effective tillers hill^{-1}
Variety				
Binadhan-8	86.23 b	15.25 b	12.44 b	2.806 b
BRRI dhan29	92.65 a	18.47 a	13.25 a	5.22 a
Level of Significant	**	*	*	*
$LSD_{(0.05)}$	0.7916	0.4773	0.4595	0.5017
Salinity level (dSm^{-1})				
0	94.44 a	17.89 a	13.56 b	4.333 a
4	94.24 a	18.00 a	14.33 a	3.667 b
8	90.19 b	16.50 b	12.44 c	4.000 ab
12	78.89 c	15.06 c	11.06 d	4.056 ab
Level of Significant	*	*	*	*
$LSD_{(0.05)}$	0.9846	0.5937	0.5717	0.624
Calcium level (mM)				
0	86.80 c	16.08 b	11.46 c	4.625 a
5	89.18 b	17.04 a	13.17 b	3.875 b
10	92.35 a	17.46 a	13.92 a	3.542 b
Level of Significant	*	*	*	**
$LSD_{(0.05)}$	1.073	0.6468	0.6229	0.68
CV (%)	4.5	10.78	11.13	5.60

*: significant at 5% level, **: significant at 1% level
Values having same letter(s) in a column do not differ significantly

4.1.4 Interaction effect of variety and salinity

The plant height of two rice varieties significantly decreased with increasing the salinity levels over all the levels of supplemental Ca (Table 2). The plant height was highest (98.78 cm) at harvest by 0 dSm^{-1} in BRRI dhan29 which was statistically identical with 4 dSm^{-1} salinity level (97.50 cm) and the shortest plant (75.44 cm) was obtained by 12 dSm^{-1} in Binadhan-8.

Table 2. Interaction effect of variety and salinity on plant height, number of total tillers $hill^{-1}$, effective tillers $hill^{-1}$ and non-effective tillers $hill^{-1}$ of rice

Variety	Salinity level (dSm^{-1})	Plant height (cm)	Total tillers $hill^{-1}$	Effective tillers $hill^{-1}$	Non-effective tillers $hill^{-1}$
Binadhan-8	0	90.10 c	16.22 c	12.67 cd	3.556 de
	4	90.99 bc	16.33 c	13.11 c	3.222 de
	8	88.39 d	15.00 d	12.11 d	2.889 e
	12	75.44 f	13.44 e	11.89 d	1.556 f
BRRI dhan29	0	98.78 a	19.56 a	14.44 b	5.111 bc
	4	97.50 a	19.67 a	15.56 a	4.111 cd
	8	92.00 b	18.00 b	12.78 cd	5.222 b
	12	82.33 e	16.67 c	10.22 e	6.444 a
Level of Significant		*	*	*	**
$LSD_{(0.05)}$		1.656	0.9984	0.9613	1.05
CV (%)		4.5	10.78	11.13	5.60

*: significant at 5% level, **: significant at 1% level
Values having same letter(s) in a column do not differ significantly

4.1.5 Interaction effect of variety and calcium

The plant height of two rice varieties significantly increased with increasing the levels of calcium over all the levels of salinity (Table 3). The plant height was highest (96.92 cm) at harvest by 10 mM Ca in BRRI dhan29 which was closely followed by 5mM Ca (92.17 cm) of the same variety and the shortest plant (84.72 cm) was obtained by 0 mM Cain Binadhan-8 which was statistically identical with 5 mM Ca of the same variety (86.18 cm). It was observed that in each variety, plant height increased with the increasing rate of calcium.

Table 3. Interaction effect of variety and calcium on plant height, number of total tillers $hill^{-1}$, effective tillers $hill^{-1}$ and non-effective tillers $hill^{-1}$ of rice

Variety	Ca level (mM)	Plant height (cm)	Total tillers $hill^{-1}$	Effective tillers $hill^{-1}$	Non-effective tillers $hill^{-1}$
Binadhan-8	0	84.72 e	14.42 d	11.25 d	3.167 c
	5	86.18 de	15.50 cd	12.67 bc	2.833 c
	10	87.79 cd	15.83 c	13.42 ab	2.417 c
BRRI dhan29	0	88.88 c	17.75 b	11.67 cd	6.083 a
	5	92.17 b	18.58 ab	13.67 ab	4.917 b
	10	96.92 a	19.08 a	14.42 a	4.667 b
Level of Significant		**	*	*	*
$LSD_{(0.05)}$		1.804	1.088	1.047	1.144
CV (%)		4.5	10.78	11.13	5.60

*: significant at 5% level, **: significant at 1% level
Values having same letter(s) in a column do not differ significantly

4.1.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, plant height varied significantly over the mean result of two rice varieties (Table 4). It was observed that, at the same salinity level, plant height increased with the increasing rate of calcium. The highest plant height (98.83 cm) was obtained from the interaction of 4 dSm^{-1} salinity and 10 mM Ca which was followed by the interaction of 0 dSm^{-1} salinity and 10 mM Ca (95.92 cm). The lowest plant height (77.00 cm) was obtained from the interaction of 12 dSm^{-1} salinity and 0 mM Ca which was statistically identical with the result (78.17 cm) of 5 mM Ca at same salinity level.

Table 4. Interaction effect of salinity and calcium on plant height, number of total tillers hill^{-1}, effective tillers hill^{-1} and non-effective tillers hill^{-1} of rice

Salinity level (dSm^{-1})	Ca level (mM)	Plant height (cm)	Total tillers hill^{-1}	Effective tillers hill^{-1}	Non-effective tillers hill^{-1}
0	0	92.70 d	17.33 b-d	12.33 de	5.000 a
	5	94.70 bc	17.83 a-c	13.83 bc	4.000 a-d
	10	95.92 b	18.50 a	14.50 ab	4.000 a-d
4	0	90.90 e	17.17 cd	13.00 cd	4.167 a-d
	5	93.00 cd	18.33 ab	14.67 ab	3.667 cd
	10	98.83 a	18.50 a	15.33 a	3.167 d
8	0	86.58 f	15.50 ef	11.00 f	4.500 a-c
	5	90.83 e	16.50 de	12.50 de	4.000 a-d
	10	93.17 cd	17.50 a-d	13.83 bc	3.667 cd
12	0	77.00 h	14.33 g	9.500 g	4.833 ab
	5	78.17 h	15.50 ef	11.67 ef	3.833 b-d
	10	81.50 g	15.33 fg	12.00 d-f	3.333 d
Level of Significant		*	*	**	*
$LSD_{(0.05)}$		1.726	1.041	1.002	1.094
CV (%)		4.5	10.78	11.13	5.60

*: significant at 5% level, **: significant at 1% level

Values having same letter(s) in a column do not differ significantly

4.1.7 Interaction effect of variety, salinity and calcium

Plant height varied significantly due to the interaction of variety, salinity and calcium. For each variety it was observed that plant height decreased with the increasing salinity level and increased with the increasing level of calcium (Table 5). The highest plant height was recorded in BRRI dhan29 (104.3 cm) at 4 dSm^{-1} salinity while incorporated with 10 mM Ca and it was statistically identical with the result obtained from the interaction of (101.0 cm) 0 dSm^{-1} salinity and 10 mM Ca of the same variety. The lowest plant height (74.67 cm) was obtained from Binadhan-8 while treated with 12 dSm^{-1} salinity and 0 mM Ca which was statistically identical with the result (78.17 cm) of 5 mM Ca ha^{-1} at same salinity level of the same variety. From the above results it appeared that salinity depressed the plant height, while increase in the Ca levels, there was a slight but significant increase in plant height. Further, the plant height increased with increasing the Ca levels in all varieties and under salinity up to 8 dSm^{-1} level. These results are in agreement with those of Hwang *et al.* (1989) who found that the application of gypsum (as 60% of Ca saturation) in saline soil increased the growth and tillering patterns of rice plants but the 2 higher rates of gypsum (as 120 and 180% of Ca saturation) did not increase the growth and tillering patterns. Kumar (1990) observed that application of gypsum in sodic soil increased green forage growth and yields of crops. Application of Ca improved all growth characteristics (tillering capacity, shoot and root length, shoot and root weights) of both salt tolerant and susceptible cultivars because of external Ca supply at 20-40 $\mu g\ mL^{-1}$ in solution culture in the presence of NaCl (Aslam *et al.*, 2001).

4.2 Number of total tillers hill^{-1}

4.2.1 Effect of variety

Effect of varieties on number of total tiller hill^{-1} was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 1). Number of total tiller hill^{-1} was highest (18.47) in BRRI dhan29 and the lowest (15.25) was obtained in Binadhan-8.

4.2.2 Effect of salinity

The average number of total tiller hill^{-1} of the selected rice varieties increased up to 4 dSm^{-1} and then decreased as the levels of salinity increased due to the mean effect of different supplemental Ca levels (Table 1). Number of total tiller hill^{-1} was highest (18.00) in 4 dSm^{-1}which was statistically identical with the result of 0 dSm^{-1} salinity levels (17.89) and the lowest total tiller hill^{-1} (15.06) was obtained by 12 dSm^{-1}.

Table 5. Interaction effect of variety, salinity and calcium on plant height, number of total tillers hill^{-1}, effective tillers hill^{-1} and non-effective tillers hill^{-1} of rice

Variety	Salinity level (dSm^{-1})	Ca level (mM)	Plant height (cm)	Total tillers hill^{-1}	Effective tillers hill^{-1}	Non-effective tillers hill^{-1}
Binadhan-8	0	0	89.07 d-g	16.00 d-g	11.67 e-h	4.333 b-e
		5	90.40 d-g	16.00 d-g	12.67 c-h	3.333 b-f
		10	90.83 d-f	16.67 c-g	13.67 b-g	3.000 b-f
	4	0	89.63 d-g	15.00 e-h	11.67 e-h	3.333 b-f
		5	90.00 d-g	17.00 b-f	13.67 b-g	3.333 b-f
		10	93.33 cd	17.00 b-f	14.00 a-f	3.000 b-f
	8	0	85.50 gh	14.00 f-h	11.00 g-i	3.000 b-f
		5	89.33 d-g	15.00 e-h	12.00 e-h	3.000 b-f
		10	90.33 dg	16.00 d-g	13.33 b-h	2.667 c-f
	12	0	74.67 j	12.67 h	10.67 hi	2.000 d-f
		5	75.00 j	14.00 gh	12.33 d-h	1.667 ef
		10	76.67 ij	13.67 gh	12.67 c-h	1.000 f
BRRI dhan29	0	0	96.33 bc	18.67 a-d	13.00 b-h	5.667 a-c
		5	99.00 b	19.67 a-c	15.00 a-d	4.667 a-e
		10	101.0 ab	20.33 a	15.33 a-c	5.000 a-d
	4	0	92.17 c-e	19.33 a-c	14.33 a-e	5.000 a-d
		5	96.00 bc	19.67 a-c	15.67 ab	4.000 b-f
		10	104.3 a	20.00 ab	16.67 a	3.333 b-f
	8	0	87.67 e-g	17.00 b-f	11.00 g-i	6.000ab
		5	92.33 c-e	18.00 a-e	13.00 b-h	5.000 a-d
		10	96.00 bc	19.00 a-d	14.33 a-e	4.667 a-e
	12	0	79.33 ij	16.00 d-g	8.333 i	7.667 a
		5	81.33 hi	17.00 b-f	11.00 g-i	6.000 ab
		10	86.33 f-h	17.00 b-f	11.33 f-h	5.667 a-c
Level of significant			*	**	**	**
$LSD_{(0.05)}$			5.103	3.077	2.963	3.234
CV (%)			4.5	10.78	11.13	5.60

*: significant at 5% level, **: significant at 1% level

Values having same letter(s) in a column do not differ significantly

4.2.3 Effect of calcium

The number of total tiller hill^{-1} of selected rice varieties increased with increasing of the Ca levels over all the levels of salinity (Table 1). The number of total tiller hill^{-1} was highest (17.46) by 10 mM Ca which was statistically identical with the result of 5 mM Ca (17.04) and the lowest result (16.08) was obtained from 0 mM Ca.

4.2.4 Interaction effect of variety and salinity

Number of total tiller hill^{-1} of two rice varieties significantly increased up to 4 dSm^{-1} and then decreased with increasing the salinity levels (Table 2). The highest number of total tiller hill^{-1} (19.67) was resulted from 4 dSm^{-1} in BRRI dhan29 which was statistically similar with 0 dSm^{-1} salinity levels (19.56) of the same variety and the lowest number of total tiller hill^{-1} (13.44) was obtained from 12 dSm^{-1} in Binadhan-8.

4.2.5 Interaction effect of variety and calcium

Number of total tiller hill^{-1} of two rice varieties significantly increased with increasing the levels of calcium over all the levels of salinity (Table 3). It was highest (19.08) from 10 mM Ca in BRRI dhan29 which was statistically identical with 5 mM Ca treatment of the same variety (18.58) and the lowest number of total tiller hill^{-1} (14.42) was obtained by 0 mM Ca in Binadhan-8 which was statistically identical with 5 mM Ca of the same variety (15.50). It was observed that in each variety, number of effective tiller hill^{-1} increased with the increasing rate of calcium.

4.2.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, number of total tiller hill^{-1} varied significantly over the mean result of two rice varieties. It was observed that, at the same salinity level, number of total tiller hill^{-1} increased with the increasing rate of calcium. The highest total tiller hill^{-1} (18.50) was obtained from two interactions which were 0 and 4 dSm^{-1} salinity with 10 mM Ca. They were followed by interactions of 4 dSm^{-1} salinity and 5 mM Ca (18.33), 0 dSm^{-1} salinity and 5 mM Ca (17.83) and 8 dSm^{-1} salinity and 10 mM Ca (17.50). The lowest number of total tiller hill^{-1} (14.33) was obtained from the interaction of 12 dSm^{-1} salinity and 0 mM Ca which was statistically identical with the result (15.33) of 10 mM Ca at same salinity level (Table 4).

