EFFECTS OF SALINITY ON GERMINATION, MORPHOLOGY AND MINERAL CONTENTS OF SEEDLINGS OF DIFFERENT RICE (*Oryza sativa L.*) CULTIVARS

By

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CERTIFICATE

This is to certify that the thesis entitled "EFFECTS OF SALINITY ON GERMINATION, MORPHOLOGY AND MINERAL CONTENTS OF SEEDLINGS OF DIFFERENT RICE (*Oryza sativa L.*) CULTIVARS" 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 KH. ASHRAF-UZ-ZAMAN, Registration. No. 05-01653, 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 has duly been acknowledged.

Dated: 07.8.2012
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Dedicated to

My

Beloved Parents

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ABSTRACT

An experiment was conducted to study the effect of salinity on germination, morphology and mineral contents of seedlings of 28 different rice (*Oryza sativa L.*) cultivars under 5 levels of salinity (0, 3, 6, 9 and 12 dS m^{-1}) using completely randomized design with three replications. The germination percentage, seedling height, root dry weight, shoot dry weight and total dry matter of seedlings were significantly influenced by salinity. The higher germination percentage, seedling height, root dry weight, shoot dry weight and total dry matter were found in cultivars Nona Bokkra, Heera-2, Sadamota, Lalmota, BINA Sal-2 and BRRI dhan47 while the lower values were recorded in BRRI dhan28 followed by BRRI dhan29 and BR 22. The percent germination, root dry weight, shoot dry weight and total dry matter decreased with increasing salinity levels. Though lower levels of salinity (0 to 3 dS m^{-1}) did not significantly affect on percent germination. The concentration of Na^{+}, Ca^{2+} and Mg^{2+} except K^{+} and values of Na/K, Na/Ca and Na/Mg ratio significantly increased in seedlings irrespective of cultivars with increasing levels of salinity. Value of Na/K increased slowly in cultivars Bashiraj, BINA Sal-2, Nona Bokkra, Komragor, Lalmota and BRRI dhan47 which is an indication of salt tolerance.

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LIST OF ABBREVIATIONS

Abbreviated Form	Elaborated Form
EC	Electrical Conductivity
dS	Deci Siemens
m^{-1}	Per meter
L^{-1}	Per Litre
g	Gram
kg	Kilogram
et al.	and others
mmol	Milli mole
BRRI	Bangladesh Rice Research Institute
BINA	Bangladesh Institute of Nuclear Agriculture
LSD	Least Significant Difference
CV %	Co-efficient of variation percentage

Chapter 1

Introduction

CHAPTER 1

INTRODUCTION

Millions of hectares in the humid regions of South and Southeast Asia are technically suited for rice production but are left uncultivated or are grown with very low yields because of salinity and problem soils. Furthermore, mineral deficiencies and toxicities compound the problem of salinity as it seldom happens in isolation. These soil stresses vary in magnitude and interactions over time and place, making long-term adaptability of a variety dependent on its level of tolerance to all the stresses that occur in its growing environment. In general, the term salinity includes all the problems due to salts present in the soil while in strict terms, these soils are categorized into two types: sodic (or alkali) and saline (a third type can be referred to as saline-sodic soils). Saline soils are again dominated by sodium cations with electrical conductivity (EC) more than $4dSm^{-1}$, but the dominant anions are usually soluble chloride and sulphate. Exchangeable Sodium Percentage ($ESP < 15$) and pH values of these soils are much lower than in sodic soils.

Salinity in soil or water is one of the major stresses that severely limit crop production. The deleterious effects of salinity on plant growth are associated with (i) low osmotic potential of soil solution (water stress), (ii) nutritional imbalance, (iii) specific ion effect, or (iv) a combination of these factors (Asch *et al.*, 2000, Juan *et al.* 2005, Hu *et al.* 2005). In fact, under saline conditions, soils contain extreme ratios of Na^+/Ca^{2+}, Na^+/K^+, Ca^{2+}/Mg^{2+}, and Cl^-/NO_3^-, leading to specific ion toxicities (e.g., Na^+ and Cl^-) and ionic imbalance (Grattan and Grieve, 1999).

At present, out of 1.5 billion hectares (ha) of cultivated land around the world, about 77 million hectares (5 %) is affected by excess salt content (Sheng *et al.*, 2008). According to a report of Alam (2001), saline/sodic soils cover about 26 % of the world's cultivated land. Incidentally, most of the developing and underdeveloped countries of South and Southeast Asia, Africa and South America are the worst affected by this menace. More than 80 million hectares of such soils are in Africa, 50 million hectares in Europe, 357 million hectares in Austral-Asia, nearly 147 million hectares in Central, North and South America. Similarly, a large bulk of about 320 million hectares of land in South and Southeast Asia is under the grip of salinity. It shows that no continent on our planet is free from salt-affected soils.

Worldwide, the research to overcome salt related problems is based on two approaches;

1. Change the growing environment (make it normal) suitable for the normal growth of plants; or

2. Select the crop and/or change genetic architecture of the plant so that it could be grown in such areas.

The first approach involves major engineering and soil amelioration process which need lot of resources are often out of the reach of small and marginal farmers.

The second approach i.e. breeding crop varieties with in-built salt tolerance is realized as the most promising, less resource consuming /economical and socially acceptable approach. So the ability of the plant to tolerate the salt stress up to an extent is of paramount importance to manage the resources optimally and this is the reason to develop the tailored crops with higher salt tolerance suited to salt stress environments.

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

Existence of genetic variability for salt tolerance within species is of paramount importance in crop improvement programme. Therefore choice of germplasm in breeding programme is most crucial as the success lies on it. Extensive germplasm collection provides a useful source of genetic diversity for the studied traits. Yeo and Flowers (1982) reported varietal differences in rice for salinity tolerance.

Rice (*Oryza sativa*) 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). In Asia, China is the major rice producing country followed by India, Indonesia and Bangladesh. However, yield per hectare is highest (6.1 tons) in Japan followed by China (5.1 tons ha^{-1}).

In Bangladesh, rice is grown on about 10.71 million hectares of land (BBS 2000). Rice provides about 71 percent of the total calories and 51 percent of the protein intake of the people's diet. The modern rice varieties cover about 62 percent of the total rice areas, which contribute to about 77 percent of the total rice production of the country. Area covered by modern varieties of rice is about 33, 48 and 98 percent for the Aus, Aman and Boro seasons, respectively. Thus it is clear that there is ample scope and need for expansion of the modern varieties particularly in the Aus and Aman seasons. In the coastal regions, about one million hectares of land are affected by soil salinity in varying degrees. Crop production in these areas is dominated by the traditional T-Aman rice with yields of about 2 t/ha. During the monsoon, salinity levels usually remain low (2-6 dS m^{-1} EC) and modern varieties may eventually replace the traditional varieties.

The rice production system plays a great role in the reduction of hunger and poverty in Bangladesh. In 1975-76 total rice production in Bangladesh was 10.32 million tons when the country's population was 79.90 million and rice area was 10.32 million ha. In 2007-8 the country produced 27.32 million tons in 10.71 million ha of rice area to feed more than 145 million people (BBS & DAE, 2007). This indicates the growth of rice production was much faster than the growth of population while the cultivable rice area is not significantly different between these three decades. This increase in rice production has been achieved due to the adoption of modern rice varieties on around 73% of the rice land which contributes to about 85% of the country's total rice production, the use of modern rice cultivation technology, improvement irrigation and the proper use of fertilizer and pesticides (BBS, 2006). Rice breeders have used genetic variability to produce cultivars that have high yield potential and that resist disease and insect damage and that tolerate cold, drought, and even floods. But apart from some sporadic work in Sri Lanka and India, little has been done until recently to identify any breed/cultivars adaptable to adverse soil conditions such as salinity. Rice (*Oryza sativa* L.) is a crop that has ability to grow well in standing water, so it is recommended as a desalinization crop (Abrol and Bhumbla, 1978).

Coastal areas constitute about 2.5 million hectares which amount to about 25 percent of the total cropland of the country in Bangladesh. Of this, nearly 0.84 million hectares are affected by varying intensities of salinity, resulting in very poor land utilization (Karim *et al.*, 1990). The majority of the saline land (0.65 million ha) exists in the districts of Satkhira, Khulna, Bagerhat, Barguna, Patuakhali, Pirojpur and Bhola on the western coast and a smaller portion (0.18 million ha) in the districts of Chittagong, Cox's Bazar, Noakhali, Lakshmipur, Feni and Chandpur. According to the report of Soil Resource Development Institute (SRDI, 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 moderately (8-12 dSm^{-1}) and 0.490 million ha is strongly (>12 dSm^{-1}) salt affected soils in southwestern part of the coastal area of Bangladesh. Large fluctuations in salinity levels over time are also observed at almost all sites in these regions. The common trend is an increase in salinity with time, from November- December to March-April, until the onset of the monsoon rains.

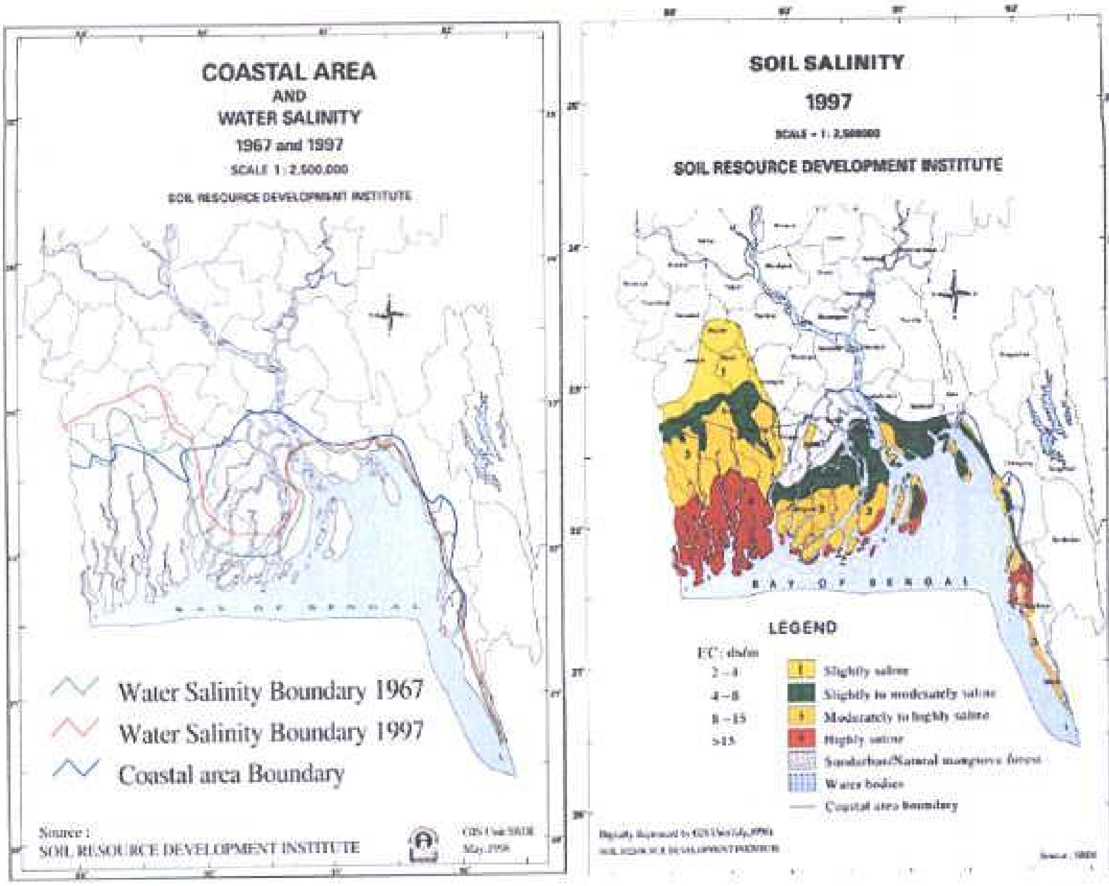

Figure 1. Water and Soil salinity area map in Bangladesh (Source: SRDI,2007).