4.2.7 Interaction effect of variety, salinity and calcium

Number of total tiller hill^{-1} varied significantly due to the interaction of variety, salinity and calcium (Table 5). For each variety it was observed that number of total tiller hill^{-1} decreased with the increasing salinity level while increased with the increasing doses of calcium. The highest number of total tiller hill^{-1} was recorded in BRRI dhan29 (20.33) at 0 dSm^{-1} salinity while incorporated with 10 mM Ca and it was statistically identical with the result (20.00) obtained from the interaction of 4 dSm^{-1} salinity and 10 mM Ca of the same variety. The lowest number of total tiller hill^{-1} (12.67) was obtained from Binadhan-8 while treated with 12 dSm^{-1} salinity and 0 mM Ca which was closely followed by 10 mM Ca at same salinity level of the same variety (13.67). Hwang *et al.* (1989) and Kumar (1990) stated that the addition of gypsum increased the growth and tillering patterns of rice plants. Aslam *et al.* (2003) noted that when Ca (as gypsum) was applied in saline environment, a positive, improving and stimulative effect of Ca was observed in growth characteristics (shoot and root weights and tillering capacity) in both salt-tolerant and salt-sensitive rice cultivars. They further stated that the ameliorative effect of Ca was because of increased Ca: Na ratio in growth medium. Sarfraz *et al.* (2002) stated that the number of tillers, grain and straw yields significantly increased with the application of NPK + sulfur fertilizer as compared to that without sulfur fertilizer.

4.3 Number of effective tiller hill^{-1}

4.3.1 Effect of variety

Effect of variety on number of effective tiller $hill^{-1}$ was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 11). Number of effective tiller $hill^{-1}$ was highest (13.25) in BRRI dhan29 and the lowest (12.44) was obtained in Binadhan-8.

4.3.2 Effect of salinity

The average number of effective tiller $hill^{-1}$ of the selected rice varieties increased up to 4 dSm^{-1} and then decreased as the levels of salinity increased due to the mean effect of different supplemental Ca levels. Number of effective tiller $hill^{-1}$ was highest (14.33) in 4 dSm^{-1} which was closely followed by the result of 0 dSm^{-1} salinity levels (13.56) and the lowest effective tiller $hill^{-1}$ (11.06) was obtained by 12 dSm^{-1} (Table 1).

4.3.3 Effect of calcium

The number of effective tiller $hill^{-1}$ of selected rice varieties increased with increasing of the Ca levels over all the levels of salinity (Table 1). The number of effective tiller $hill^{-1}$ was highest (13.92) by 10 mM Ca and the lowest result (11.46) was obtained from 0 mM Ca.

4.3.4 Interaction effect of variety and salinity

Number of effective tiller $hill^{-1}$ of two rice varieties significantly increased up to 4 dSm^{-1} and then decreased with increasing the salinity levels (Table 2). The highest effective tiller $hill^{-1}$ (15.56) was found from 4 dSm^{-1} in BRRI dhan29 which was closely followed by 0 dSm^{-1} salinity levels (14.44) of the same variety and the lowest number of effective tiller $hill^{-1}$ (10.22) was obtained from 12 dSm^{-1} in BRRI dhan29.

4.3.5 Interaction effect of variety and calcium

Number of effective tiller $hill^{-1}$ of two rice varieties significantly increased with increasing the levels of calcium over all the levels of salinity (Table 3). It was highest (14.42) from 10 mM Ca in BRRI dhan29 which was statistically identical with 5 mM Ca treatment of the same variety (13.67) and 10 mM Ca in Binadhan-8. The lowest number of effective tiller hill^{-1} (11.25) was obtained by 0 mM Ca in Binadhan-8 which was statistically identical with 0 mM Ca of the BRRI dhan29 (11.67). It was observed that in each variety, number of effective tiller hill^{-1} increased with the increasing rate of calcium.

4.3.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, number of effective tiller hill^{-1} varied significantly over the mean result of two rice varieties. It was observed that, at the same salinity level, number of effective tiller hill^{-1} increased with the increasing rate of calcium. The highest number of effective tiller hill^{-1} (15.33) was obtained from the interaction of 4 dSm^{-1} salinity with 10 mM Ca which was statistically identical with 4 dSm^{-1} salinity with 5 mM Ca (14.67) and 0 dSm^{-1} salinity with 10 mM Ca (14.50). The lowest number of effective tiller hill^{-1} (9.50) was obtained from the interaction of 12 dSm^{-1} salinity and 0 mM Ca (Table 4).

4.3.7 Interaction effect of variety, salinity and calcium

Number of effective tiller hill^{-1} varied significantly due to the interaction of variety, salinity and calcium. For each variety it was observed that number of effective tiller hill^{-1} decreased with the increasing salinity level while increased with the increasing doses of calcium (Table 5). The highest number of effective tiller hill^{-1} was recorded in BRRI dhan29 (16.67) at 4 dSm^{-1} salinity while incorporated with 10 mM Ca and it was statistically identical with the result (15.67) obtained from the interaction of 4 dSm^{-1} salinity and 5 mM Ca of the same variety. The lowest number of effective tiller hill^{-1} (8.333) was obtained from BRRI dhan29 while treated with 12 dSm^{-1} salinity and 0 mM Ca which was closely followed by the result of same salinity level with 0 mM Ca of Binadhan-8 (10.67). These results are in agreement with those of Khatun *et al.* (1995) found that salinity delayed flowering, reduced the number of productive tillers, the number of fertile florets per panicle. Salt tolerance indexes in terms of seed yield, seed weight panicle^{-1}, spikelet number panicle^{-1}, and tiller number plant^{-1} were reduced with increasing salinity (Zeng *et al.*, 2002).

4.4 Number of non-effective tiller hill^{-1}

4.4.1 Effect of variety

Number of non-effective tiller hill^{-1} varied significantly among the varieties due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 1). Number of non-effective tiller hill^{-1} was highest (5.22) in BRRI dhan29 and the lowest (2.81) was obtained in Binadhan-8.

4.4.2 Effect of salinity

The average number of non-effective tiller hill^{-1} of the selected rice varieties decreased up to 4 dSm^{-1} and then increased as the levels of salinity increased due to the mean effect of different supplemental Ca levels (Table 1). Number of non-effective tiller hill^{-1} was highest (4.33) in 0 dSm^{-1} which was closely followed by the result of 12 dSm^{-1} salinity levels (4.056) and the lowest non-effective tiller hill^{-1} (3.67) was obtained by 4 dSm^{-1}.

4.4.3 Effect of calcium

The number of non-effective tiller hill^{-1} of selected rice varieties decreased with increasing of the Ca levels over all the levels of salinity (Table 1). The number of non-effective tiller hill^{-1} was highest (4.625) by 0 mM Ca and the lowest result (3.542) was obtained from 10 mM Ca.

4.4.4 Interaction effect of variety and salinity

Number of non-effective tiller hill^{-1} varied significantly among the varieties due to the different salinity levels (Table 2). But the two varieties followed different pattern here. In Binadhan-8, number of non-effective tiller hill^{-1} decreased with increasing salinity level. On the other hand, in BRRI dhan29 number of non-effective tiller hill^{-1} decreased up to 4 dSm^{-1} and then increased as the levels of salinity increased. The highest number of non-effective tiller hill^{-1} (6.444) was resulted from 12 dSm^{-1} in BRRI dhan29 which was closely followed by 8 dSm^{-1} salinity levels (5.222) of the same variety and the lowest number of non-effective tiller hill^{-1} (1.556) was obtained from 12 dSm^{-1} in Binadhan-8.

4.4.5 Interaction effect of variety and calcium

Number of non-effective tiller hill^{-1} of two rice varieties significantly decreased with increasing the levels of calcium over all the levels of salinity (Table 3). It was highest (6.083) from 0 mM Ca ha^{-1} in BRRI dhan29. The lowest number of non-effective tiller hill^{-1} (2.417) was obtained by 10 mM Ca ha^{-1} in Binadhan-8. It was observed that in each variety, number of non-effective tiller hill^{-1} decreased with the increasing rate of calcium.

4.4.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, number of non-effective tiller hill^{-1} varied significantly over the mean result of two rice varieties (Table 4). It was observed that, at the same salinity level, number of non-effective tiller hill^{-1} decreased with the increasing rate of calcium. The highest number of non-effective tiller hill^{-1} (5.000) was obtained from the interaction of 0 dSm^{-1} salinity and 0 mM Ca. The lowest number of non-effective tiller hill^{-1} (3.167) was obtained from the interaction of 4 dSm^{-1} salinity and 10 mM Ca which was statistically identical with 12 dSm^{-1} salinity and 10 mM Ca (3.333).

4.4.7 Interaction effect of variety, salinity and calcium

Number of non-effective tiller hill^{-1} varied significantly due to the interaction of variety, salinity and calcium (Table 5). The highest number of non-effective tiller hill^{-1} was recorded in BRRI dhan29 (7.667) at 12 dSm^{-1} salinity while incorporated with 0 mM Ca ha^{-1} and it was statistically identical with the results (6.00 and 6.00) obtained from the interaction of 12 dSm^{-1} salinity and 5 mM Ca ha^{-1} as well as 8 dSm^{-1} salinity and 0 mM Ca of the same variety. The lowest number of non-effective tiller hill^{-1} (1.00) was obtained from Binadhan-8 while treated with 12 dSm^{-1} salinity and 10 mM Ca which was closely followed by the result of same salinity level with 5mM Ca of Binadhan-8 (1.667). These results are in agreement with those of Alam *et al.* (2001) stated that the salinity at reproductive stage of rice depressed grain yield much more than that of vegetative growth stage and at critical salinity levels it might give a normal straw yield of rice but produced little or no grain. They also observed that when the plants were continuously exposed to saline media, salinity affected the panicle initiation, spikelet formation, fertilization of the florets and germination of pollen grains and hence caused an increase in number of sterile florets.

4.5 Panicle length

4.5.1 Effect of variety

Effect of variety on panicle length (cm) was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 6). The panicle length was highest (24.34 cm) in Binadhan-8 at harvest and the shortest (23.84 cm) was obtained in BRRI dhan29.

4.5.2 Effect of salinity

The average panicle length of the selected rice varieties decreased after 4 dSm^{-1} as the levels of salinity increased due to the mean effect of different supplemental Ca levels (Table 6). Panicle length was highest (25.14 cm) at harvest in 4 dSm^{-1} and the shortest panicle length (23.00 cm) was obtained by 12 dSm^{-1}.

4.5.3 Effect of calcium (Ca)

The panicle length of two rice varieties increased with increasing the Ca levels over all the levels of salinity (Table 6). The panicle length was highest (24.94 cm) at harvest by 10 mM Ca and the shortest panicle (23.13 cm) was obtained from 0 mM Ca.

Table 6. Effect of variety, salinity and calcium on panicle length, number of spikelets panicle^{-1}, filled grains panicle^{-1} and unfilled grains panicle^{-1} of rice

Treatments	Panicle length (cm)	No. of spikelets panicle^{-1}	No. of filled grains panicle^{-1}	No. of unfilled grains panicle^{-1}
Variety				
Binadhan-8	24.34 a	122.0 b	97.62 b	24.36 b
BRRI dhan29	23.84 b	143.8 a	100.2 a	43.60 a
Level of significant	*	**	**	*
$LSD_{(0.05)}$	0.3606	0.9013	0.9003	0.6854
Salinity level (dSm^{-1})				
0	24.59 b	150.6 b	118.6 b	32.03 b
4	25.14 a	154.2 a	124.7 a	29.52 c
8	23.63 c	128.2 c	102.6 c	25.63 d
12	23.00 d	98.59 d	49.82 d	48.77 a
Level of significant	**	*	**	**
$LSD_{(0.05)}$	0.4484	1.121	1.12	0.8526
Calcium level (mM)				
0	23.13 c	128.8 c	90.17 c	38.68 a
5	24.20 b	133.1 b	99.46 b	33.66 b
10	24.94 a	136.7 a	107.1 a	29.62 c
Level of significant	**	*	*	**
$LSD_{(0.05)}$	0.4887	1.222	1.22	0.9289
CV (%)	2.45	7.88	4.65	13.9

*: significant at 5% level, **: significant at 1% level

Values having same letter(s) in a column do not differ significantly

4.5.4 Interaction effect of variety and salinity

The panicle length of two rice varieties significantly decreased after 4 dSm^{-1} with increasing the salinity levels over all the levels of supplemental Ca (Table 7). The panicle length was highest (25.20 cm) by 4 dSm^{-1} in BRRI dhan29 which was statistically identical with 4 dSm^{-1} salinity level (25.09 cm) in Binadhan-8 and the shortest panicle (22.51 cm) was obtained by 12 dSm^{-1} in BRRI dhan29.

Table 7. Interaction effect of variety and salinity on panicle length, number of spikelets panicle^{-1}, filled grains panicle^{-1} and unfilled grains panicle^{-1} of rice

Variety	Salinity level (dSm^{-1})	Panicle length (cm)	No. of spikelets panicle^{-1}	No. of filled grains panicle^{-1}	No. of unfilled grains panicle^{-1}
Binadhan-8	0	24.66 ab	139.3 c	114.2 c	25.05 f
	4	25.09 a	145.9 b	123.0 b	22.89 g
	8	24.14 bc	120.3 e	101.8 d	18.47 h
	12	23.49 cd	82.49 g	51.44 e	31.05 e
BRRI dhan29	0	24.52 ab	162.0 a	123.0 b	39.01 b
	4	25.20 a	162.5 a	126.3 a	36.14 c
	8	23.11 de	136.1 d	103.3 d	32.78 d
	12	22.51 e	114.7 f	48.20 f	66.48 a
Level of significant		*	**	*	**
$LSD_{(0.05)}$		0.7543	1.886	1.883	1.434
CV (%)		2.45	7.88	4.65	13.9

*: significant at 5% level, **: significant at 1% level
Values having same letter(s) in a column do not differ significantly

4.5.5 Interaction effect of variety and calcium

The panicle length of two rice varieties significantly increased with increasing the levels of calcium over all the levels of salinity (Table 8). The panicle length was highest (25.01 cm) at harvest by 10 mM Ca in Binadhan-8 which was closely followed by 10 mM Ca of the BRRI dhan29 variety (24.87 cm) and the shortest panicle (22.69 cm) was obtained by 0 mM Ca in BRRI dhan29. It was observed that in each variety, panicle length increased with the increasing rate of calcium.

Table 8. Interaction effect of variety and calcium on panicle length, number of spikelets panicle^{-1}, filled grains panicle^{-1} and unfilled grains panicle^{-1} of rice

Variety	Ca level (mM)	Panicle length (cm)	No. of spikelets panicle^{-1}	No. of filled grains panicle^{-1}	No. of unfilled grains panicle^{-1}
Binadhan-8	0	23.58 c	116.9 e	88.19 e	28.67 d
	5	24.45 ab	121.2 d	97.51 c	23.71 e
	10	25.01 a	127.9 c	107.2 a	20.72 f
BRRI dhan29	0	22.69 d	140.8 b	92.14 d	48.69 a
	5	23.95 bc	145.0 a	101.4 b	43.61 b
	10	24.87 a	145.6 a	107.1 a	38.51 c
Level of significant		**	**	*	*
$LSD_{(0.05)}$		0.8218	2.054	2.052	1.562
CV (%)		2.45	7.88	4.65	13.9

*: significant at 5% level, **: significant at 1% level

Values having same letter(s) in a column do not differ significantly

4.5.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, panicle length varied significantly over the mean result of two rice varieties. It was observed that, at the same salinity level, panicle length increased with the increasing rate of calcium. The highest panicle length (25.90 cm) was obtained from the interaction of 4 dSm^{-1} salinity and 10 mM Ca which was followed by the interaction of 4 dSm^{-1} salinity and 5mM Ca (25.25 cm) as well as 0 dSm^{-1} salinity and 10 mM Ca (25.18 cm). The lowest panicle length (21.70 cm) was obtained from the interaction of 12 dSm^{-1} salinity and 0 mM Ca which was closely followed by the result of 8 dSm^{-1} salinity level and 0 mM Ca (22.62 cm) (Table 9).

Table 9. Interaction effect of salinity and calcium on panicle length, number of spikelets panicle^{-1}, filled grains panicle^{-1} and unfilled grains panicle^{-1} of rice

Salinity level (dSm^{-1})	Ca level (mM)	Panicle length (cm)	No. of spikelets panicle^{-1}	No. of filled grains panicle^{-1}	No. of unfilled grains panicle^{-1}
0	0	23.93 cde	146.6 d	110.6 e	35.97 d
	5	24.65 bc	150.2 c	118.3 d	31.89 e
	10	25.18 ab	155.1 b	126.8 b	28.23 f
4	0	24.28 cd	150.2 c	117.2 d	32.97 e
	5	25.25 ab	154.1 b	124.5 c	29.64 f
	10	25.90 a	158.2 a	132.3 a	25.93 g
8	0	22.62 f	123.1 g	94.21 g	28.90 f
	5	23.68 de	128.1 f	102.5 f	25.61 g
	10	24.59 bc	133.4 e	111.0 e	22.37 h
12	0	21.70 g	95.43 i	38.56 j	56.86 a
	5	23.21 ef	100.0 h	52.53 i	47.50 b
	10	24.08 cd	100.3 h	58.38 h	41.93 c
Level of significant		*	*	**	*
$LSD_{(0.05)}$		0.7861	1.965	1.963	1.494
CV (%)		2.45	7.88	4.65	13.9

*: significant at 5% level, **: significant at 1% level

Values having same letter(s) in a column do not differ significantly

4.5.7 Interaction effect of variety, salinity and calcium

Panicle length varied significantly due to the interaction of variety, salinity and calcium. For each variety it was observed that panicle length decreased with the increasing salinity level and increased with the increasing level of calcium. The highest panicle length was recorded in BRRI dhan29 (26.07 cm) at 4 dSm^{-1} salinity while incorporated with 10 mM Ca and it was closely followed by the result obtained from the interaction of 4 dSm^{-1} salinity and 10 mM Ca (25.73 cm) of the Binadhan-8. The lowest panicle length (21.13 cm) was obtained from BRRI dhan29 while treated with 12 dSm^{-1} salinity and 0 mM Ca (Table 10). Our results corroborate with those of Alam *et al.* (2001) reported that salinity severely reduces the panicle length, seed setting percentage and panicle weight, thereby reducing the grain yield. Abdullah *et al.* (2001) observed that panicle length was significantly decreased due to salinity stress. Aslam *et al.* (2003) stated that panicle length of rice adversely affected by both saline and saline sodic soils.

Table 10. Interaction effect of variety, salinity and calcium on panicle length, number of spikelets panicle^{-1}, filled grains panicle^{-1} and unfilled grains panicle^{-1} of rice

Variety	Salinity level (dSm^{-1})	Ca level (mM)	Panicle length (cm)	No. of spikelets panicle^{-1}	No. of filled grains panicle^{-1}	No. of unfilled grains panicle^{-1}
Binadhan-8	0	0	24.27 a-f	133.5 d-f	103.6 h	29.93gh
		5	24.73 a-e	138.1 de	113.8 ef	24.29 ij
		10	24.97 a-e	146.1 c	125.2 bc	20.93jk
	4	0	24.47 a-f	139.3 d	112.1 ef	27.20 hi
		5	25.07 a-d	146.0 c	123.9 bc	22.13jk
		10	25.73 ab	152.4 b	133.1 a	19.33kl
	8	0	23.30 c-h	113.9 gh	93.07 j	20.80jk
		5	24.27 a-f	118.9 g	100.2 hi	18.73kl
		10	24.87 a-e	128.1 f	112.2 ef	15.87l
	12	0	22.27 f-h	80.69 i	43.96 m	36.73 ef
		5	23.73 b-g	81.84 i	52.17 l	29.67gh
		10	24.47 a-f	84.95 i	58.21 k	26.74hi
BRRI dhan29	0	0	23.60 b-g	159.7 a	117.7 de	42.00d
		5	24.57 a-f	162.3 a	122.8 b-d	39.48de
		10	25.40 a-d	164.0 a	128.5 ab	35.53ef
	4	0	24.10 a-g	161.1 a	122.4 cd	38.75de
		5	25.43 a-c	162.3 a	125.1 bc	37.15e
		10	26.07 a	164.0 a	131.5 a	32.53fg
	8	0	21.93 gh	132.4 ef	95.36 ij	37.00e
		5	23.10 d-h	137.3 de	104.8 gh	32.48fg
		10	24.31 a-f	138.7 d	109.8 fg	28.87gh
	12	0	21.13 h	110.2 h	33.17 n	77.00 a
		5	22.69 e-h	118.2 g	52.89 kl	65.34 b
		10	23.70 b-g	115.7 gh	58.56 k	57.11c
Level of significant			*	*	*	**
$LSD_{(0.05)}$			2.324	5.811	5.804	4.419
CV (%)			2.45	7.88	4.65	13.9

*: significant at 5% level, **: significant at 1% level

Values having same letter(s) in a column do not differ significantly

4.6 Number of spikelet panicle^{-1}

4.6.1 Effect of variety

Effect of varieties on number of spikelet panicle^{-1} was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 6). Number of spikelet panicle^{-1} was highest (143.8) in BRRI dhan29 and the lowest (122.0) was obtained in Binadhan-8.

4.6.2 Effect of salinity

The average number of spikelet panicle^{-1} of the selected rice varieties increased up to 4 dSm^{-1} and then decreased as the levels of salinity increased due to the mean effect of different supplemental Ca levels (Table 6). Number of spikelet panicle^{-1} was highest (154.2) in 4 dSm^{-1} which was closely followed by the result of 0 dSm^{-1} salinity levels (150.6) and the lowest spikelet panicle^{-1} (98.59) was obtained by 12 dSm^{-1}.

4.6.3 Effect of calcium

The number of spikelet panicle^{-1} of selected rice varieties increased with increasing of the Ca levels over all the levels of salinity (Table 6). The number of spikelet panicle^{-1} was highest (136.7) by 10 mM Ca and the lowest result (128.8) was obtained from 0 mM Ca.

4.6.4 Interaction effect of variety and salinity

Number of spikelet panicle^{-1}of two rice varieties significantly increased up to 4 dSm^{-1} and then decreased with increasing the salinity levels (Table 7). The highest number of spikelet panicle^{-1} (162.5) was resulted from 4 dSm^{-1} in BRRI dhan29 which was closely followed by 0 dSm^{-1} salinity levels (162.0) of the same variety and the lowest number of spikelet panicle^{-1} (82.49) was obtained from 12 dSm^{-1} in Binadhan-8.

4.6.5 Interaction effect of variety and calcium

Number of spikelet panicle^{-1} of two rice varieties significantly increased with increasing the levels of calcium over all the levels of salinity (Table 8). It was highest (145.6) from 10 mM Ca in BRRI dhan29 which was statistically identical with 5 mM Ca treatment of the same variety (145.0). The lowest number of spikelet panicle^{-1} (116.9) was obtained by 0 mM Ca in Binadhan-8. It was observed that in each variety, number of spikelet panicle^{-1} increased with the increasing rate of calcium.

4.6.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, number of spikelet panicle^{-1} varied significantly over the mean result of two rice varieties. It was observed that, at the same salinity level, number of spikelet panicle^{-1} increased with the increasing rate of calcium. The highest number of spikelet panicle^{-1} (158.2) was obtained from the interaction of 4 dSm^{-1} salinity with 10 mM Ca. The lowest number of spikelet panicle^{-1} (95.43) was obtained from the interaction of 12 dSm^{-1} salinity and 0 mM Ca (Table 9).

4.6.7 Interaction effect of variety, salinity and calcium

Number of spikelet panicle^{-1} varied significantly due to the interaction of variety, salinity and calcium. For each variety it was observed that number of spikelet panicle^{-1} decreased with the increasing salinity level while increased with the increasing doses of calcium (Table 10). The highest number of spikelet panicle^{-1} (164.0) was recorded in BRRI dhan29 at 0 and 4 dSm^{-1} salinity while incorporated with 10 mM Ca. The lowest number of spikelet panicle^{-1} (80.69) was obtained from Binadhan-8 while treated with12 dSm^{-1} salinity and 0 mM Ca which was closely followed by the result of same salinity level with 5 and 10 mM Ca of Binadhan-8 (81.84 and 84.95).

4.7 Number of filled grain panicle^{-1}

4.7.1 Effect of variety

Effect of variety on number of filled grain panicle^{-1} was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 6). Number of filled grain panicle^{-1} was highest (100.2) in BRRI dhan29 and the lowest (97.62) was obtained in Binadhan-8.

4.7.2 Effect of salinity

The average number of filled grain panicle^{-1} of the selected rice varieties increased up to 4 dSm^{-1} and then decreased as the levels of salinity increased due to the mean effect of different supplemental Ca levels (Table 6). Number of filled grain panicle^{-1} was highest (124.7) in 4 dSm^{-1} which was closely followed by the result of 0 dSm^{-1} salinity levels (118.6) and the lowest filled grain panicle^{-1} (49.82) was obtained by 12 dSm^{-1}.

4.7.3 Effect of calcium (Ca)

The number of filled grain panicle^{-1} of selected rice varieties increased with increasing of the Ca levels over all the levels of salinity (Table 6). The number of filled grain panicle^{-1} was highest (107.1) by 10 mM Ca and the lowest result (90.17) was obtained from 0 mM Ca.

4.7.4 Interaction effect of variety and salinity

Number of filled grains panicle^{-1}of two rice varieties significantly increased up to 4 dSm^{-1} and then decreased with increasing the salinity levels (Table 7). The highest number of filled grains panicle^{-1} (126.3) was resulted from 4 dSm^{-1} in BRRI dhan29 which was closely followed by 0 dSm^{-1} salinity levels (123.0) of the same variety and 4 dSm^{-1} in Binadhan-8 (123.0). The lowest number of filled grains panicle^{-1} (48.20) was obtained from 12 dSm^{-1} in BRRI dhan29.

4.7.5 Interaction effect of variety and calcium

Number of filled grains panicle^{-1} of two rice varieties significantly increased with increasing the levels of calcium over all the levels of salinity (Table 8). It was highest (107.2) from 10 mM Ca ha^{-1} in Binadhan-8 which was statistically identical with 10 mM Ca treatment of BRRI dhan29 (107.1). The lowest number of filled grains panicle^{-1} (88.19) was obtained by 0 mM Ca in Binadhan-8. It was observed that in each variety, number of filled grains panicle^{-1} increased with the increasing rate of calcium.

4.7.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, number of filled grains panicle^{-1} varied significantly over the mean result of two rice varieties. It was observed that, at the same salinity level, number of filled grains panicle^{-1} increased with the increasing rate of calcium. The highest number of filled grains panicle^{-1} (132.3) was obtained from the interaction of 4 dSm^{-1} salinity with 10 mM Ca. The lowest number of filled grains panicle^{-1} (38.56) was obtained from the interaction of 12 dSm^{-1} salinity and 0 mM Ca (Table 9).

4.7.7 Interaction effect of variety, salinity and calcium

Number of filled grains panicle^{-1} varied significantly due to the interaction of variety, salinity and calcium. For each variety it was observed that number of filled grains panicle^{-1} decreased with the increasing salinity level while increased with the increasing doses of calcium (Table 10). The highest number of filled grains panicle^{-1} were recorded in Binadhan-8 (133.1) followed by BRRI dhan29 (131.5) at 4 dSm^{-1} salinity while incorporated with 10 mM Ca. The lowest number of filled grains panicle^{-1} (33.17) was obtained from BRRI dhan29 while treated with 12 dSm^{-1} salinity and 0 mM Ca which was closely followed by the result of same salinity level with 10 mM Ca of Binadhan-8 (43.96). From the results it is evident that the number of filled grains panicle^{-1} increased with increase in salinity up to 4 dSm^{-1} level in all varieties. After 4 dSm^{-1}, filled grain decreased with increasing the salinity level. These results confirmed those of Islam *et al.* (1998) who found that filled grains $panicle^{-1}$ at maturity were higher in Binadhan-13 and Binadhan-19 at lower salinity levels (3.6-6.9 dSm^{-1}). 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.