Rice is least tolerant to salinity during seedling stage, but its tolerance increase with age and varieties differ in their tolerance to salinity. Available information on tolerance to salinity in rice at flowering stage is contradictory (Bernstein and Hayward, 1958). Early seedling stage in paddy has been reported to be more sensitive than later stage (Pearson, Cha-um *et al.* (2005) conducted an investigation with an objective to evaluate the effective salt-tolerance defense mechanisms in aromatic rice varieties. Pathumthani 1 (PT1), Jasmine (KDML105), and Homjan (HJ) aromatic rice varieties were chosen as plant materials. Rice seedlings photoautotrophically grown *in-vitro* were treated with 0, 85, 171, 256, 342, and 427 mM NaCl in the media. Data, including sodium ion (Na^+) and potassium ion (K^+) accumulation, osmolarity, chlorophyll pigment concentration, and the fresh and dry weights of seedlings were collected after salt-treatment for 5 days. Na^+ in salt-stressed seedlings gradually accumulated, while K^+ decreased, especially in the 342-427 mM NaCl salt treatments. The Na^+ accumulation in both salt-stressed root and leaf tissues was positively related to osmolarity, leading to chlorophyll degradation. In the case of the different rice varieties, the results showed that the HJ variety was identified as being salt-tolerant, maintaining root and shoot osmolarities as well as pigment stabilization when exposed to salt stress or Na^+ enrichment in the cells. On the other hand, PT1 and KDML105 varieties were classified as salt-sensitive, determined by chlorophyll degradation using Hierarchical cluster analysis. In conclusion, the HJ-salt tolerant variety should be further utilized as a parental line or genetic resource in breeding programs because of the osmoregulation defensive response to salt-stress.

Fageria (2003) evaluated the dry matter production and the concentration of nutrients in rice (*Oryza sativa* L.) cultivars from soil adjusted to different levels of salinity under a greenhouse conditions. Soil salinity levels were produced by applying 0.34 mol L^{-1} solution of NaCl which resulted in the following levels, control (0.29), 5, 10 and 15 dS

m^{-1} conductivity of saturation extract. The effect of salinity on dry matter production varied from cultivar to cultivar. The concentrations of P and K in the tops of rice cultivars decreased with increasing soil salinity. But the concentrations of Na, Zn, Cu and Mn increased. Significant varietal differences were found in relation to salinity tolerance.

Thomas and Nambisan (1999) assessed uptake and partitioning of Na, K and Ca in 14-day-old seedlings of rice cv. Pokkali, IR 20 and Jyoti under conditions of salt stress. Cation contents in different parts of the shoot were estimated by flame photometry. Cultivar differences were observed both in the uptake of the three cations and their translocation into different plant parts. The study attributes the superior salt tolerance of Pokkali over IR 20 and Jyoti to its ability to limit Na uptake into shoots by retention in root, higher uptake and translocation of K into shoot, translocation of K from outer leaf and leaf base into inner leaf, translocation of Na into outer leaf and limiting entry into the inner leaf, maintaining high Ca content in shoots, and an overall higher salt uptake required for maintaining tissue water content under saline conditions.

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

Chapter 3
Methods and Materials

CHAPTER 3

METHODS AND MATERIALS

The experiment was conducted under pot-culture at the net house of the Department of Genetics and Plant Breeding and Laboratory of Department of Agricultural Chemistry Sher-e-Bangla Agricultural University, Dhaka-1207 to study the effect of salinity on the growth and nutrient contents of twenty eight (28) selected rice varieties during Aman season (2010). This chapter of dissertation is an important component that essentially maps out the method that was utilized when researching and writing this work. It describes the key method, use of different parameters to correlate with raising of rice seedlings. It further covers the data collection procedure, source of data and way data were analyzed. To fulfill the objective of this thesis various types of salinity level and the raising of rice seedling at each level of salinity were used. Different parameters which are related to physiology and nutrient contents of rice seedlings were used in this thesis. This thesis is laid out in 2 (two) factors including different salinity levels and cultivars of rice. In this thesis, used all data are primary data.

3.1 Site of the experiment

The experiment was conducted at the net house of Department of Genetics and Plant Breeding and Laboratory of Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka.

1959) whereas Bernstein and Hayward (1958) reported that seedling and flowering stages of the crop are more sensitive to salinity while germination stage is most tolerant.

The present population of Bangladesh is about 160 million. The alarming growth of population and loss of arable land due to urbanization are main causes of concern for finding ways and means for augmenting food production particularly rice. The possibility of increasing food production by increasing land area is seriously limited in Bangladesh. The only feasible alternative is to increase the cultivated areas by bringing salt affected soils under cultivation with high yielding salt tolerant rice cultivars.

Considering the above circumstances, the present study has been designed and planned with the following objectives -

a. to observe the seedling growth under different salinity levels,

b. to study the mineral composition of seedling shoots at different salinity levels, and

c. to isolate tolerant and susceptible rice cultivars.

Chapter 2
Review of Literature

CHAPTER 2

REVIEW OF LITERATURE

Rice is the staple food in many parts of the world. It is sensitive to various environmental factors *viz.* variety, soil salinity, nutrient availability, temperature, humidity, light intensity and moisture for proper growth and yield. Many researches have been conducted on various aspects of rice in different countries. A lot of research works have been conducted about effect of salinity on many crops, but a little information is available about the physiological and chemical change of seedlings of tolerant and susceptible rice cultivars. Available literatures related to the present study are reviewed here.

Ashraf *et al.* (2010) conducted a hydroponics experiment to evaluate the role of potassium (K) and silicon (Si) in mitigating the deleterious effects of NaCl on rice cultivars differing in salt tolerance. Two salt-sensitive (CPF 243 and SPF 213) and two salt-tolerant (HSF 240 and CP 77-400) rice cultivars were grown for six weeks in ½ strength Johnson's nutrient solution. The nutrient solution was salinized by two NaCl levels (0 and 100 mmol L^{-1} NaCl) and supplied with two levels of K (0 and 3 mmol L^{-1}) and Si (0 and 2 mmol L^{-1}). Applied NaCl enhanced Na^+ concentration in plant tissues and significantly ($P \leq 0.05$) reduced shoot and root dry matter in four rice cultivars. However, the magnitude of reduction was much greater in salt-sensitive cultivars than salt-tolerant cultivars.

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

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

Aslam *et al.* (2003) stated that an increase in potassium and K^+/Na^+ ratio was an indication of salt tolerance due to the application of additional Ca in both salt tolerant and susceptible rice cultivars under saline environment. These authors mentioned that salt affected soils showed an improvement in the paddy yield of both salt tolerant and salt sensitive rice cultivars due to Ca application as gypsum at the rate of 25% of gypsum requirement of soil.

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

Many scientists have suggested that selection is more convenient and practicable if the plant species possesses distinctive indicators of salt tolerance at the whole plant, tissue or cellular level (Ashraf and Sarwar, 2002; Epstein and Rains, 1987; Jacoby, 1999; Munns, 2002). Physiological criteria are able to supply more objective information than agronomic parameters or visual assessment while screening for component traits of complex characters (Yeo, 1994). There are no well-defined plant indicators for salinity tolerance that could practically be used by plant breeders for improvement of salinity tolerance in a number of important agricultural crops. This is partly due to the fact that the mechanism of salt tolerance is so complex that variation occurs not only amongst species but, in many cases, also among cultivars within a single species (Ashraf and Sarwar, 2002). During the course of plant growth, the form and functions of various organs undergo significant change and the ability of the plant to react to salinity stress depend on those genes that are expressed at the stage of development during which the stress is imposed (Epstein and Rains, 1987). The mechanism of salinity tolerance becomes even more complicated when the response of a plant also varies with the concentration of saline medium and the environmental conditions in which the plant is grown.

Under salt stress conditions there was a decrease in the Ca/Na ratio in the root environment which affected membrane properties, due to displacement of membrane-associated Ca^{2+} by Na^{+}, leading to a disruption of membrane integrity and selectivity (Cramer *et al.*, 1985; Kinraide, 1998).

Choi *et al.* (2003) observed that the plant height decreased in the 0.5% saline water in the soil. Khan *et al.* (1997) conducting a pot experiment with three rice cultivars reported that plant height was seriously decreased by salinity. Similar opinion was also postulated by Saleque *et al.* (2005). During vegetative period, the most common salinity effect was stunting of plant growth, whereas leaf withering was less apparent (Alam *et al.*, 2001). The mutant variety maintained its superiority in various characteristics such as plant height, higher number of fertile panicles per plant and high plant yield (Baloch *et al.*, 2003).

Regulation of ion transport is one of the important factors responsible for salt tolerance of plants. Membrane proteins play a significant role in selective distribution of ions within the plant or cell (Ashraf and Harris, 2004). According to Du-Pont (1992) the membrane proteins involved in cation selectivity and redistribution of Na^+ and K^+. It is well established that Na^+ moves passively through a general cation channel from the saline growth medium into the cytoplasm of plant cells (Marschner, 1995; Jacoby, 1999; Mansour *et al.*, 2003) and the active transport of Na^+ through Na^+/H^+ antiports in plant cells is also evident (Shi *et al.*, 2003). Salt tolerance in plants is generally associated with low uptake and accumulation of Na^+, which is mediated through the control of influx and/ or by active efflux from the cytoplasm to the vacuoles and also back to the growth medium (Jacoby, 1999). Energy-dependent transport of Na^+ and Cl^- into the apoplast and vacuole can occur along the H^+ electrochemical potential gradients generated across the plasma membrane and tonoplast (Hasegawa *et al.*, 2000). The tonoplast H^+ pumps (H^+-ATPase and H^+-pyrophosphatase) also play a significant role in the transport of H^+ into the vacuole and generation of proton (H^+) which operates the Na^+/H^+ antiporters (Mansour *et al.*, 2003; Blumwald, 2000)

Baba and Fujiyama (2003) investigated short-term (72 hours) 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.

Castillo (2003) examined the effects of the osmotic component of salt stress on rice cultivar IR64. Treatments were four combinations of two levels of osmotic stress at two developmental stages: medium- and high-level stress applied at the vegetative and reproductive stages using salt (NaCl) and polyethylene glycol-6000 (PEG) as sources of osmotic stress. Both PEG and NaCl reduced the total above ground biomass and delayed flowering and maturity, with a longer delay observed with the high-level stress. The sodium concentration in plant tissues also increased in plants treated with NaCl, indicating that besides osmotic stress, plants were also subjected to ionic stress. Treatment with NaCl decreased the potassium concentration in plant tissues but did not cause significant differences in phenology, biomass accumulation, yield or N uptake compared with PEG. They concluded that the response of IR64 to NaCl was attributed to the osmotic component. These findings may be specific to IR64, which has a medium tolerance to salinity stress.