4.8 Number of unfilled grains $panicle^{-1}$

4.8.1 Effect of variety

Effect of variety on number of unfilled grains $panicle^{-1}$ was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 6). Number of unfilled grains $panicle^{-1}$ was highest (43.60) in BRRI dhan29 and the lowest (24.36) was obtained in Binadhan-8.

4.8.2 Effect of salinity

The average number of unfilled grains $panicle^{-1}$ of the selected rice varieties decreased up to 8 dSm^{-1} and then increased a lot in the highest level of salinity due to the mean effect of different supplemental Ca levels (Table 6). Number of unfilled grains $panicle^{-1}$ was highest (48.77) in 12 dSm^{-1} and the lowest unfilled grains $panicle^{-1}$ (49.82) was obtained by 12 dSm^{-1}.

4.8.3 Effect of calcium (Ca)

The number of unfilled grains $panicle^{-1}$ of selected rice varieties decreased with increasing of the Ca levels over all the levels of salinity (Table 6). The number of unfilled grains panicle^{-1} was highest (38.68) by 0 mM Ca and the lowest result (29.62) was obtained from 10 mM Ca.

4.8.4 Interaction effect of variety and salinity

Number of unfilled grains panicle^{-1} of two rice varieties significantly decreased up to 8 dSm^{-1} and then increased a lot in the highest level of salinity (Table 7). The highest number of unfilled grains panicle^{-1} (66.48) was resulted from 12 dSm^{-1} in BRRI dhan29. The lowest number of unfilled grains panicle^{-1} (18.47) was obtained from 8 dSm^{-1} in Binadhan-8.

4.8.5 Interaction effect of variety and calcium

Number of unfilled grains panicle^{-1} of two rice varieties significantly decreased with increasing the levels of calcium over all the levels of salinity (Table 8). It was highest (48.69) from 0 mM Ca in BRRI dhan29. The lowest number of unfilled grain panicle^{-1} (20.72) was obtained by 10 mM Ca in Binadhan-8. It was observed that in each variety, number of unfilled grains panicle^{-1} increased with the increasing rate of calcium.

4.8.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, number of unfilled grains panicle^{-1} varied significantly over the mean result of two rice varieties (Table 9). It was observed that, at the same salinity level, number of unfilled grains panicle^{-1}decreased with the increasing rate of calcium. The highest number of unfilled grains panicle^{-1} (56.86) was obtained from the interaction of 12 dSm^{-1} salinity with 0 mM Ca. The lowest number of unfilled grains panicle^{-1} (22.37) was obtained from the interaction of 8 dSm^{-1} salinity and 10 mM Ca.

4.8.7 Interaction effect of variety, salinity and calcium

Number of unfilled grains panicle^{-1} varied significantly due to the interaction of variety, salinity and calcium. For each variety it was observed that number of unfilled grains panicle^{-1} increased with the increasing salinity level while decreased with the increasing doses of calcium. The highest number of unfilled grains panicle^{-1} were recorded in BRRI dhan29 (77.00) at 12 dSm^{-1} salinity while incorporated with 0 mM Ca. The lowest number of unfilled grains panicle^{-1} (15.87) was obtained from Binadhan-8 while treated with 8 dSm^{-1} salinity and 10 mM Ca (Table 10). This results corroborate with those of Asch *et al.* (1999) observed that salinity was a major yield-reducing stress in much arid and/or coastal irrigation system for rice.

4.9 Root Dry Weight (RDW) hill^{-1}

4.9.1 Effect of variety

Effect of variety on root dry weight (RDW) hill^{-1} was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 11). RDW hill^{-1} was highest (6.62 g) in BRRI dhan29 and the lowest (5.17 g) was obtained in Binadhan-8.

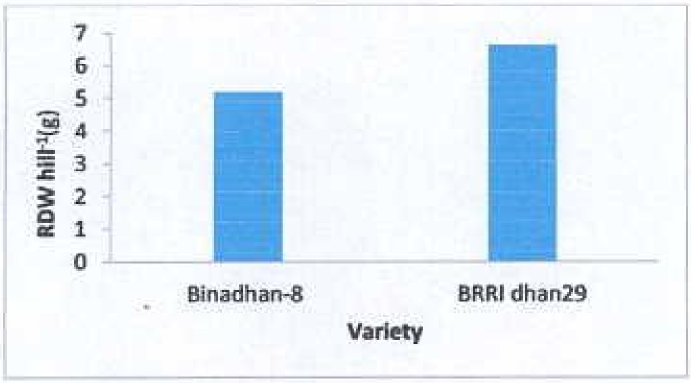

Figure 1: Variation of RDW hill^{-1} due to the varietal differences

4.9.2 Effect of salinity

The average RDW hill^{-1} of the selected rice varieties increased up to 4 dSm^{-1} and then decreased as the levels of salinity increased due to the mean effect of different supplemental Ca levels (Table11). RDW hill^{-1} was highest (7.05 g) in 4 dSm^{-1} which was closely followed by the result of 0 dSm^{-1} salinity level (6.87 g) and the lowest RDW (4.16 g) was obtained by 12 dSm^{-1}.

4.9.3 Effect of calcium

The RDW hill^{-1} of selected rice varieties increased with increasing of the Ca levels over all the levels of salinity (Table 11). The RDW hill^{-1} was highest (6.591 g) by 10 mM Ca and the lowest result (5.332 g) was obtained from 0 mM Ca.

Table 11. Effect of variety, salinity and calcium on root, shoot and total dry weight, 1000-grain weight and grain yield hill^{-1} of rice

Treatments	RDW hill^{-1} (g)	SDW hill^{1} (g)	TDW hill^{-1} (g)	1000-grain weight (g)	Grain yield (g hill^{-1})
Variety					
BINA 8	5.186 b	45.82 b	51.00 b	20.09 a	22.74 a
BRRI dhan29	6.622 a	53.38 a	60.00 a	15.30 b	21.08 b
Significance level	**	**	**	**	**
$LSD_{0.05}$	0.2714	0.5031	0.5587	0.3261	0.5031
Salinity level (dSm^{-1})					
0	6.868 a	55.63 b	62.50 b	17.37 b	26.14 b
4	7.054 a	59.62 a	66.67 a	18.59 a	28.35 a
8	5.537 b	51.77 c	57.31 c	18.18 a	23.44 c
12	4.156 c	31.37 d	35.52 d	16.63 c	9.697 d
Significance level	**	**	**	*	**
$LSD_{(0.05)}$	0.3376	0.6258	0.6951	0.4056	0.6258
Calcium level (mM)					
0	5.332 c	41.18 c	46.51 c	16.23 c	17.19 c
5	5.788 b	50.41 b	56.20 b	17.83 b	22.44 b
10	6.591 a	57.20 a	63.79 a	19.03 a	26.09 a
Significance level	*	**	*	**	*
$LSD_{(0.05)}$	0.3678	0.6819	0.7574	0.4419	0.6819
CV (%)	3.87	9.73	6.22	7.89	10.31

*: significant at 5% level, **: significant at 1% level
Values having same letter(s) in a column do not differ significantly

4.9.4 Interaction effect of variety and salinity

RDW hill^{-1} of two rice varieties significantly varied due to the different salinity levels (Table 12). But the two varieties followed two different patterns here. In Binadhan-8, RDW hill^{-1} decreased with increasing salinity level. On the other hand, in BRRI dhan29 RDW hill^{-1} increased up to 4 dSm^{-1} and then decreased as the levels of salinity increased. The highest RDW hill^{-1} (8.309 g) was resulted from 4 dSm^{-1} in BRRI dhan29 which was closely followed by 0 dSm^{-1} salinity levels (7.693 g) of the same variety and the lowest RDW $hill^{-1}$ (4.104 g) was obtained from 12 dSm^{-1} in Binadhan-8 which was statistically similar with 12 dSm^{-1} salinity in BRRI dhan29 (4.207 g).

Table 12. Interaction effect of variety and salinity on root, shoot and total dry weight, 1000-grain weight and grain yield $hill^{-1}$ of rice

Variety	Salinity level (dSm^{-1})	**RDW $hill^{-1}$ (g)**	**SDW $hill^{-1}$ (g)**	**TDW $hill^{-1}$ (g)**	**1000-grain weight (g)**	**Grain yield (g $hill^{-1}$)**
Binadhan-8	0	6.043 c	50.16 d	56.21 e	19.46 c	25.78 cd
	4	5.800 c	54.32 c	60.12 d	21.42 a	29.04 a
	8	4.794 d	48.43 e	53.22 f	20.58 b	24.86 d
	12	4.104 e	30.36 g	34.46 h	18.89 c	11.28 f
BRRI dhan29	0	7.693 b	61.10 b	68.80 b	15.29 d	26.51 c
	4	8.309 a	64.91 a	73.22 a	15.78 d	27.67 b
	8	6.279 c	55.12 c	61.40 c	15.75 d	22.01 e
	12	4.207 e	32.38 f	36.58 g	14.37 e	8.109 g
Level of significant		*	*	**	**	**
$LSD_{(0.05)}$		0.5677	1.053	1.169	0.6821	1.053
CV (%)		3.87	9.73	6.22	7.89	10.31

*: significant at 5% level, **: significant at 1% level
Values having same letter(s) in a column do not differ significantly

4.9.5 Interaction effect of variety and calcium

RDW $hill^{-1}$ of two rice varieties significantly increased with increasing the levels of calcium over all the levels of salinity (Table 13). It was highest (7.35 g) from 10 mM Ca in BRRI dhan29. The lowest RDW $hill^{-1}$ (4.66 g) was obtained by 0 mM Ca in Binadhan-8. It was observed that in each variety, RDW $hill^{-1}$ increased with the increasing rate of calcium.

Table 13. Interaction effect of variety and calcium on root, shoot and total dry weight, 1000-grain weight and grain yield $hill^{-1}$ of rice

Variety	Ca level (mM)	RDW $hill^{-1}$ (g)	SDW $hill^{-1}$ (g)	TDW $hill^{-1}$ (g)	1000-grain weight (g)	Grain yield (g $hill^{-1}$)
Binadhan-8	0	4.660 d	38.92 f	43.58 f	18.70 c	18.16 d
	5	5.069 d	46.08 d	51.15 d	20.27 b	22.93 c
	10	5.827 c	52.44 c	58.27 c	21.29 a	27.13 a
BRRI dhan29	0	6.004 bc	43.44 e	49.44 e	13.75 f	16.23 e
	5	6.507 b	54.74 b	61.24 b	15.39 e	21.95 c
	10	7.354 a	61.96 a	69.31 a	16.76 d	25.05 b
Level of significant		**	**	*	**	**
$LSD_{(0.05)}$		0.6185	1.147	1.274	0.7432	1.147
CV (%)		3.87	9.73	6.22	7.89	10.31

*: significant at 5% level, **: significant at 1% level
Values having same letter(s) in a column do not differ significantly

4.9.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, RDW $hill^{-1}$ varied significantly over the mean result of two rice varieties. It was observed that, at the same salinity level, RDW $hill^{-1}$ increased with the increasing rate of calcium. The highest RDW $hill^{-1}$ (7.86 g) was obtained from the interaction of 4 dSm^{-1} salinity with 10 mM Ca which was statistically similar with the interaction of 0 dSm^{-1} salinity with 10 mM Ca (7.723 g). The lowest RDW $hill^{-1}$ (3.858 g) was obtained from the interaction of 12 dSm^{-1} salinity (Figure 6) and 0 mM Ca (Figure 7).

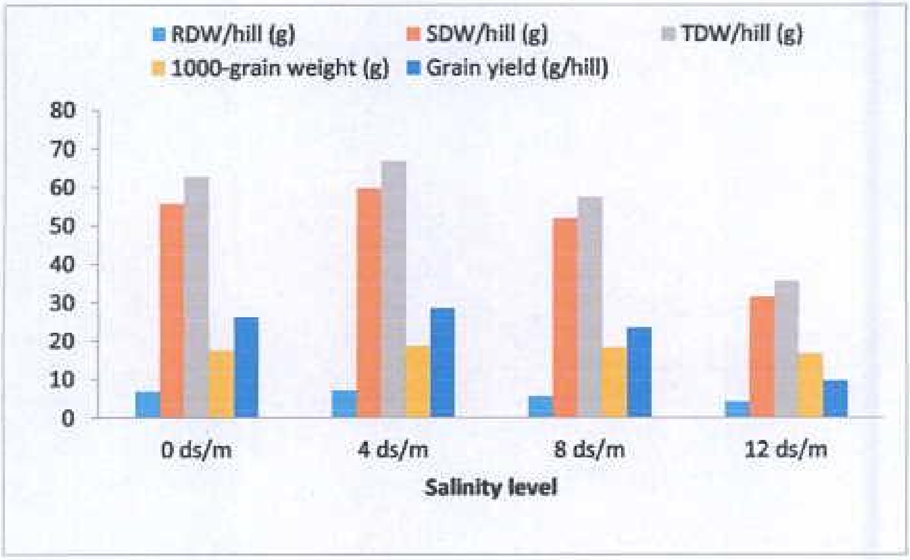

Figure 2: Variation of root, shoot and total dry weight, 1000-grain weight and grain yield hill^{-1} of rice due to the differences of salinity level

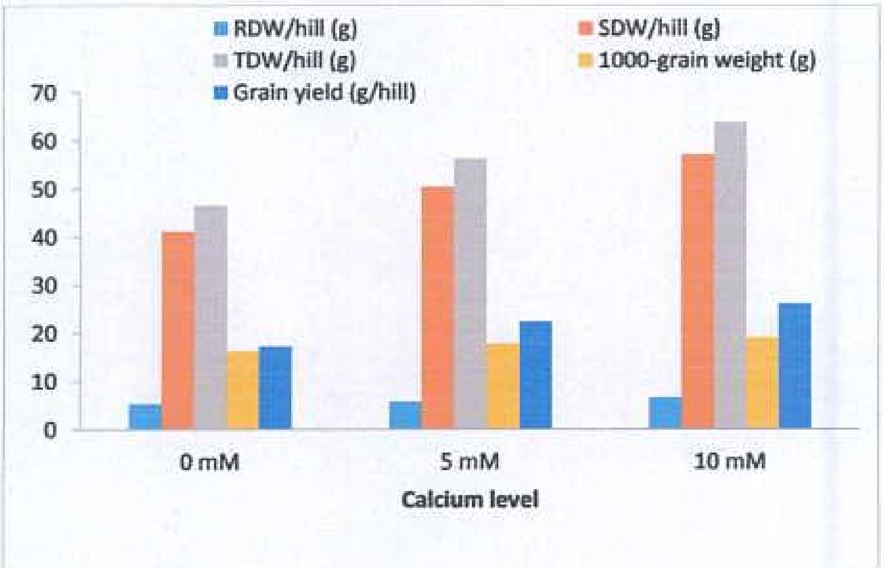

Figure 3: Variation of root, shoot and total dry weight, 1000-grain weight and grain yield hill^{-1} of rice due to the differences of calcium level

4.9.7 Interaction effect of variety, salinity and calcium

RDW $hill^{-1}$ varied significantly due to the interaction of variety, salinity and calcium. For each variety it was observed that RDW $hill^{-1}$ decreased with the increasing salinity level while increased with the increasing doses of calcium. The highest RDW $hill^{-1}$ (9.03 g) was recorded in BRRI dhan29 at 4 dSm^{-1} salinity while incorporated with 10 mM Ca. The lowest RDW $hill^{-1}$ (3.67 g) was obtained from Binadhan-8 while treated with 12 dSm^{-1} salinity and 0 mM Ca (Table 14). Our results corroborate with those of Kumar (1990) and Aslam *et al*. (2001, 2003) who found that application of Ca improved all growth characteristics such as tillering capacity, shoot and root dry weight of both salt tolerant and salt sensitive rice cultivars under salt stress.

Table 14. Interaction effect of variety, salinity and calcium on root, shoot and total dry weight, 1000-grain weight and grain yield hill^{-1} of rice

Variety	Salinity level (dSm^{-1})	Ca level (mM)	RDW hill^{-1} (g)	SDW hill^{-1} (g)	TDW hill^{-1} (g)	1000-grain weight (g)	Grain yield (g hill^{-1})
Binadhan -8	0	0	5.517 f-j	44.25 kl	49.77 hi	17.27 f-i	21.22 hi
		5	5.940 d-i	51.19 hi	57.13 g	20.29 b-d	26.55 d-f
		10	6.673 c-h	55.05 e-g	61.72 ef	20.81 bc	29.56 b-d
	4	0	5.033 h-k	46.21 jk	51.25 hi	19.61 b-e	23.51 f-h
		5	5.677 e-j	54.63 e-g	60.31 e-g	21.42 ab	28.68 b-d
		10	6.690 c-h	62.12 d	68.81 d	23.23 a	34.91 a
	8	0	4.417 i-k	41.00 m	45.41 j	19.60 b-e	19.43 i
		5	4.660 i-k	48.28 ij	52.94 h	20.64 bc	24.59 e-g
		10	5.307 g-k	56.00 ef	61.31 ef	21.51 ab	30.56 bc
	12	0	3.673 k	24.23 p	27.91 m	18.33 d-g	8.463 m
		5	4.000 jk	30.23 o	34.23 l	18.72 c-f	11.91 kl
		10	4.640 i-k	36.6 n	41.25 k	19.60 b-e	13.48 jk
BRRI dhan29	0	0	6.927 c-g	52.24 gh	59.17 fg	14.32 j-m	21.20 hi
		5	7.380 a-e	62.27 d	69.65 cd	15.18 i-m	27.61 c-e
		10	8.773 ab	68.80 b	77.58 b	16.37 g-j	30.72 bc
	4	0	7.490 a-d	53.77 f-h	61.26 ef	14.16 k-m	23.70 f-h
		5	8.403 a-c	64.72 cd	73.12 c	15.78 h-k	27.76 c-e
		10	9.033 a	76.25 a	85.28 a	17.31 f-h	31.55 b
	8	0	5.557 f-j	42.11 lm	47.67 ij	13.40 lm	15.70 j
		5	6.087 d-i	57.43 e	63.52 e	15.88 h-k	22.54 g-i
		10	7.193 b-f	65.83 bc	73.02 c	18.07 e-g	27.80 c-e
	12	0	4.043 jk	25.63 p	29.68 m	13.12 m	4.333 n
		5	4.160 jk	34.53 n	38.69 k	14.70 j-m	9.883 lm
		10	4.417 i-k	36.96 n	41.38 k	15.30 h-l	10.11 lm
Level of significant			*	*	**	**	*
$LSD_{(0.05)}$			1.750	3.244	3.602	2.102	3.24
CV (%)			3.87	9.73	6.22	7.89	10.31

*: significant at 5% level, **: significant at 1% level
Values having same letter(s) in a column do not differ significantly

4.10 Shoot Dry Weight (SDW) hill^{-1}

4.10.1 Effect of variety

Effect of variety on shoot dry weight (SDW) $hill^{-1}$ was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 11). SDW $hill^{-1}$ was highest (53.38 g) in BRRI dhan29 and the lowest (45.82 g) was obtained in Binadhan-8.

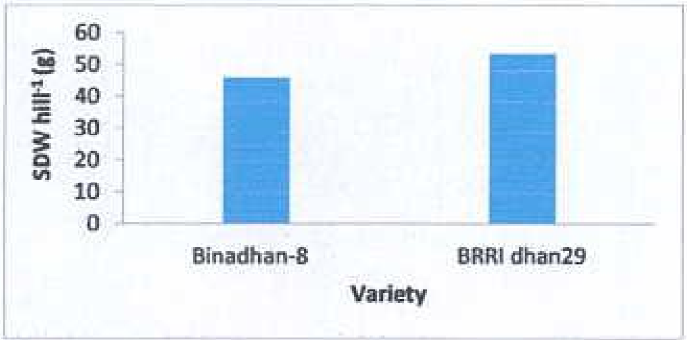

Figure 4: Variation of SDW $hill^{-1}$ due to the varietal differences

4.10.2 Effect of salinity

The average SDW $hill^{-1}$ of the selected rice varieties increased up to 4 dSm^{-1} and then decreased as the levels of salinity increased due to the mean effect of different supplemental Ca levels (Table 11). SDW $hill^{-1}$ was highest (59.62 g) in 4 dSm^{-1} which was followed by the result of 0 dSm^{-1} salinity levels (55.63 g) and the lowest SDW $hill^{-1}$ (31.37 g) was obtained by 12 dSm^{-1}.

4.10.3 Effect of calcium (Ca)

The SDW $hill^{-1}$ of selected rice varieties increased with increasing of the Ca levels over all the levels of salinity (Table 11). The SDW $hill^{-1}$ was highest (57.20 g) by 10 mM Ca and the lowest result (41.18 g) was obtained from 0 mM Ca.

4.10.4 Interaction effect of variety and salinity

SDW $hill^{-1}$ of two rice varieties significantly varied due to the different salinity levels (Table 12). In both varieties, SDW $hill^{-1}$ increased up to 4 dSm^{-1} and then decreased as the levels of salinity increased. The highest SDW $hill^{-1}$ (64.91 g) was resulted from 4 dSm^{-1} in BRRI dhan29 which was closely followed by 0 dSm^{-1} salinity levels (61.10 g) of the same variety and the lowest SDW $hill^{-1}$ (30.36 g) was obtained from 12 dSm^{-1} in Binadhan-8 which was closely followed by 12 dSm^{-1} salinity in BRRI dhan29 (32.38 g).

4.10.5 Interaction effect of variety and calcium

SDW $hill^{-1}$ of two rice varieties significantly increased with increasing the levels of calcium over all the levels of salinity (Table 13). It was highest (61.96 g) from 10 mM Ca in BRRI dhan29. The lowest SDW $hill^{-1}$ (38.92 g) was obtained by 0 mM Cain Binadhan-8. It was observed that in each variety, SDW $hill^{-1}$ increased with the increasing rate of calcium.

4.10.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, SDW $hill^{-1}$ varied significantly over the mean result of two rice variety. It was observed that, at the same salinity level, SDW $hill^{-1}$ increased with the increasing rate of calcium. The highest SDW $hill^{-1}$ (69.18 g) was obtained from the interaction of 4 dSm^{-1} salinity with 10 mM Ca which was closely followed by the interaction of 0 dSm^{-1} salinity with 10 mM Ca (61.93 g). The lowest SDW $hill^{-1}$ (24.93 g) was obtained from the interaction of 12 dSm^{-1} salinity (Figure 6) and 0 mM Ca (Figure 7).

4.10.7 Interaction effect of variety, salinity and calcium

SDW $hill^{-1}$ varied significantly due to the interaction of variety, salinity and calcium. For each variety it was observed that SDW $hill^{-1}$ decreased with the increasing salinity level while increased with the increasing doses of calcium. The highest SDW $hill^{-1}$ (76.25 g) was recorded in BRRI dhan29 at 4 dSm^{-1} salinity while incorporated with 10 mM Ca. The lowest SDW hill^{-1} (24.23 g) was obtained from Binadhan-8 while treated with 12 dSm^{-1} salinity and 0 mM Ca and it was statistically similar with the result (25.63 g) obtained from BRRI dhan29 while treated with same salinity and same Ca level (Table 14). Franco *et al.* (1999) 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+}. Girija *et al.* (2002) suggested that the addition of Ca^{2+} to the root environment of NaCl-stressed plants would help organic solute accumulation in the roots, which could contribute to root osmotic adjustment, favouring the maintenance of plant-water balance and growth. Pua *et al.* (2001) observed that the addition of $CaSO_4$ to salt sensitive and salt tolerant rice cultivars in salinized medium increased the total leaf area, fresh and dry weights of shoots and roots, K^+ uptake and rates of photosynthesis. They also stated that the ability of $CaSO_4$ to ameliorate the effects of salinity on the growth of IR29 (salt sensitive rice variety) seedlings could be attributed to the environment of its Ca^{2+} in some regulatory mechanisms.

4.11 Total Dry Weight (TDW) hill^{-1}

4.11.1 Effect of variety

Effect of variety on total dry weight (TDW) hill^{-1} was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 11). TDW hill^{-1} was highest (60.00 g) in BRRI dhan29 and the lowest (51.00 g) was obtained in Binadhan-8.

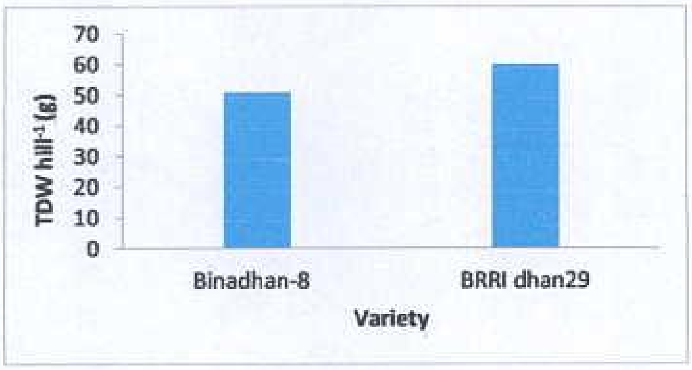

Figure 5: Variation of TDW hill^{-1} due to the varietal differences

4.11.2 Effect of salinity

The average TDW hill^{-1} of the selected rice varieties increased up to 4 dSm^{-1} and then decreased as the levels of salinity increased due to the mean effect of different supplemental Ca levels (Table 11). TDW hill^{-1} was highest (66.67 g) in 4 dSm^{-1} which was closely followed by the result of 0 dSm^{-1} salinity levels (62.50 g) and the lowest TDW (35.52 g) was obtained by 12 dSm^{-1}.

4.11.3 Effect of calcium

The TDW hill^{-1} of selected rice varieties increased with increasing of the Ca levels over all the levels of salinity (Table 11). The TDW hill^{-1} was highest (63.79 g) by 10 mM Ca and the lowest result (46.51 g) was obtained from 0 mM Ca.

4.11.4 Interaction effect of variety and salinity

TDW hill^{-1}of two rice varieties significantly varied due to the different salinity levels (Table 12). In both varieties, TDW hill^{-1} increased up to 4 dSm^{-1} and then decreased as the levels of salinity increased. The highest TDW hill^{-1} (73.22 g) was resulted from 4 dSm^{-1} in BRRI dhan29 which was closely followed by 0 dSm^{-1} salinity levels (68.80 g) of the same variety and the lowest TDW hill^{-1} (34.46 g) was obtained from 12 dSm^{-1} in Binadhan-8 which was closely followed by 12 dSm^{-1} salinity in BRRI dhan29 (36.58 g).

4.11.5 Interaction effect of variety and calcium

TDW $hill^{-1}$ of two rice varieties significantly increased with increasing the levels of calcium over all the levels of salinity (Table 13). It was highest (69.31 g) from 10 mM Ca in BRRI dhan29. The lowest TDW $hill^{-1}$ (43.58 g) was obtained by 0 mM Ca in Binadhan-8. It was observed that in each variety, TDW $hill^{-1}$ increased with the increasing rate of calcium.

4.11.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, TDW $hill^{-1}$ varied significantly over the mean result of two rice varieties. It was observed that, at the same salinity level, TDW $hill^{-1}$ increased with the increasing rate of calcium. The highest TDW $hill^{-1}$ (77.05 g) was obtained from the interaction of 4 dSm^{-1} salinity with 10 mM Ca which was followed by the interaction of 0 dSm^{-1} salinity with 10 mM Ca (69.65 g). The lowest TDW $hill^{-1}$ (28.79 g) was obtained from the interaction of 12 dSm^{-1} salinity (Figure 6) and 0 mM Ca (Figure 7).