3.2 Experimental period

The experiment was conducted in pots during Aman rice cropping season 2010.

3.3 Collection of the seeds of cultivars

The seeds of 28 cultivars/ lines of rice were collected from the saline prone area, Bangladesh Institute of Nuclear Agriculture (BINA) and Bangladesh Rice Research Institute (BRRI) to conduct the experiment. The list of cultivars/lines is given in Table 1.

Table 1: *List of cultivars/ lines/ genotypes with their collecting source*

Sl. No.	Cultivars/lines	Source
1.	Pokkali	Bangladesh Rice Research Institute (BRRI)
2.	Nona Bokkra	Bagerhat
3.	Sadamota	Bagerhat
4.	Lalmota	Bagerhat
5.	Kajal Sail	BRRI
6.	Kajal Lata	Satkhira
7.	Nona Kachu	Bagerhat
8.	Chapsal	Bagerhat
9.	Kalarmocha	Bangladesh Institute of Nuclear Agriculture (BINA)
10.	Sarna Balam	Satkhira

Table 1(Contd.): List of cultivars/ lines/ genotypes with their collecting source

Sl. No.	Cultivars/lines	Source
11.	Bashiraj	BINA
12.	Jabra	BINA
13.	Komragor	Satkhira
14.	Udichadra	Satkhira
15.	Jatabalam	Khulna
16.	Palavir	BINA
17.	BINA- Sal-2	BINA
18.	BRRI dhan40	BRRI
19.	BRRI dhan41	BRRI
20.	BRRI dhan47	BRRI
21.	BR 10	BRRI
22.	BR 11	BRRI
23.	BR 22	BRRI
24.	BR 23	BRRI
25.	BRRI dhan28	BRRI
26.	BRRI dhan29	BRRI
27.	BRRI dhan30	BRRI
28.	Heera-2	Supreme Seed Company, Uttara, Dhaka

3.4 Experimental design

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

Factor 1: Cultivars- 28

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

Replication: 3

The twenty eight cultivars/ lines in combination with five salinity levels were randomly assigned to 420 ($28\times5\times3 = 420$) experimental units.

3.5 Salinity treatments

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

3.6 Sterilization of seed

Prior to germination test seeds were surface sterilized with 1% sodium hypochlorite solution. The glass vials containing distilled water for seed rinsing was sterilized for 20 minutes in an autoclave at 121 ± 1^0 C and at 15 bar air pressure.

3.7 Germination test

Germination test was carried out in Petri-dishes of 15 cm diameter. Twenty seeds were placed on filter paper bed and 5-10 mL of treatment solutions of different salinity levels were used in each Petri-dish to immerse the seeds partially for ensuring aeration. Six to eight Petri-dishes were placed in a plastic tray and kept in a tightly closed polythene bag, and the seeds were allowed to germinate at room temperature. Distilled water was added to each Petri-dish everyday as per necessity. Seeds were considered germinated when both the plumule and radicle generated and were extended to more than 2 mm and the number of seeds germinated was recorded at an interval of 24 hours. Plumule and radicle lengths were measured from their junction with a centimeter scale.

3.8 Collection and preparation of soil

The soil of the experiment was collected from the field of Sher-e Bangla Agricultural University (SAU) Farm. The soil was shallow red brown terrace soil under Tejgaon series belonging to the Agro-Ecological Zone 28 (Modhupur Tract). The soils were clay loam in texture with common fine medium distinct dark yellowish brown mottles. The collected soil was pulverized and inert materials, visible insect pest and plant propagules were removed. The soil was dried in the sun, crushed carefully and thoroughly mixed.

3.9 Raising of seedlings

The seedlings were grown in large size plastic tray and the soil was used as growth medium. Chemical fertilizers namely urea, triple supper phosphate (TSP) and muriate of potash (MOP) were used for N, P and K. The rate of Urea, TSP and MOP fertilizers were 120, 100 and 75 kg ha^{-1} respectively. The fertilizers were applied one day before sowing seeds in the seed bed. Sterilized seeds were imbibed in distilled water for 24 hours and then washed thoroughly in fresh water, and the seeds were incubated for sprouting. After sprouting, they were placed on the thin layer of wet seed bed of soils in the trays. Saline solution was added after 1-2 leaf stage of seedling in each tray according to the treatments. To avoid osmotic shock, the required amount (at the rate of 640 mg per litre distilled water for 1 dS m^{-1}) of salt solution was added in three equal installments on alternate days until the expected conductivity was reached. The salinity *i.e.* electric conductivity (EC) of each tray was measured with a conductivity meter (Model-DiST 4 HANNA HI 98304) and the necessary adjustments of salinity were made.

3.10 Collection of data

The seedlings were up rooted 6 weeks after sowing. Ten plants of each cultivar/ line per treatment were up rooted. The seedlings of salt susceptible genotypes were also up rooted when those completely died. The samples of control treatment were also collected in the same manner.

3.10.1 Percent germination: Number of seeds germinated were recorded at an interval of 24 hours and continued for 7 days and the results were converted to percent.

3.10.2 Seedling height: Seedling height (cm) was measured from the root base to the tip of the longest leaf at the time of up rooting of seedlings.

3.10.3 Root dry weight of seedlings: Roots were separated from the seedlings and washed with tap water and finally with distilled water. The roots samples were oven-dried to a constant weight at 70° C. The mean seedling dry weight of root (g) was calculated for each treatment.

3.10.4 Shoot dry weight of seedlings: After separation of roots from up rooted seedlings, the seedling shoots were washed with tap water and finally with distilled water. Then the shoot samples were oven-dried to a constant weight at 70° C. The mean seedling dry weight of shoot (g) was calculated for each treatment.

3.10.5 Total dry matter of seedlings: The total dry matter seedling^{-1} (g) was calculated from the summation of root and shoot dry weight for each treatment.

3.10.6 Relative growth data: The relative growth performance of seedlings of different cultivars/ lines was calculated to evaluate the salt tolerance for each genotype by the following formula proposed by Ashraf and Waheed (1990):

$$\text{Relative growth data (\%)} = \frac{\text{The data of salt treated seedling of a cultivar}}{\text{The data of control treated seedling of that cultivar}} \times 100$$

3.10.7 Chemical analysis

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

Oven-dried shoot samples of rice seedlings were ground in a Wiley Hammer Mill, passed through 40 mesh screens, mixed well and stored in plastic vials. The ground samples were digested by Micro-Kjeldahl method (Thomas *et al.*, 1967). Exactly 0.25 g oven-dried shoot samples of rice seedlings were taken in kjeldahl flasks. About 5 mL of concentrated sulphuric acid and 1 mL H_2O_2 were taken in a digestion tube and left to stand for 20 minutes and then transferred to a digestion block and continued heating at

100°C. The temperature was increased to 365°C gradually to prevent frothing (50°C steps) and left to digest until yellowish color of the solution turned to whitish color. Then the digestion tubes were removed from the heating source and allowed to cool to room temperature. About 40 mL of de-ionised water was carefully added to the digestion tubes and the contents filtered through Whatman no. 40 filter paper into a 100 mL volumetric flask and the volume was made up to the mark with de-ionised water. The samples were stored at room temperature in clearly marked containers.

After digestion, approximately 10 mL of each digest samples was stored in a plastic bottle for determination of the Na^+, K^+, Ca^{2+} and Mg^{2+}. Content of Na^+ and K^+ were determined by Flame photometer while Ca^{2+} and Mg^{2+} by atomic absorption spectrophotometer (Model- PERKIN- ELMER, 2380). After that, the Na/K, Na/Ca and Na/Mg values were also calculated from concentrations of Na, K, Ca, and Mg in the plant tissues.

3.11 Statistical analysis

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

Chapter 4
Results and Discussion

CHAPTER 4

RESULTS AND DISCUSSION

The germination percentage, different morphological parameters including seedling height, root dry weight, shoot dry weight and total dry matter, major nutrients' (Na^{+}, K^{+}, Ca^{+} and Mg^{2+}) content and the ratio of Na^{+} & K^{+}, Na^{+} & Ca^{2+} and Na^{+} & Mg^{2+} of the selected 28 rice cultivars were studied in view to evaluate their response to different salinity levels. To evaluate the varietal performance both the absolute and relative values of different morphological characters have been taken into consideration and presented hereunder.

4.1 Germination

Results presented in Figure 2 show that the mean effect of different salinity levels on the percent germination of 28 rice cultivars differed significantly. The percent germination was found highest in the cultivars Sadamota (94.67%) followed by Lalmota (94.33%), BINA Sal-2 (93%) and BRRI dhan47 (92.67%) and it was the lowest (74%) in BRRI dhan29, and remaining cultivars were of intermediate status (Appendix 1).

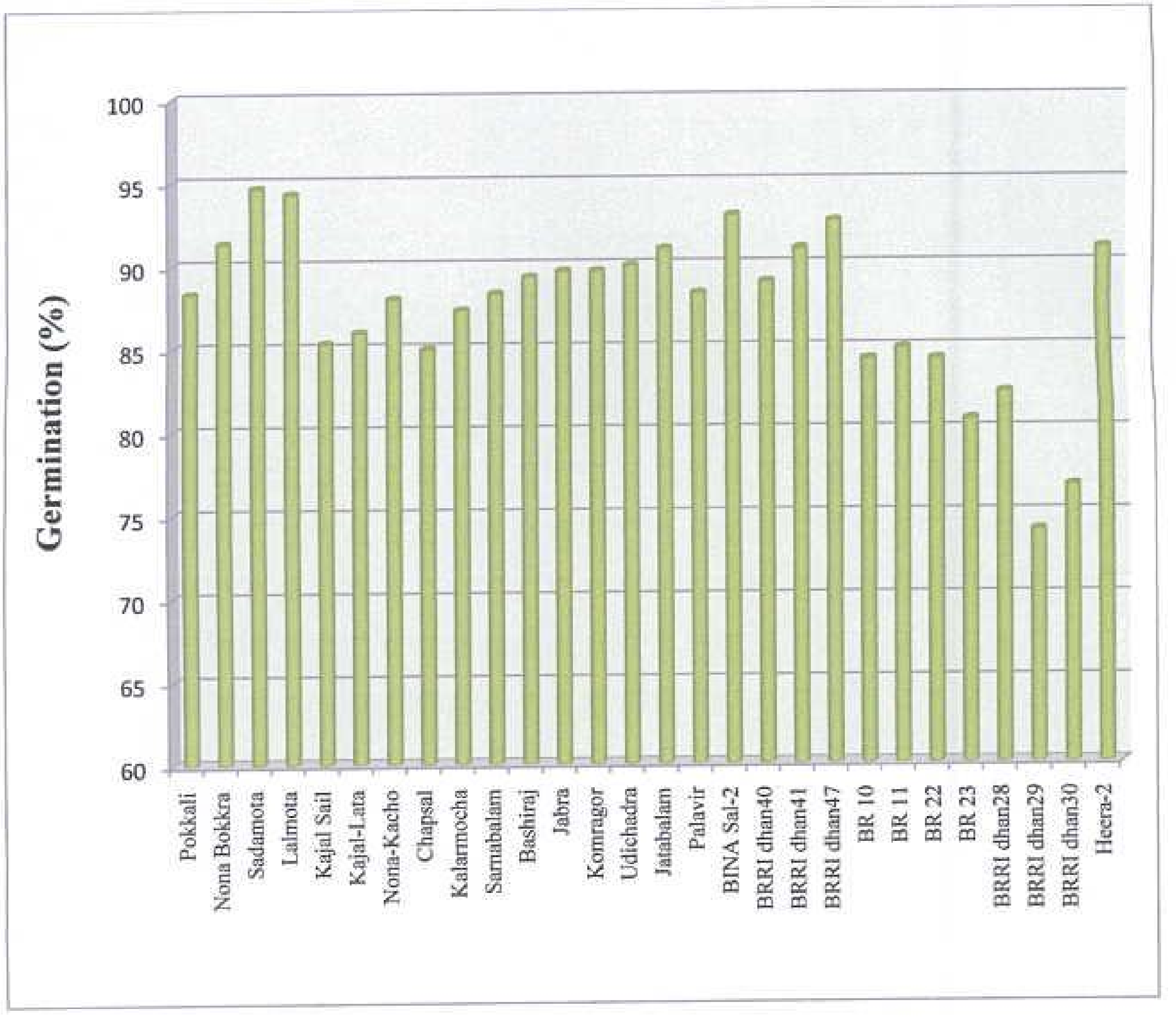

Figure 2. The effect of cultivar on germination percentage (mean of 5 salinity levels)

The effect of different levels of salinity on germination (mean of 28 cultivars) was found significant (Appendix 2). The percent germination decreased with increasing salinity levels (Figure 3). The percent germination was found highest (93.45%) in control condition and the lowest (75.06%) was observed at the highest level of salinity (12 dS m^{-1}).