4.11.7 Interaction effect of variety, salinity and calcium

TDW $hill^{-1}$ varied significantly due to the interaction of variety, salinity and calcium. For each variety it was observed that TDW $hill^{-1}$ decreased with the increasing salinity level while increased with the increasing doses of calcium. The highest TDW $hill^{-1}$ (85.28 g) was recorded in BRRI dhan29 at 4 dSm^{-1} salinity while incorporated with 10 mM Ca. The lowest TDW $hill^{-1}$ (27.91 g) was obtained from Binadhan-8 while treated with 12 dSm^{-1} salinity and 0 mM Ca and it was statistically similar with the result (29.68 g) obtained from BRRI dhan29 while treated with same salinity and same Ca level (Table 14). The above results corroborate with the observations of Hwang *et al.* (1989); Kumar (1990); Franco *et al.* (1999); Aslam *et al.* (2001); Pua *et al.* (2001); Girija *et al.* (2002). Yaduvanshi (2001) found that continuous use of phosphorus fertilizer with green manuring and farm yard manure to the crops in gypsum amended sodic soils significantly enhanced the yields of rice. Sharma (1989) stated that rice yields increased in saline soil with increasing the rates of gypsum and pyrites.

4.12 1000-grain weight

4.12.1 Effect of variety

Effect of variety on 1000-grain weight (g) was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 11). 1000-grain weight was highest (20.09 g) in Binadhan-8 and the lowest (15.30 g) was obtained from BRRI dhan29.

4.12.2 Effect of salinity

The average 1000-grain weight of the selected rice varieties increased up to 4 dS m^{-1} and then decreased as the levels of salinity increased due to the mean effect of different supplemental Ca levels (Table 11). 1000-grain weight was highest (18.59 g) in 4 dSm^{-1} which was statistically similar with the result of 8 dSm^{-1} salinity levels (18.18 g) and the lowest 1000-grain weight (16.63 g) was obtained by 12 dSm^{-1}.

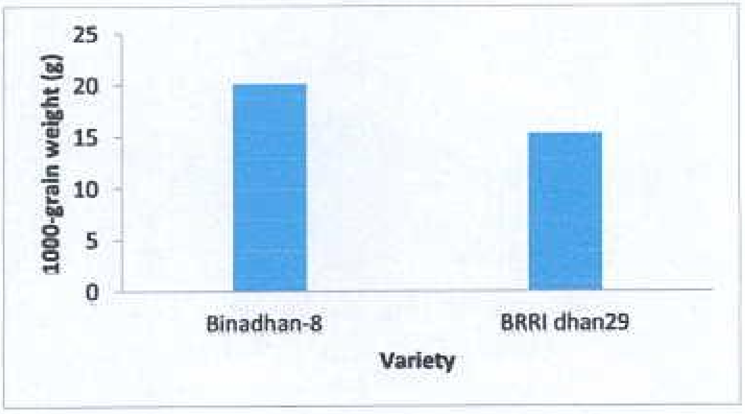

Figure 6: Variation of 1000-grain weight due to the varietal differences

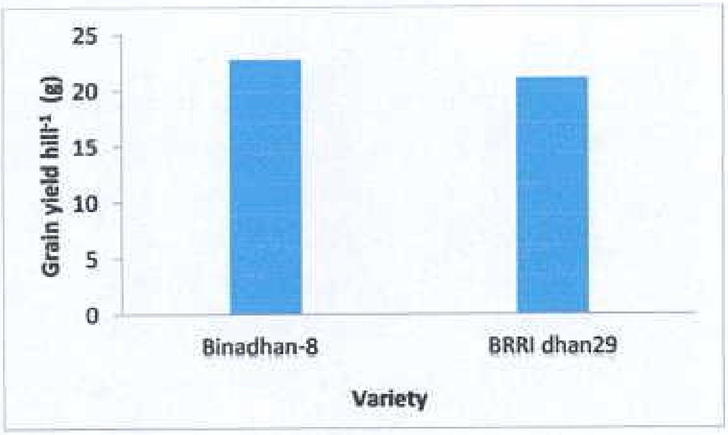

Figure 7: Variation of grain yield hill^{-1} due to the varietal differences

4.12.3 Effect of calcium

The 1000-grain weight of selected rice varieties increased with increasing of the Ca levels over all the levels of salinity (Table 11). The 1000-grain weight was highest (19.03 g) by 10 mM Ca and the lowest result (16.23 g) was obtained from 0 mM Ca.

4.12.4 Interaction effect of variety and salinity

1000-grain weight of two rice varieties significantly varied due to the different salinity levels (Table 12). In both varieties, 1000-grain weight increased up to 4 dSm^{-1} and then decreased as the levels of salinity increased. The highest 1000-grain weight (21.42 g) was resulted from 4 dSm^{-1} in Binadhan-8 which was closely followed by the same variety while treated with 8 dSm^{-1} salinity (20.58 g). The lowest 1000-grain weight (14.37 g) was obtained from 12 dSm^{-1} in BRRI dhan29.

4.12.5 Interaction effect of variety and calcium

1000-grain weight of two rice varieties significantly increased with increasing the levels of calcium over all the levels of salinity (Table 13). It was highest (21.29 g) from 10 mM Ca in Binadhan-8 which was closely followed by 5 mM Ca treatment with same variety (20.27 g). The lowest 1000-grain weight (13.75 g) was obtained by 0 mM Ca in BRRI dhan29.

4.12.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, 1000-grain weight varied significantly over the mean result of two rice varieties (Figure 6 & 7). It was observed that, at the same salinity level, 1000-grain weight increased with the increasing rate of calcium. The highest 1000-grain weight (20.27 g) was obtained from the interaction of 4 dSm^{-1} salinity with 10 mM Ca which was statistically similar with the interaction of 8 dSm^{-1} salinity with 10 mM Ca (19.79 g). The lowest 1000-grain weight (15.73 g) was obtained from the interaction of 12 dSm^{-1} salinity and 0 mM Ca which was statistically similar with the interaction of 0 dSm^{-1} salinity with 0 mM Ca (15.80 g).

4.12.7 Interaction effect of variety, salinity and calcium

1000-grain weight varied significantly due to the interaction of variety, salinity and calcium. For each variety it was observed that 1000-grain weight decreased with the increasing salinity level except 4 dSm^{-1} while increased with the increasing doses of calcium (Table 14). The highest 1000-grain weight (23.23 g) was recorded in Binadhan-8 at 4 dSm^{-1} salinity while incorporated with 10 mM Ca which was followed by the interactions of 8 dS m^{-1} salinity with 10 mM Ca (21.51 g) and 4 dSm^{-1} salinity with 5 mM Ca (21.42 g) in same variety. The lowest 1000-grain weight (13.12 g) was obtained from BRRI dhan29 while treated with 12 dSm^{-1} salinity and 0 mM Ca and it was followed by the interaction of 8 dSm^{-1} salinity and 0 mM Ca level from BRRI dhan29 (13.40 g).

4.13 Grain yield

4.13.1 Effect of variety

Effect of variety on grain yield (g) $hill^{-1}$ was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 11). Grain yield $hill^{-1}$ was highest (22.74 g) in Binadhan-8 and the lowest (21.08 g) was obtained in BRRI dhan29.

4.13.2 Effect of salinity

The average grain yield $hill^{-1}$ of the selected rice varieties increased up to 4 dSm^{-1} and then decreased as the levels of salinity increased due to the mean effect of different supplemental Ca levels (Table 11). Grain yield $hill^{-1}$ was highest (28.35 g) in 4 dSm^{-1} which was closely followed by the result of 0 dSm^{-1} salinity levels (26.14 g) and the lowest grain yield $hill^{-1}$ (9.70 g) was obtained by 12 dSm^{-1}.

4.13.3 Effect of calcium

The grain yield hill^{-1} of selected rice varieties increased with increasing of the Ca levels over all the levels of salinity (Table 11). The grain yield hill^{-1} was highest (26.09 g) by 10 mM Ca and the lowest result (17.19 g) was obtained from 0 mM Ca.

4.13.4 Interaction effect of variety and salinity

Grain yield hill^{-1}of two rice varieties significantly varied due to the different salinity levels (Table 12). In both varieties, grain yield hill^{-1} increased up to 4 dSm^{-1} and then decreased as the levels of salinity increased. The highest grain yield hill^{-1} (29.04 g) was resulted from 4 dSm^{-1} in Binadhan-8 which was closely followed by 4 dSm^{-1} salinity levels (27.67 g) of BRRI dhan29 and the lowest grain yield hill^{-1} (8.11 g) was obtained from 12 dSm^{-1} in BRRI dhan29 which was closely followed by 12 dSm^{-1} salinity in Binadhan-8 (11.28 g).

4.13.5 Interaction effect of variety and calcium

Grain yield hill^{-1} of two rice varieties significantly increased with increasing the levels of calcium over all the levels of salinity (Table 13). It was highest (27.13 g) from 10 mM Ca in Binadhan-8 which was closely followed by BRRI dhan29 with same Ca treatment (25.05 g). The lowest grain yield hill^{-1} (16.23 g) was obtained by 0 mM Ca in BRRI dhan29 which was closely followed by Binadhan-8 with same Ca treatment (18.16 g). It was observed that in each variety, grain yield hill^{-1} increased with the increasing rate of calcium.

4.13.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, grain yield hill^{-1} varied significantly over the mean result of two rice varieties. It was observed that, at the same salinity level, grain yield hill^{-1} increased with the increasing rate of calcium. The highest grain yield hill^{-1} (33.23 g) was obtained from the interaction of 4 dSm^{-}

^{1} salinity with 10 mM Ca which was followed by the interaction of 0 dSm^{-1} salinity with 10 mM Ca (30.14 g). The lowest grain yield $hill^{-1}$ (6.39 g) was obtained from the interaction of 12 dSm^{-1} salinity (Figure 6) and 0 mM Ca (Figure 7).

4.13.7 Interaction effect of variety, salinity and calcium

Grain yield $hill^{-1}$ varied significantly due to the interaction of variety, salinity and calcium. For each variety it was observed that grain yield $hill^{-1}$ decreased with the increasing salinity level except 4 dSm^{-1} while increased with the increasing doses of calcium. The highest grain yield $hill^{-1}$ (34.91 g) was recorded in Binadhan-8 at 4 dSm^{-1} salinity while incorporated with 10 mM Ca which was followed by the interaction of 0 dSm^{-1} salinity with 10 mM Ca in BRRI dhan29 (31.55 g). The lowest grain yield $hill^{-1}$ (4.33 g) was obtained from BRRI dhan29 while treated with 12 dSm^{-1} salinity and 0 mM Ca and it was followed by the result (8.46 g) obtained from Binadhan-8 while treated with same salinity and same Ca level (Table 14). From the above results it was observed that grain yield was significantly different among the two varieties. It was also observed that grain yield increased up to 4 dSm^{-1} salinity level and then decreased again. May be this slight saline condition provided as a better osmotic balance in soil than no salinity. If we observe the yield of two varieties it can be easily revealed that yield reduction was lower in Binadhan-8 than BRRI dhan29 due to the higher salinity levels. This happened because Binadhan-8 was able to retain higher effective tillers per hill, filled grains per panicle and 1000-grain weight in higher salinity levels compared to BRRI dhan29 and showed more tolerance to salinity among these two varieties. 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). They found that panicle number per unit area and percentage of ripened grain *i.e.* filled grain dramatically decreased in 0.5% saline water in the soil with low salinity level and in 0.1%

saline water in soil with medium salinity level. The number of filled grains panicle^{-1} was less affected at 6 dSm^{-1} level of salinity in mutant variety Iratom24 which was in conformity with the findings of Baloch *et al.* (2003). They observed that the mutant variety of rice "Shua-92" maintained its superiority in various characteristics such as plant height, higher number of fertile panicles per plant and more fertile grains panicle^{-1} at 7.11- 8.0 dSm^{-1} level of salinity.

Mineral content in shoot (K, Na and Ca in percentage)

4.14 K content in shoot

4.14.1 Effect of variety

Effect of variety on K content in shoot (%) was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 15). K content in shoot was highest (2.00%) in Binadhan-8 and the lowest (1.86%) was obtained from BRRI dhan29.

4.14.2 Effect of salinity

The average K content in shoot of the selected rice varieties decreased as the levels of salinity increased due to the mean effect of different supplemental Ca levels (Table 15). K content in shoot was highest (2.80%) in 0 dSm^{-1} which was followed by the result of 4 dSm^{-1} salinity levels (2.33%) and the lowest K content in shoot (0.98%) was obtained by 12 dSm^{-1}.

4.14.3 Effect of calcium

The K content in shoot of selected rice varieties increased with increasing of the Ca levels over all the levels of salinity (Table 15). The K content in shoot was highest (2.11%) by 10 mM Ca and the lowest result (1.71%) was obtained from 0 mM Ca.

Table 15. Effect of variety, salinity and calcium on K, Na and Ca content in rice straw

Treatments	K content in shoot (%)	Na content in shoot (%)	Ca content in shoot (%)
Variety			
Binadhan-8	2.000 a	0.8281 b	0.2535 b
BRRI dhan29	1.864 b	1.411 a	0.3175 a
Level of significant	*	**	*
$LSD_{0.05}$	0.1242	0.08363	0.01757
Salinity level (dSm^{-1})			
0	2.802 a	0.2332 d	0.2511 c
4	2.334 b	0.6637 c	0.2587 c
8	1.611 c	1.397 b	0.2833 b
12	0.9806 d	2.185 a	0.3489 a
Level of significant	*	**	*
$LSD_{(0.05)}$	0.1545	0.1039	0.02122
Calcium level (mM)			
0	1.711 b	1.264 a	0.2377 c
5	1.975 a	1.121 b	0.2853 b
10	2.110 a	0.9737 c	0.3336 a
Level of significant	*	**	**
$LSD_{(0.05)}$	0.1685	0.1132	0.02484
CV (%)	4.87	6.49	8.89

*: significant at 5% level, **: significant at 1% level
Values having same letter(s) in a column do not differ significantly

4.14.4 Interaction effect of variety and salinity

K content in shoot of two rice varieties significantly varied due to the different salinity levels (Table 16). In both varieties, K content in shoot decreased as the levels of salinity increased. The highest K content in shoot (3.03%) was resulted from 0 dSm^{-1} in BRRI dhan29 and the lowest K content in shoot (0.54%) was obtained from 12 dSm^{-1} in BRRI dhan29.

Table 16. Interaction effect of variety and salinity on K, Na and Ca content in rice straw

Variety	Salinity level (dSm^{-1})	K content in straw (%)	Na content in straw (%)	Ca content in straw (%)
Binadhan-8	0	2.569 b	0.2166 f	0.2430 c
	4	2.256 c	0.5518 e	0.2497 c
	8	1.754 d	0.9367 d	0.2512 c
	12	1.421 e	1.607 c	0.2702 c
BRRI dhan29	0	3.034 a	0.2499 f	0.2524 c
	4	2.413 bc	0.7756 d	0.2744 c
	8	1.468 e	1.857 b	0.3154 b
	12	0.5400 f	2.764 a	0.4277 a
Level of significant		*	**	*
$LSD_{(0.05)}$		0.2598	0.175	0.03675
CV (%)		4.87	6.49	8.89

*: significant at 5% level, **: significant at 1% level
Values having same letter(s) in a column do not differ significantly

4.14.5 Interaction effect of variety and calcium

K content in shoot of two rice varieties significantly increased with increasing the levels of calcium over all the levels of salinity (Table 17). It was highest (2.21%) from 10 mM Ca in Binadhan-8 which was closely followed by 5 mM Ca treatment with same variety (2.02%) and by 10 mM Ca treatment with BRRI dhan29 (2.00%). The lowest K content in shoot (1.65%) was obtained by 0 mM Ca in BRRI dhan29.

Table 17. Interaction effect of variety and calcium on K, Na and Ca content in rice shoot

Variety	Ca level (mM)	K content in shoot (%)	Na content in shoot (%)	Ca content in shoot (%)
Binadhan-8	0	1.768 bc	0.9648 c	0.2204 d
	5	2.020 ab	0.8161 cd	0.2484 d
	10	2.212 a	0.7033 d	0.2918 bc
BRRI dhan29	0	1.653 c	1.564a	0.2549 cd
	5	1.930 abc	1.426 ab	0.3222 b
	10	2.008 ab	1.244 b	0.3754 a
Level of significant		*	**	*
$LSD_{(0.05)}$		0.2832	0.19	0.03928
CV (%)		4.87	6.49	8.89

*: significant at 5% level, **: significant at 1% level
Values having same letter(s) in a column do not differ significantly

4.14.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, K content in shoot varied significantly over the mean result of two rice varieties (Table 18). It was observed that, at the same salinity level, K content in shoot increased with the increasing rate of calcium. The highest K content in shoot (2.95%) was obtained from the interaction of 0 dSm^{-1} salinity with 10 mM Ca which was statistically similar with the interaction of same salinity level with 5mM Ca (2.86%). The lowest K content in shoot (0.75%).

Table 18. Interaction effect of salinity and calcium on K, Na and Ca content in rice straw

Salinity level (dSm^{-1})	Ca level (mM)	K content in shoot (%)	Na content in shoot (%)	Ca content in shoot (%)
0	0	2.605 bc	0.2693 g	0.2127 h
	5	2.855 ab	0.2288 g	0.2482 fgh
	10	2.945 a	0.2015 g	0.2923 cde
4	0	2.078 d	0.7223 f	0.2192 gh
	5	2.330 cd	0.6623 f	0.2577 efg
	10	2.595 bc	0.6063 f	0.2993 cd
8	0	1.413 f	1.574 d	0.2367 gh
	5	1.645 ef	1.399 de	0.2837 def
	10	1.775 e	1.217 e	0.3297 bc
12	0	0.7467 h	2.492 a	0.2822 def
	5	1.070 g	2.194 b	0.3517 b
	10	1.125 g	1.870 c	0.4130 a
Level of significant		*	**	*
$LSD_{(0.05)}$		0.2710	0.1820	0.03738
CV (%)		4.87	6.49	8.89

*: significant at 5% level, **: significant at 1% level

Values having same letter(s) in a column do not differ significantly

4.14.7 Interaction effect of variety, salinity and calcium

K content in shoot varied significantly due to the interaction of variety, salinity and calcium. For each variety it was observed that K content in shoot decreased with the increasing salinity level while increased with the increasing doses of calcium. The highest K content in shoot (3.15%) was recorded in BRRI dhan29 at 0 dSm^{-1} salinity while incorporated with 10 mM Ca which was followed by the interactions of 0 dSm^{-1} salinity with 5 mM Ca (3.120 %) in same variety. The lowest K content in shoot (0.20%) was obtained from BRRI dhan29 while treated with 12 dSm^{-1} salinity and 0 mM Ca (Table 19). K content in shoot decreased with increasing level of salinity. But there was a positive influence of the effect of different supplemental Ca on K content in shoots of the two selected rice varieties. The K content in shoots of the selected rice varieties increased progressively at all levels of salinity with increase in the Ca levels. These findings are in agreement with the observation of Baba and Fujiyama (2003). The addition of supplemental Ca to the root environment has been suggested as a mean of enhancing plant tolerance to salt stress (Rengel, 1992; Epstein, 1998). Under salt stress conditions, Ca^{2+}/ Na^{+} ratio decreased in root environment which might have affected membrane properties due to displacement of membrane- associated Ca^{2+} by Na^{+}, leading to disruption of membrane integrity and ion selectivity (Cramer *et al.*, 1985; Kinraide, 1998). The disruption in membrane integrity of cells that would accentuate and change enzyme activity, disturbance in K^{+} uptake and partitioning in the cells throughout the plant might even affect stomatal opening (Epstein, 1998). This author continued 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^{+}. The displacement of membrane- associated Ca^{2+} by Na^{+} was the immediate increase of K efflux across the plasma membrane of salt stressed cotton roots at the salt concentrations above 100 mM NaCl, whereas supplemental Ca reduced this effect at concentrations above 150 mM NaCl (Cramer *et al.*, 1985).

4.15 Na content in shoot

4.15.1 Effect of variety

Effect of variety on Na content in shoot (%) was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 15). Na content in shoot was lowest (0.83%) in Binadhan-8 and the highest (1.41%) was obtained from BRRI dhan29.

4.15.2 Effect of salinity

The average Na content in shoot of the selected rice varieties increased as the levels of salinity increased due to the mean effect of different supplemental Ca levels (Table 15). Na content in shoot was highest (2.19%) in 12 dSm^{-1} which was followed by the result of 8 dSm^{-1} salinity levels (1.38%) and the lowest Na content in shoot (0.23%) was obtained by 0 dSm^{-1}.

4.15.3 Effect of calcium (Ca)

The Na content in shoot of selected rice varieties decreased with increasing of the Ca levels over all the levels of salinity (Table 15). The Na content in shoot was highest (1.26%) by 0 mM Ca and the lowest result (0.97%) was obtained from 10 mM Ca.

4.15.4 Interaction effect of variety and salinity

Na content in shoot of two rice varieties significantly varied due to the different salinity levels (Table 16). In both varieties, Na content in shoot increased as the levels of salinity increased. The highest Na content in shoot (2.76%) was resulted from 12 dSm^{-1} in BRRI dhan29 and the lowest Na content in shoot (0.25%) was obtained from 0 dSm^{-1} in Binadhan-8 followed by 0 dSm^{-1} in BRRI dhan29 (0.25%).

4.15.5 Interaction effect of variety and calcium

Na content in shoot of two rice varieties significantly decreased with increasing the levels of calcium over all the levels of salinity (Table 17). It was highest (1.56%) from 0 mM Ca in BRRI dhan29 which was closely followed by 5 mM Ca treatment with same variety (1.43%). The lowest Na content in shoot (0.70%) was obtained by 10 mM Ca in Binadhan-8.

4.15.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, Na content in shoot varied significantly over the mean result of two rice varieties. It was observed that, at the same salinity level, Na content in shoot decreased with the increasing rate of calcium. The highest Na content in shoot (2.49%) was obtained from the interaction of 12 dSm^{-1} salinity with 0 mM Ca. The lowest Na content in shoot (0.20%) was recorded from interaction of 0 dSm^{-1} salinity with 10 mM Ca (Table 18).

4.15.7 Interaction effect of variety, salinity and calcium

Na content in shoot varied significantly due to the interaction of variety, salinity and calcium. For each variety it was observed that Na content in shoot increased with the increasing salinity level while decreased with the increasing doses of calcium. The highest Na content in shoot (3.01%) was recorded in BRRI dhan29 at 12 dSm^{-1} salinity while incorporated with 0 mM Ca which was followed by the interactions of 12dS m^{-1} salinity with 5 mM Ca (2.83%) in same variety. The lowest Na content in shoot (0.19%) was obtained from Binadhan-8 while treated with 0 dSm^{-1} salinity and 10 mM Ca (Table 19). Salinity significantly increased the percent Na content in rice shoots while it decreased significantly with increase in the levels of Ca supplementation. The susceptible variety BRRI dhan29 contained the highest amount of Na as compared to tolerant ones as influenced by different supplemental Ca and salinity levels. These findings are in agreement with the opinion of Pua *et al.* (2001); Ochiai and Matoh (2004). Aslam *et al.* (2003) observed that increasing supply of Ca tended to decrease Na and Cl concentration in the shoots of both tolerant and susceptible rice varieties; shoot concentration of Na and Cl were much lower in tolerant than susceptible varieties. The interaction effects of varieties and salinity levels in relation to Na content under different Ca levels indicated that the Na concentrations in shoot of all the selected two varieties progressively increased with increase in the levels of salinity from 0 to 12 dSm^{-1}.

Table 19. Interaction effect of variety, salinity and calcium on K, Na and Ca content in rice straw

Variety	Salinity level (dSm^{-1})	Ca level (mM)	K content in shoot (%)	Na content in shoot (%)	Ca content in shoot (%)
Binadhan-8	0	0	2.380 b-e	0.2353 lm	0.2097 k
		5	2.590 bc	0.2213 m	0.2377 h-k
		10	2.737 ab	0.1930 m	0.3017 d-h
	4	0	1.907 e-h	0.5853 i-k	0.2147 jk
		5	2.240 c-f	0.5503 i-l	0.2437 h-k
		10	2.620 bc	0.5197 j-m	0.2707 d-k
	8	0	1.493 g-j	1.065 fg	0.2247 i-k
		5	1.800 f-i	0.9353 gh	0.2497 g-k
		10	1.970 d-g	0.8093 g-j	0.2793 d-j
	12	0	1.293 j	1.973 c	0.2327 i-k
		5	1.450 h-j	1.557 de	0.2627 e-k
		10	1.520 g-j	1.291 ef	0.3153 c-g
BRRI dhan29	0	0	2.830 ab	0.3033 k-m	0.2157 i-k
		5	3.120 a	0.2363 lm	0.2587 f-k
		10	3.153 a	0.2100 m	0.2830 d-i
	4	0	2.250 c-f	0.8593 g-i	0.2237 i-k
		5	2.420 b-d	0.7743 g-j	0.2717 d-k
		10	2.570 bc	0.6930 h-j	0.3280 c-e
	8	0	1.333 ij	2.082 c	0.2487 g-k
		5	1.490 g-j	1.863 cd	0.3177 c-f
		10	1.580 g-j	1.625 d	0.3800 bc
	12	0	0.2000 l	3.011 a	0.3317 cd
		5	0.6900 k	2.831 a	0.4407 b
		10	0.7300 k	2.448 b	0.5107 a
Level of significant			*	**	*
$LSD_{(0.05)}$			0.4556	0.3063	0.06318
CV (%)					

*: significant at 5% level, **: significant at 1% level
Values having same letter(s) in a column do not differ significantly

4.16 Ca content in shoot

4.16.1 Effect of variety

Effect of variety on Ca content in shoot (%) was statistically significant due to the mean effect of different combinations of salinity and supplemental Ca levels (Table 15). Ca content in shoot was lowest (0.26%) in Binadhan-8 and the highest (0.32%) was obtained from BRRI dhan29.

4.16.2 Effect of salinity

The average Ca content in shoot of the selected rice varieties increased as the levels of salinity increased due to the mean effect of different supplemental Ca levels (Table 15). Ca content in shoot was highest (0.35%) in 12 dSm^{-1} which was followed by the result of 8 dSm^{-1} salinity levels (0.29%) and the lowest Ca content in shoot (0.25%) was obtained by 0 dSm^{-1}.

4.16.3 Effect of calcium

The Ca content in shoot of selected rice varieties increased with increasing of the Ca levels over all the levels of salinity (Table 15). The Ca content in shoot was highest (0.33%) by 10 mM Ca and the lowest result (0.24%) was obtained from 0 mM Ca.

4.16.4 Interaction effect of variety and salinity

Ca content in shoot of two rice varieties significantly varied due to the different salinity levels (Table 16). In both varieties, generally the Ca content in shoot increased as the levels of salinity increased. The highest Ca content in shoot (0.43%) was resulted from 12 dSm^{-1} in BRRI dhan29 and the lowest Ca content in shoot (0.24%) was obtained from 0 dSm^{-1} in Binadhan-8 which was followed by 4 dSm^{-1} in same variety (0.25%).

4.16.5 Interaction effect of variety and calcium

Ca content in shoot of two rice varieties significantly increased with increasing the levels of calcium over all the levels of salinity (Table 17). It was highest (0.38%)

from 10 mM Ca in BRRI dhan29 which was closely followed by 5 mM Ca treatment with same variety (0.32%). The lowest Ca content in shoot (0.22%) was obtained by 0 mM Ca in Binadhan-8.