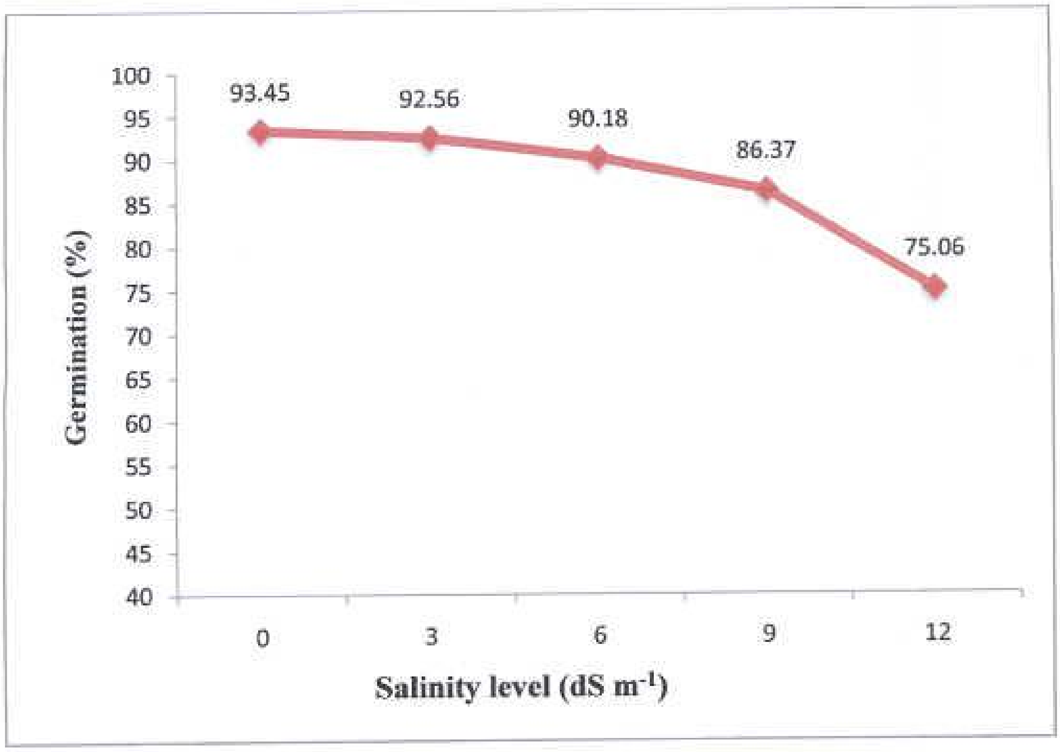

Figure 3. The effect of salinity on germination percentage (mean of 28 rice cultivars)

On the basis of Figure 4, it was noted that the percent germination increased in cultivars Lalmota, Kolarmocha, Nona-Kachu, BRRI dhan47, Bashiraj and Heera-2 with the increase in salinity upto 6 dS m^{-1} level while it decreased sharply in cultivars BRRI dhan28, BRRI dhan29 and BRRI dhan30 (Appendix 3).

Lower levels of salinity (0 to 3 dS m^{-1}) had little effect on percent germination (Figure 4), where a significant reduction in germination was found from 6 dS m^{-1} level of salinity. While considering genotypic performance it was revealed that Sadamota, Lalmota and BINA Sal-2 were highly tolerant and BRRI dhan29, BRRI dhan30 & BR 23 were the least tolerant.

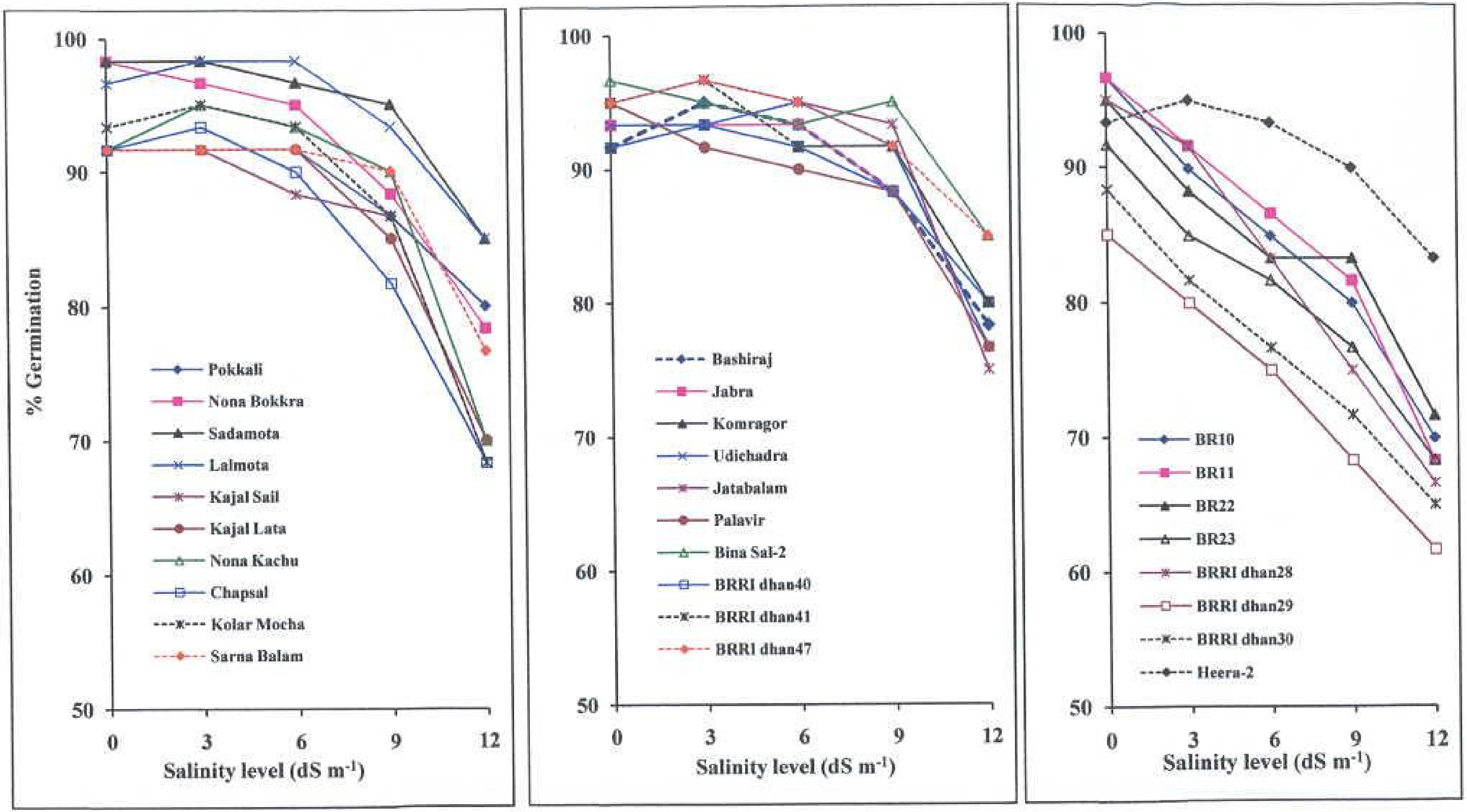

Figure 4. The effect of different salinity levels on germination of 28 rice cultivars

Thirumeni *et al.* (2001) and Pushpam and Rangasamy (2002) observed that seed germination was affected by the increase of salinity. Cristo *et al.* (2001) revealed that the % germination was different due to rice genotypes. They also stated that the new rice lines 8736 and 8734 showed better performance than Pokkali. Pareek *et al.* (1998) stated that the NaCl stress caused a reduction in percentage germination of the rice seeds. High salt concentrations *i.e.* 2-4% showed strong inhibitory effect and markedly decreased the final germination (Alam *et al.*, 2001) which corroborate our results.

Morphological characters

Different morphological characters of the rice seedlings of 28 selected cultivars/ lines /genotypes were studied in view to evaluate their response to different levels of salinity. The morphological characters of the seedlings studied include plant height, root and shoot dry weight, and total dry matter content of the rice cultivars/ lines under study and the results have been expressed in terms of absolute values (Appendix 3) (Dewey,1960) and relative values (Appendix 1, 2 & 4) (Maas and Hoffman, 1977; Maas, 1986) of the characters. The relative growth performance of seedlings of different cultivars/ lines was calculated to evaluate the salt tolerance for each genotype by formula proposed by Ashraf and Waheed (1990). They further stated that the relative growth data is very effective to evaluate the salt tolerance of different cultivars/ lines to minimize the genetic growth performance *i.e.* short or long.

$$Relative\ Growth\ Data\ (\%) = \frac{\text{The data of salt treated seedling of a genotype}}{\text{The data of control treated seedling of that genotype}} \times 100.$$

4.2 Seedling height

The relative seedling height (%) of different rice cultivars differed significantly at 1% level of probability due to the mean effect of different salinity levels under study (Figure 5). The cultivars Heera-2, Sadamota, Jotabalam, Chapsal, Pokkali and BINA Sal-2 produced higher seedling height. On the other hand, cultivars BR 23 showed the lowest performance followed by BR 22 (Appendix 1).

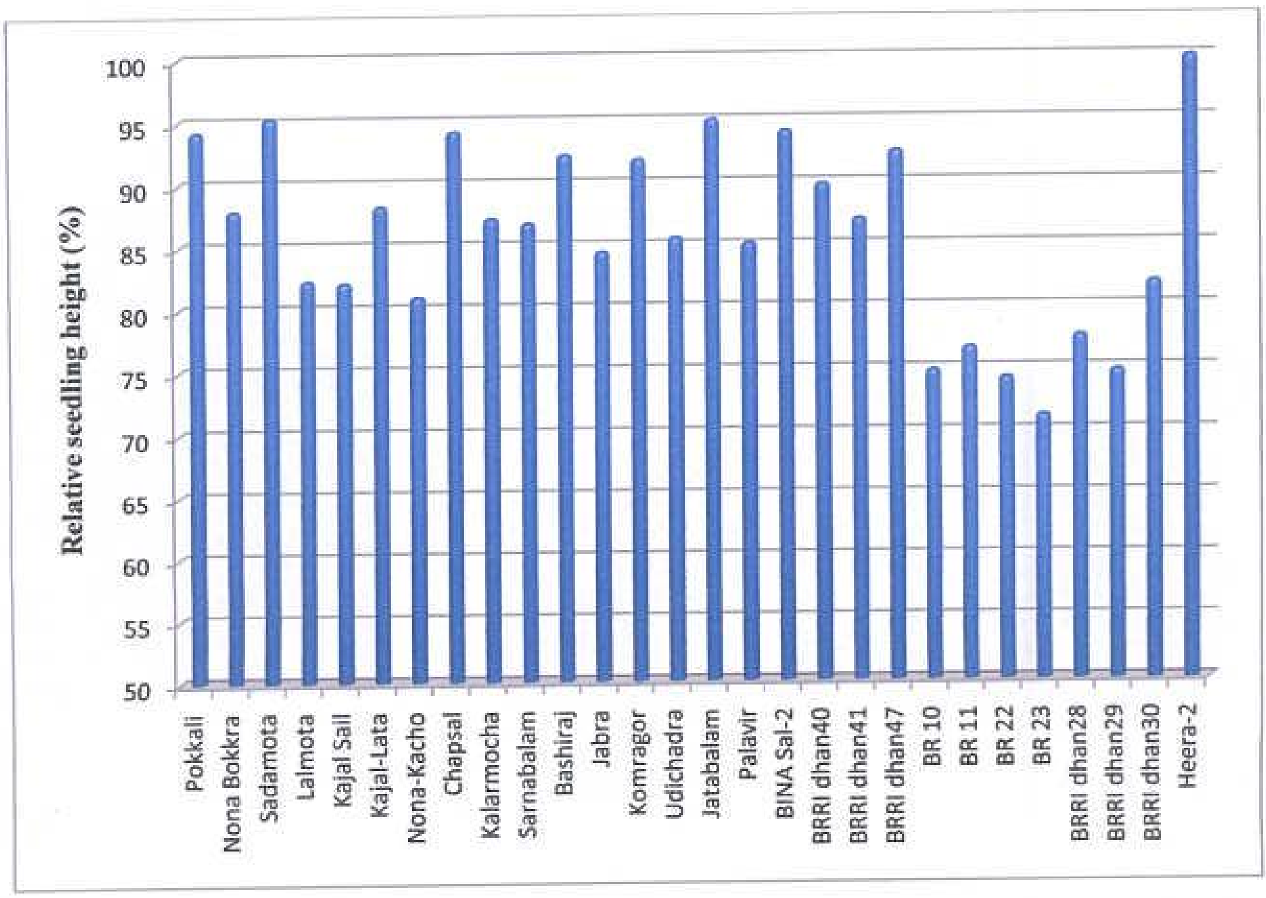

Figure 5.The effect of cultivar on seedling height of rice plant (mean of 5 salinity levels)

The results in Figure 6 show that the relative seedling height (% seedling height to control conditions) significantly decreased due to the effect of different salinity levels. The highest % relative seedling height was obtained at 3 dS m^{-1} level of salinity (101.54%) and the second highest (100%) was obtained with control (0 dS m^{-1}); there after the plant height gradually decreased with the increase in salinity levels and reached to the lowest (63.09%) at 12 dS m^{-1}(Appendix 2).

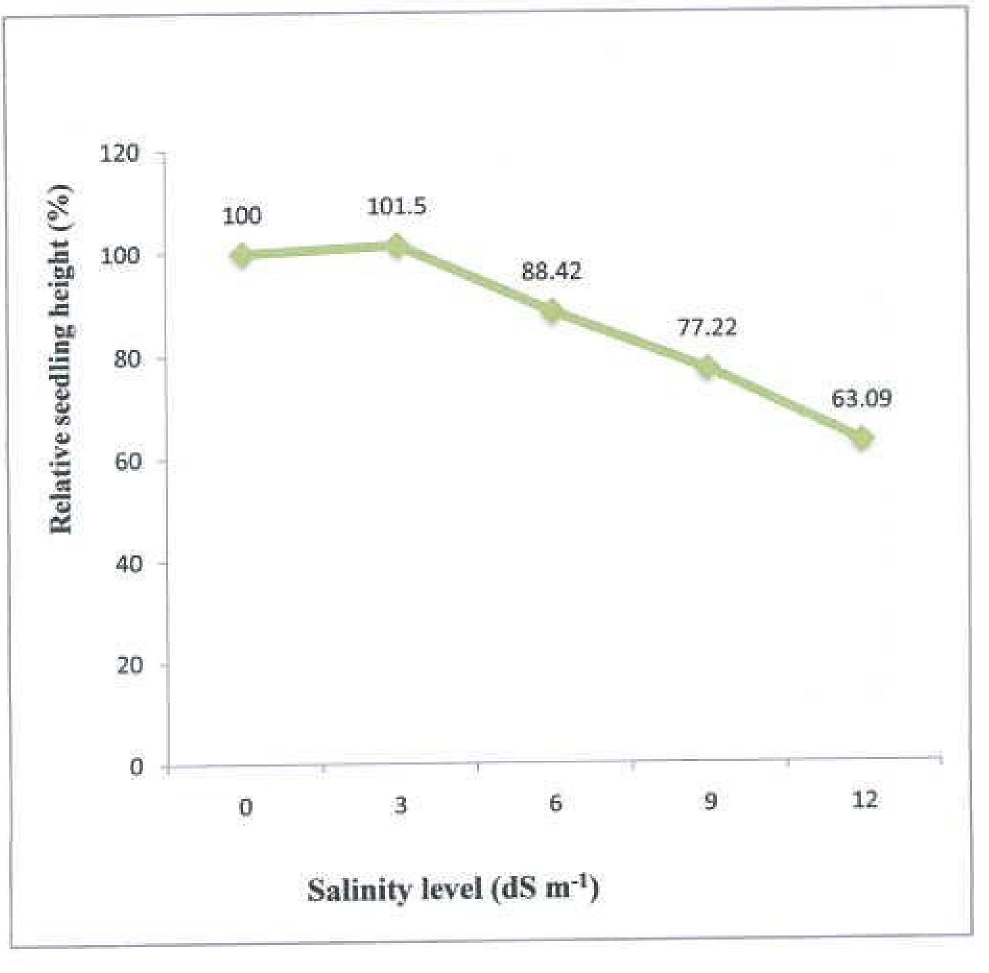

Figure 6. The effect of salinity on seedling height of rice plant (mean of 28 rice cultivars)

Relative seedling height differed significantly due to the interaction effect of cultivar and salinity. The % relative seedling height was found to decrease slowly with the increase in salinity levels in cultivars Heera-2, Sadamota, Chapsal and Pokkali and it sharply decreased in cultivar BR 23 (Figure 7 and Appendix 4).

Cristo *et al.* (2001) conducting a laboratory experiment with new rice lines 8610, 8736, 8734 and cultivars Pokkali (salt tolerant) and Amistad-82 (salt susceptible), at different saline concentrations (0.4, 0.7 and 1.0%) found that plant height was affected by the increase of salinity levels and the rice lines 8736 and 8734 were better than Pokkali.

Thirumeni *et al.* (2001) found that % germination and seedling growth decreased with increasing salt concentration in rice cultivars. Alam *et al.* (2001) stated that the critical level of salinity for seedling growth was about 5 dS m^{-1}, the most common salinity effect was stunting of plant growth, whereas leaf withering was less apparent and the growth parameters such as dry matter, seedling height, root length and emergence of new roots decreased significantly at electrical conductivity value of 5-6 dS m^{-1}. Seedling height, root length, seedling dry weight were highly correlated with the saline stress tolerance index, indicating that measuring varietal ratings for salt tolerance at the early stage of growth via these traits was likely to be effective (Gonzalez and Ramirez, 1998).

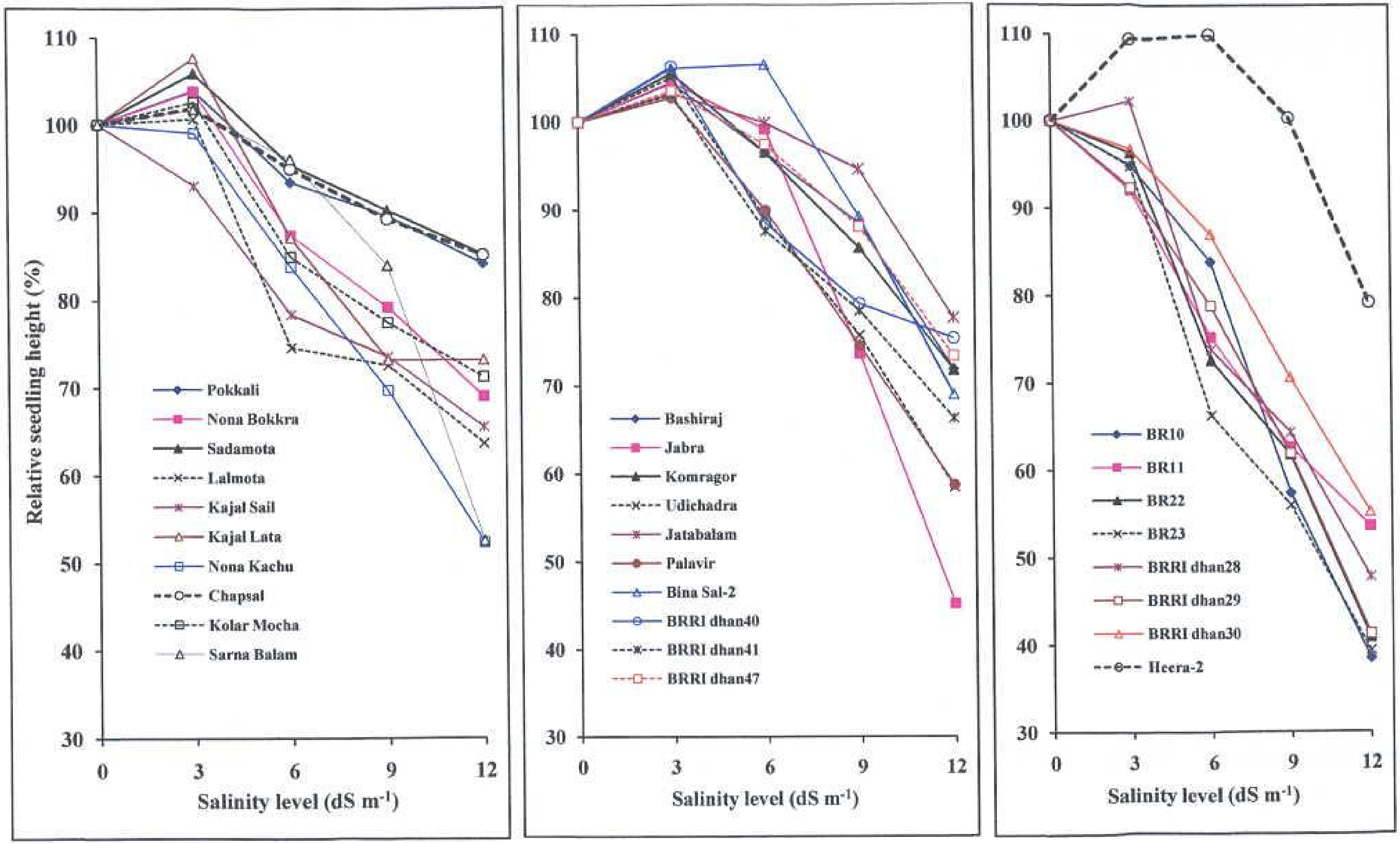

Figure 7. The effect of different salinity levels on seedling height of 28 rice cultivars

4.3 Root dry weight

Among the 28 rice genotypes/cultivars, % relative RDW differed significantly due to the mean effect of different salinity levels (Figure 8). The higher % relative RDW values were observed in Nona Bokkra (100.20%) that was significantly similar to Heera-2 (99.59%), Pokkali (97.07%), Jotabalam (96.47%) and BRRI dhan47 (95.69%) and the lower values were recorded in BRRI dhan28 (60.25%) followed by BRRI dhan29 (61.62%) and BR 22 (62.32%). The relative RDW of the remaining cultivars ranged from 64.42 – 90.82% (Appendix 1).