4.16.6 Interaction effect of salinity and calcium

Due to the interaction of salinity and calcium levels, Ca content in shoot varied significantly over the mean result of two rice varieties. It was observed that, at the same salinity level, Ca content in shoot increased with the increasing rate of calcium. The highest Ca content in shoot (0.41%) was obtained from the interaction of 12 dSm^{-1} salinity with 10 mM Ca. The lowest Ca content in shoot (0.21%) was recorded from interaction of 0 dSm^{-1} salinity with 0 mM Ca (Table 18).

4.16.7 Interaction effect of variety, salinity and calcium

Ca content in shoot varied significantly due to the interaction of variety, salinity and calcium. For each variety it was observed that Ca content in shoot increased with the increasing salinity level and doses of calcium. The highest Ca content in shoot (0.51%) was recorded in BRRI dhan29 at 12 dSm^{-1} salinity while incorporated with 10 mM Ca which was followed by the interactions of 12 dSm^{-1} salinity with 5 mM Ca (0.44%) in same variety. The lowest Ca content in shoot (0.21%) was obtained from Binadhan-8 while treated with 0 dSm^{-1} salinity and 0 mM Ca (Table 19). A greater accumulation of Ca was observed in salt sensitive variety BRRI dhan29 over that of the variety Binadhan-8. Statistically similar results were also observed on the mean effect of different salinity levels on Ca content in shoots of two selected rice varieties at different levels of Ca supplementation. The interaction effect of different salinity and Ca levels on % Ca content in shoots of rice showed a significant increase. Silva *et al.* (2003) stated that the Ca addition partially overcome the salt stress induced decrease in Ca^{2+} and Mg^{2+}. Aslam *et al.* (2003) reported that when Ca (as gypsum) was applied in saline environment, a positive improving and stimulative effect of Ca was found in growth characteristics in both salt-tolerant and salt-sensitive rice cultivars. They further stated that the ameliorative effect of Ca was because of increased Ca: Na ratio in growth medium as well as in plant tissues. In rice and tomato, supplemental Ca improved the nutritional balance in Na-salinization by suppressing the transport of Na and enhancing that of the other cations in avoidably the deterioration of the water status (Baba and Fujiyama, 2003).

Chapter 5
Summary and conclusion

CHAPTER V

SUMMARY AND CONCLUSION

A pot culture experiment was conducted at the net house of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207, to study the effect of supplemental Ca for amelioration of salinity and improve the growth of two randomly selected rice varieties. The different plant parts were collected and analyzed at the laboratory of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, during the period from May to June, 2015. Data were collected on plant height, number of total tiller, effective tiller and non-effective tiller hill^{-1}, panicle length, number of spikelet panicle^{-1}, number of filled grains and unfilled grains panicle^{-1}, root dry weight, shoot dry weight, total dry weight, 1000-grain weight and grain yield hill^{-1} and K, Na and Ca content in shoot.

Effect of variety was found significant for every growth and yield parameters as well as mineral (K, Na and Ca) content in shoot. Plant height, number of total tiller, effective tiller and non-effective tiller hill^{-1}, number of spikelet panicle^{-1}, number of filled grains and unfilled grains panicle^{-1}, root dry weight, shoot dry weight, total dry weight were higher in BRRI dhan29. But panicle length, 1000-grain weight and grain yield hill^{-1} were higher in Binadhan-8. Na and Ca content in shoot were higher in BRRI dhan29 while K content in shoot was higher in Binadhan-8.

With increasing the level of salinity plant height, number of total tiller hill^{-1}, panicle length, number of spikelet panicle^{-1}, number of filled grains panicle^{-1}, root dry weight, shoot dry weight, total dry weight, 1000-grain weight and grain yield hill^{-1} increased up to 4 dSm^{-1} and then decreased afterwards. Effective tiller decreased linearly with increasing salinity while number of unfilled grain panicle^{-1}

decreased up to 8 dSm^{-1} then increased at 12 dSm^{-1}. Na and Ca content in shoot were higher in higher salinity levels while K content in shoot showed opposite pattern.

Supplementation of Ca was found to have significant effect on growth and yield parameters as well as mineral (K, Na and Ca) content in shoot. Plant height, number of total tiller, effective tiller $hill^{-1}$, panicle length, number of spikelet $panicle^{-1}$, number of filled grains $panicle^{-1}$, root dry weight, shoot dry weight, total dry weight, 1000-grain weight and grain yield $hill^{-1}$ increased with increasing Ca supplement while non-effective tiller $hill^{-1}$ and unfilled grains $panicle^{-1}$ decreased. K and Ca content in shoot were higher in higher Ca levels while Na content in shoot showed opposite pattern.

Most of the growth and yield parameters which are positively responsible for better yield showed slight increase at 4 dSm^{-1} in comparison of 0 dSm^{-1} due to the interaction of variety and salinity. Then there was a considerable decline of yield at 12 dSm^{-1} in both of the varieties. But reduction percentage (from control salinity) at highest salinity level is higher in BRRI dhan29 than Binadhan-8. In case of mineral content in shoot, Na and Ca content increased and K content decreased with increasing salinity in both of the varieties. But Na increased a greater extent in BRRI dhan29 than Binadhan-8.

Interaction of variety and calcium significantly affected all the parameters studied. As the Ca level increased plant height, number of total tiller, effective tiller $hill^{-1}$, panicle length, number of spikelet $panicle^{-1}$, number of filled grains $panicle^{-1}$, root dry weight, shoot dry weight, total dry weight, 1000-grain weight and grain yield $hill^{-1}$ increased while non-effective tiller $hill^{-1}$ and unfilled grains $panicle^{-1}$ decreased in case of both varieties. K and Ca content in shoot were higher in higher Ca levels while Na content in shoot showed decreasing pattern for both BRRI dhan29 and Binadhan-8. Growth and yield parameters as well as mineral (K, Na and Ca) content in shoot showed significant variation due to the interaction salinity and calcium. At every salinity level, parameters such as plant height, number of total tiller, effective tiller $hill^{-1}$, panicle length, number of spikelet $panicle^{-1}$, number of filled grains $panicle^{-1}$, root dry weight, shoot dry weight, total dry weight, 1000-grain weight and grain yield $hill^{-1}$ increased with the increase of Ca while non-effective tiller $hill^{-1}$ and unfilled grains $panicle^{-1}$ decreased. On the other hand, K and Ca content increased with increasing Ca at every salinity level and Na content decreased.

Interaction of variety, salinity and calcium significantly affected all the parameters studied. Each of the variety showed significant reduction in plant height, number of total tiller, effective tiller $hill^{-1}$, panicle length, number of spikelet $panicle^{-1}$, number of filled grains $panicle^{-1}$, root dry weight, shoot dry weight, total dry weight, 1000-grain weight and grain yield $hill^{-1}$ due to higher salinity level (except at 4 dSm^{-1}) but Ca supplementation had significant positive effects on these parameters. Binadhan-8 showed higher yield potential (13.48 g $hill^{-1}$) in highest salinity level with 10 mM Ca supplement compare to BRRI dhan29 (10.11 g $hill^{-1}$) (Table no. 15). In each variety, at every salinity level, K and Ca content in shoot increased with increasing Ca supplement while Na content decreased. But Binadhan-8 showed higher K (1.52%) and lower Na (1.29%) content in highest salinity level with 10 mM Ca supplement compare to BRRI dhan29 (respectively 0.73% K and 2.45% Na).

From the above results it can be concluded that-

i. the variety Binadhan-8 had better expression of growth and yield characters than that of BRRI dhan29 at higher salinity, and
ii. reclamation of salinity may be achieved through Ca supplementation in saline areas for increasing cultivable lands in particular for rice production.

Chapter 6
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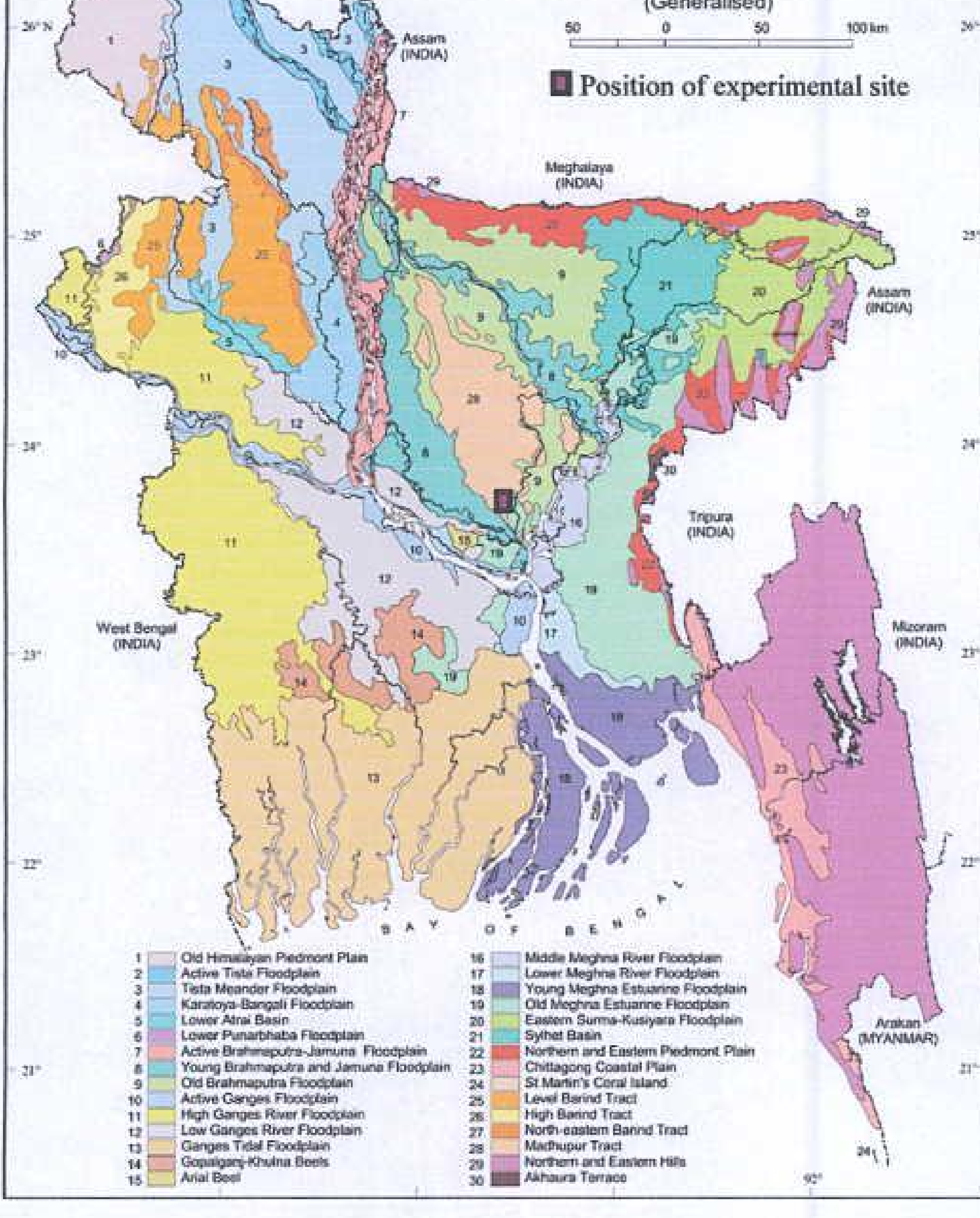
Chapter 7
Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



APPENDIX II: Mean square values for the parameter of plant height, number of total tillers hill^{-1}, effective tillers hill^{-1}, non-effective tillers hill^{-1}, panicle length, number of spikelets panicle^{-1} and number of filled grains panicle^{-1}

	Plant height	Number of total tillers hill^{-1}	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Panicle length	Number of spikelets panicle^{-1}	Number of filled grains panicle^{-1}
Factor A	742.409	186.889	11.681	105.125	4.651	8574.606	120.332
Factor B	959.800	34.463	36.495	1.347	16.588	11799.296	20843.184
Factor C	186.650	11.931	38.097	7.389	19.769	374.526	1729.698
AB	19.823	0.111	14.644	13.792	1.530	258.454	111.122
AC	37.868	0.097	14.644	1.167	0.831	76.770	32.359
BC	10.041	0.560	0.356	0.222	0.377	10.612	15.665
ABC	2.401	0.542	0.310	0.333	0.068	13.762	50.688

APPENDIX III: Mean square values for the parameter number of filled grains panicle^{-1}, unfilled grains panicle^{-1}, shoot dry weight (SDW) hill^{-1}, total dry weight (TDW) hill^{-1}, 1000-grain weight (g), grain yield (g hill^{-1}) and K content in shoot

	Number of unfilled grain panicle^{-1}	Shoot dry weight (SDW) hill^{-1}	Root dry weight (RDW) hill^{-1}	Total Dry Weight (TDW) hill^{-1}	1000-grain weight (g)	Grain yield (g hill^{-1})	K content in shoot
Factor A	6663.389	1029.143	37.138	1457.280	412.802	49.817	0.333
Factor B	1872.881	2843.651	32.673	3457.420	13.626	1265.563	11.559
Factor C	494.527	1551.902	9.746	1800.265	47.317	479.412	0.989
AB	525.446	78.097	4.467	116.538	1.858	14.275	1.539
AC	9.452	42.857	0.050	45.664	0.309	2.095	0.021
BC	25.191	23.191	0.295	26.149	0.971	11.910	0.016
ABC	13.403	9.207	0.195	10.961	1.684	2.079	0.038

APPENDIX IV: Mean square values for the parameter Na content in shoot and Ca content in shoot

	Na content in shoot	Ca content in shoot
Factor A	6.127	0.074
Factor B	13.239	0.036
Factor C	0.507	0.055
AB	1.310	0.020
AC	0.008	0.004
BC	0.098	0.001
ABC	0.011	0.001