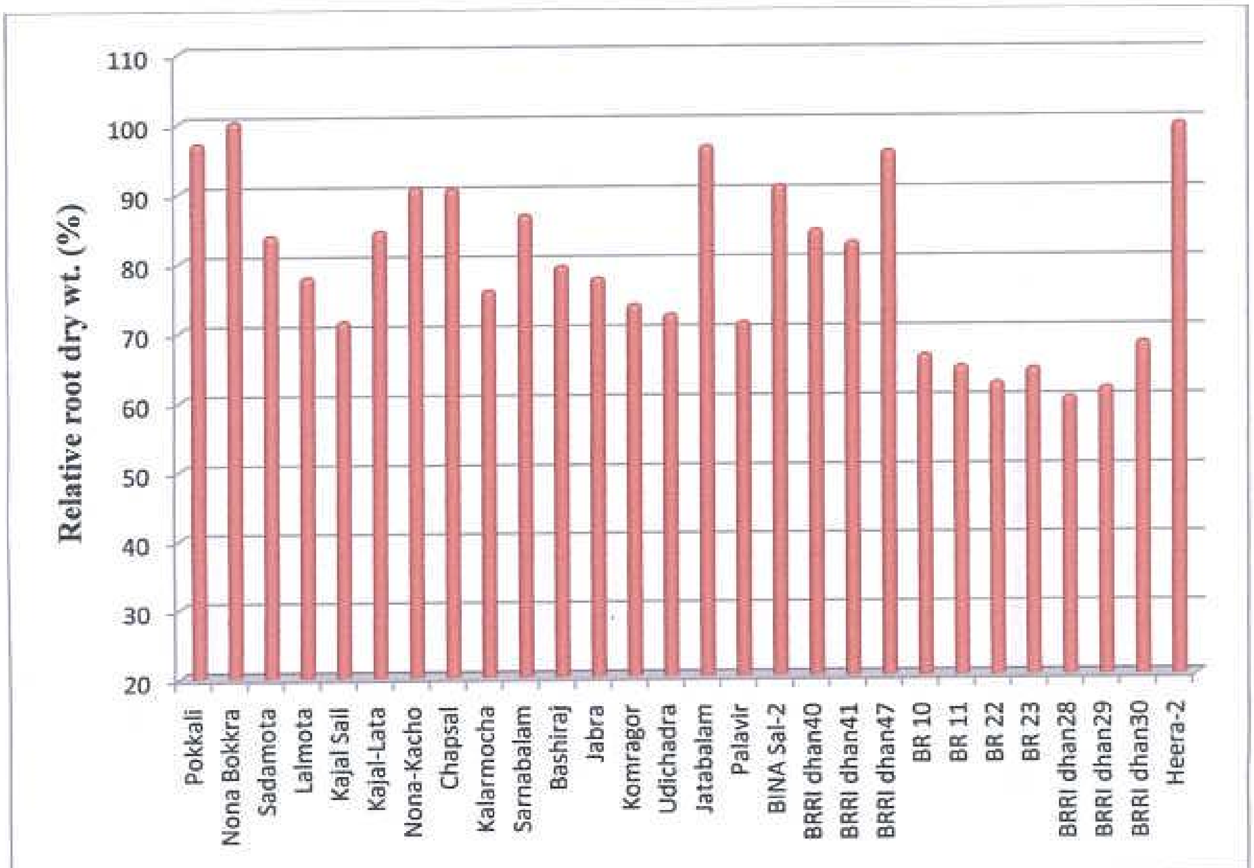

Figure 8. The effect of cultivar on root dry weight of rice plant (mean of 5 salinity levels)

The relative root dry weight (RDW) of different rice cultivars significantly decreased with the increase in salinity levels (Figure 9). The % relative RDW was highest (103.70%) at 3 dS m^{-1} salinity treatment and it was lowest (41.46%) at 12 dS m^{-1} level of soil salinity (Appendix 2).

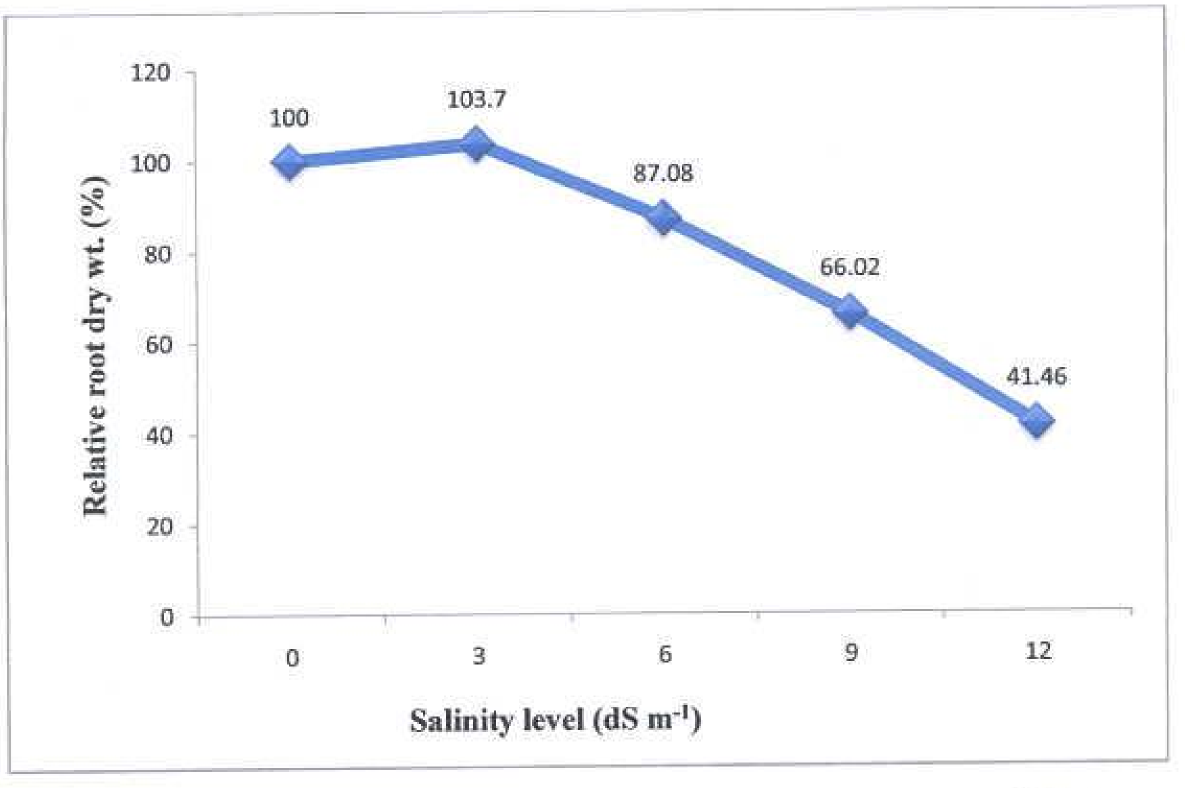

Figure 9. The effect of salinity on root dry weight of rice plant (mean of 28 rice cultivars)

The effect of different salinity levels on relative root dry weight (RDW) of different cultivars varied significantly (Appendix 4). The % relative RDW slowly decreased with increasing the salinity levels in genotypes/cultivars Heera-2, Nona Bokkra, Pokkali, BRRI dhan47 and Jatabalam and it sharply decreased with increasing salinity levels in cultivars Kajal Sail and BRRI dhan29 (Figure 10).

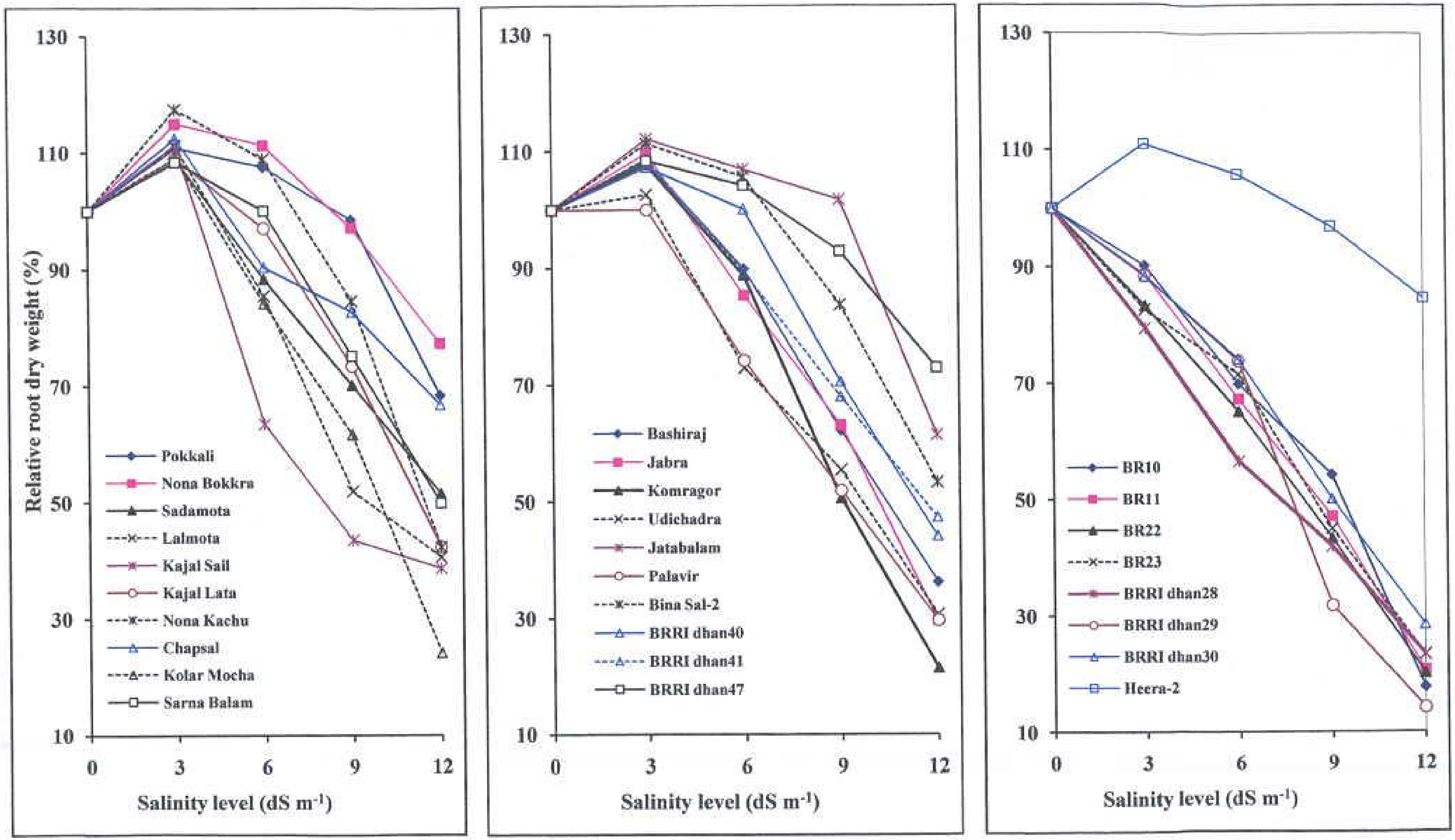

Figure 10. The effect of different salinity levels on root dry weight of 28 rice cultivars

Alam *et al.* (2001) stated that the critical level of salinity for seedling growth was about 5 dS m^{-1}. They also found that during vegetative growth, dry weight of roots and root length were affected by salinity. Pushpam and Rangasamy (2002) observed that salinity induced general reduction in shoot and root length in susceptible cultivars (IR-20, IR-50) compared to the tolerant cultivar (Pokkali).

Pareek *et al.* (1998) found that branching of the roots of the plants was arrested in 100 mM NaCl and with further increase in NaCl concentration to 200 mM, the embryonic axis emerged from the seeds but it did not show any further growth with respect to its elongation. With further increase in NaCl concentration, the root morphology was drastically affected as the development of fibrous root system was not seen in NaCl-treated seedlings. It was found that the effect of different salinity levels on the % relative RDW was less affected in cultivars Heera-2, Nona Bokkra, Pokkali, BRRI dhan47 and Jatabalam and it was highly affected in cultivars Kajal Sail and BRRI dhan29 as compared to other cultivars/genotypes (Figure 10). The suppression of root growth seems to be due to osmotic imbalance and excess concentration of Na^+, Cl^-.

4.4 Shoot dry weight

The % relative SDW of different rice genotypes/lines varied significantly due to the mean effect of salinity levels used (Appendix 1).The genotypes Heera-2, Chapsal, BINA-Sal-2, Nona Bokkra, Lalmota, Jotabalam and Pokkali produced higher % relative SDW and the cultivars BRRI dhan29 followed by BR 23, BR 10, BR22, BR 11, BRRI dhan30 and

BRRI dhan28 contained the lower relative SDW due to mean effect of the salinity levels (Figure 11).

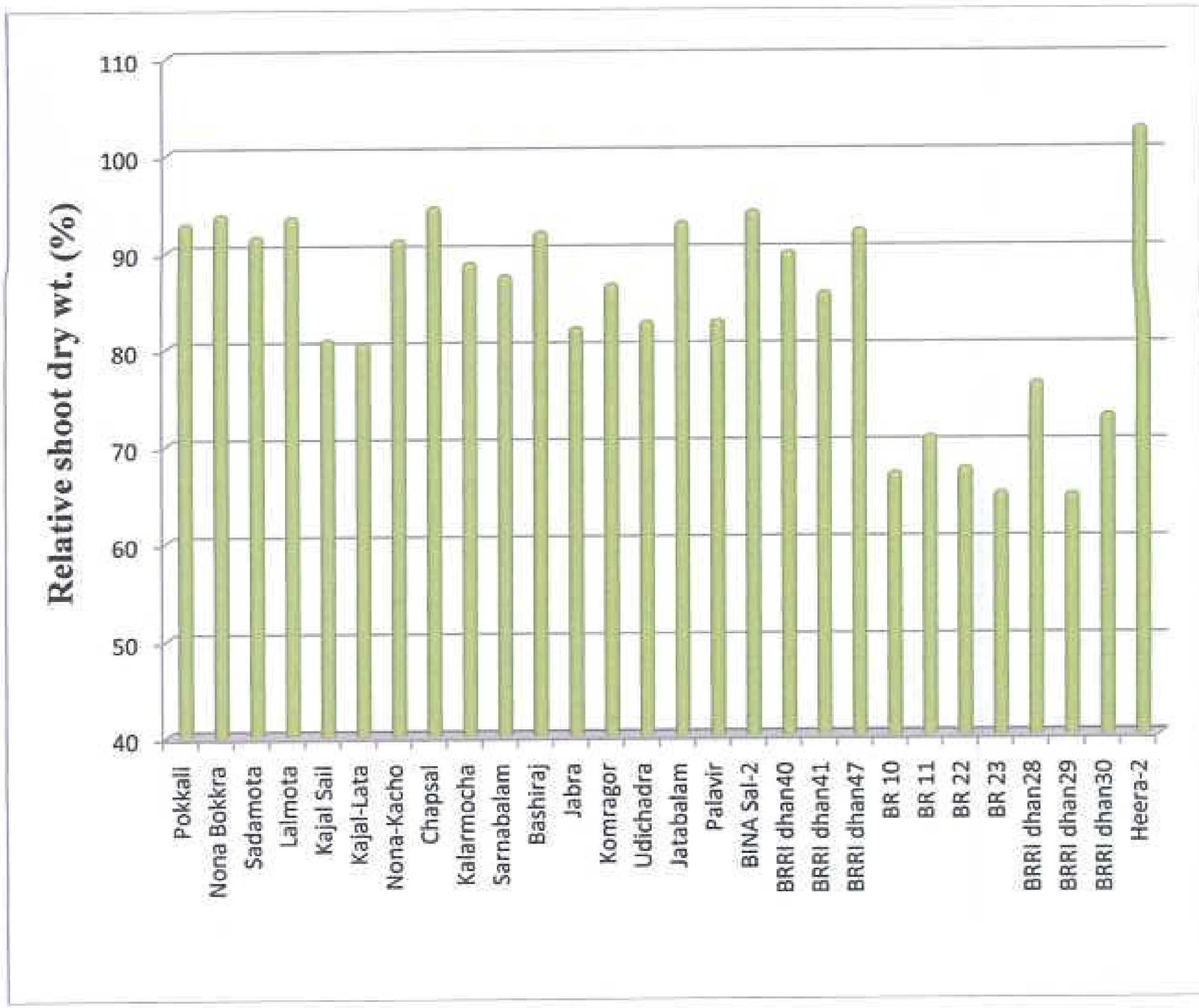

Figure 11. The effect of cultivar on shoot dry weight of rice plant (mean of 5 salinity levels)

The % relative shoot dry weight (SDW) per seedling of different rice genotypes/cultivars (mean of 28 genotypes) decreased as the level of salinity increased and the reduction was statistically significant at 1% level of probability (Figure 12). The % relative SDW was highest (105.35%) in 3 dS m^{-1} treatment and it was lowest (51.86%) at the highest level of salinity (12 dS m^{-1}) (Appendix 2).

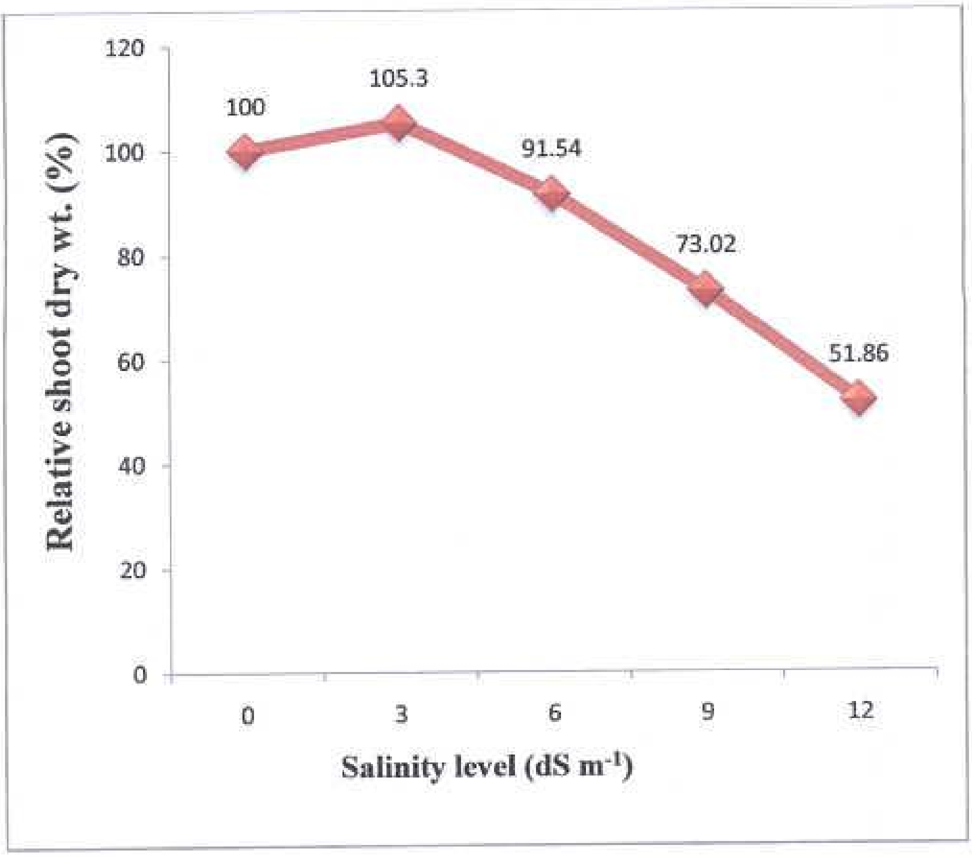

Figure 12. The effect of salinity on shoot dry weight of rice plant (mean of 28 rice cultivars)

The Figure 13 showed that the different salinity levels had significant effect on relative shoot dry weights. The % relative SDW was less affected in cultivars Heera-2, Chapsal, Lalmota and Nona Bokkra and it was highly affected in cultivars BR 23 and BRRI dhan29 as compared to other cultivars due to increase in the level of salinity (Appendix 4).

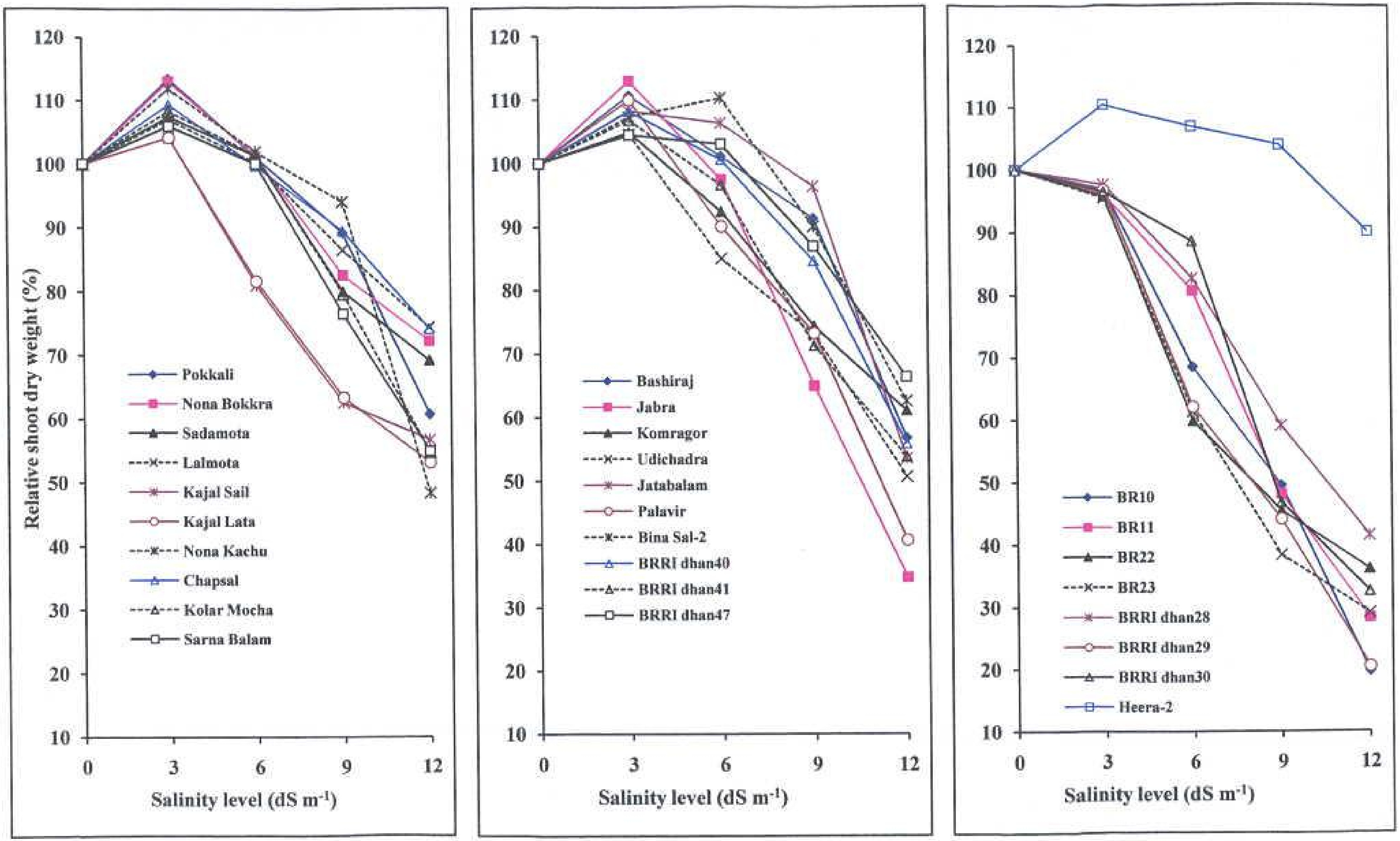

Figure 13. The effect of different salinity levels on shoot dry weight of 28 rice cultivars

Cristo *et al.* (2001) stated that at initial stage plant growth was affected by the increase of salinity level. Similar opinion was also given by Rodrigues *et al.* (2002) and Thirumeni *et al.* (2001). Alam *et al.* (2001) stated that the critical level of salinity for seedling growth was about 5 dS m^{-1} and growth parameter such as dry matter, seedling height, root length and emergence of new roots decreased significantly at an electrical conductivity value of 5-6 dS m^{-1}. They also observed that during vegetative period, the most common salinity effect was stunting of plant growth, and the shoot growth was more suppressed than that of root.

4.5 Total dry matter

The results in Figure 14 show that the mean effect of salinity levels significantly influence the % relative total dry matter (TDM) of the rice cultivars/genotypes under study. The values of % relative TDM were observed higher in Heera-2 (101.80%), Nona Bokkra (94.74%), Chapsal (93.81%), Pokkali (93.76%), BINA Sal-2 (93.57%), Jotabalam (93.29%), BRRI dhan47 (92.75%) and Lalmota (91.69%) and the lowest (64.01%) amount was found in BRRI dhan29 (Appendix 1).

The relative total dry matter (TDM) of different genotypes/cultivars of rice differed significantly due to the influence of different levels of salinity (Figure 15). The highest % relative TDM (104.95%) was obtained at 3 dS m^{-1} level and the lowest (49.49%) was at 12 dS m^{-1} level of salinity. The reduction in TDM was severe at the highest level of salinity employed (Appendix 2).

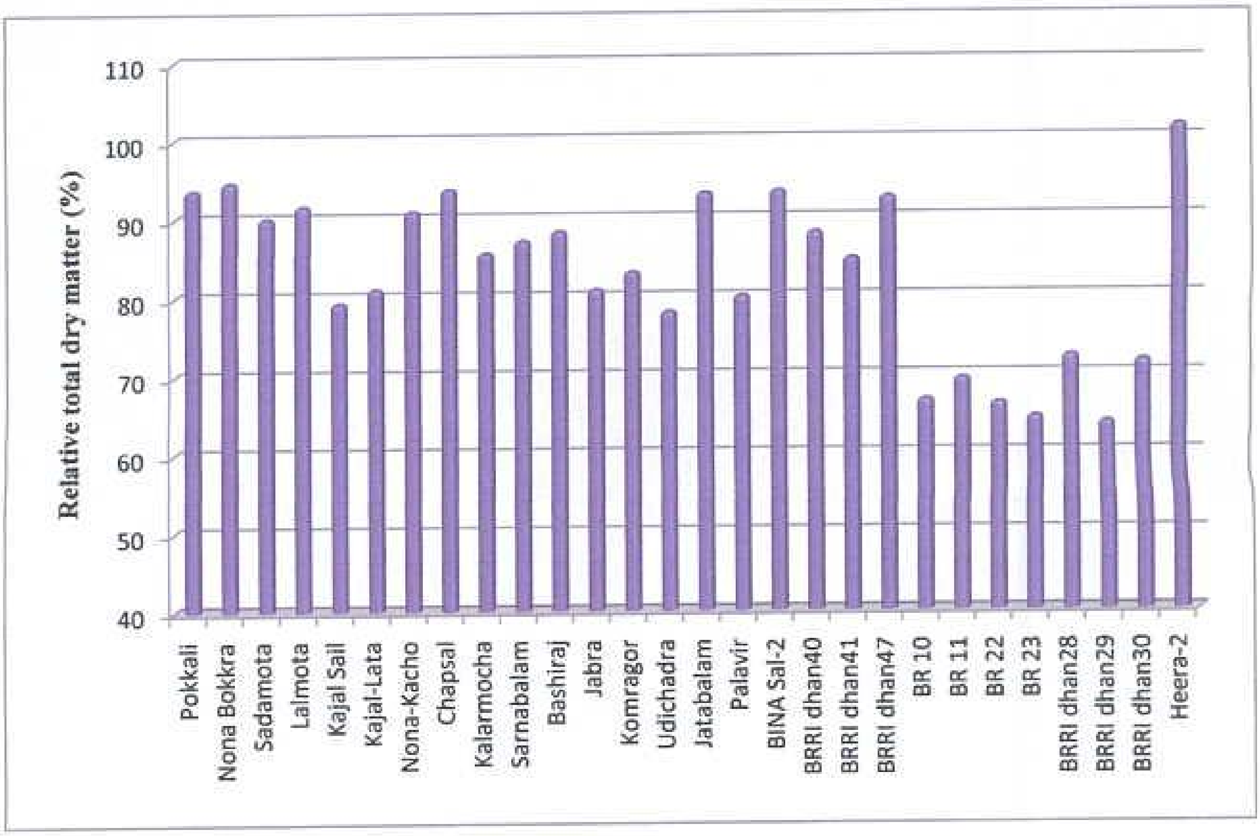

Figure 14. The effect of cultivar on total dry matter of rice plant (mean of 5 salinity levels)

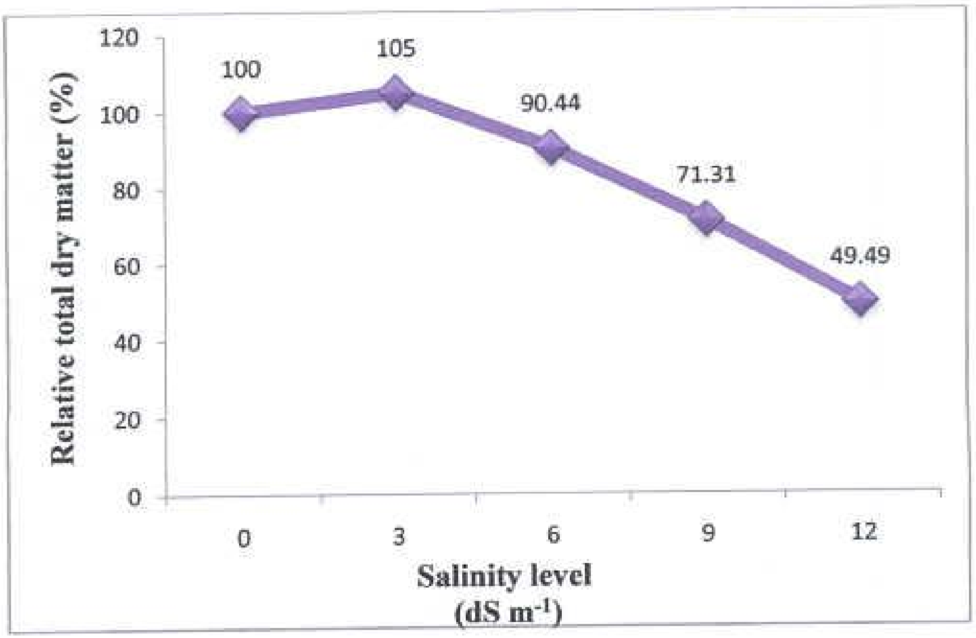

Figure 15. The effect of salinity on total dry matter (TDM) (mean of 28 cultivars)

The results indicate that there were significant differences on the effect of different salinity levels on relative TDM yield per seedling of different rice cultivars (Figure 16). The % relative TDM yield slowly decreased with increase in the salinity levels in cultivars Heera-2, Chapsal and Nona Bokkra and it decreased sharply with increase in salinity levels in cultivars BRRI dhan29 and BR 23. It has been shown (Figure 16) that TDM yield of all the cultivars/genotypes studied decreased with rise the salinity levels from 3 dS m^{-1} to 12 dS m^{-1} though some of the cultivars (Heera-2, Nona Bokkra, Chapsal, Pokkali, BINA Sal-2, Jotabalam, BRRI dhan47 and Lalmota) produced higher TDM indicating that those were some what tolerant (Appendix 4).

These findings are in agreement with Shannon *et al.* (1998) who observed that salinity led to reductions in shoot and root dry weights. Zeng and Shannon (2000) in greenhouse experiment in sand and irrigated with nutrient solution amended with NaCl and $CaCl_2$ (2:1 mole ratio) at 1.9, 3.4, 4.5, 6.1,7.9, and 11.5 dS m^{-1} EC with rice cultivar M-202 studied the salinity effect on seedling and yield components of rice. They observed that seedling growth was significantly reduced by salinity even at the lowest salinity treatment of 1.9 dS m^{-1} as compared to control treatment. Gonzalez and Ramirez (1998) reported that seedling height, root length, seedling dry weight and relative leaf water content were highly correlated with the saline stress tolerance index. Alam *et al.* (2001) stated that the critical level of salinity for seedling growth was about EC 5 dS m^{-1}. They also found that growth parameters such as dry matter, seedling height, root length and emergence of new roots decreased significantly at an electrical conductivity value of 5-6 dS m^{-1}.

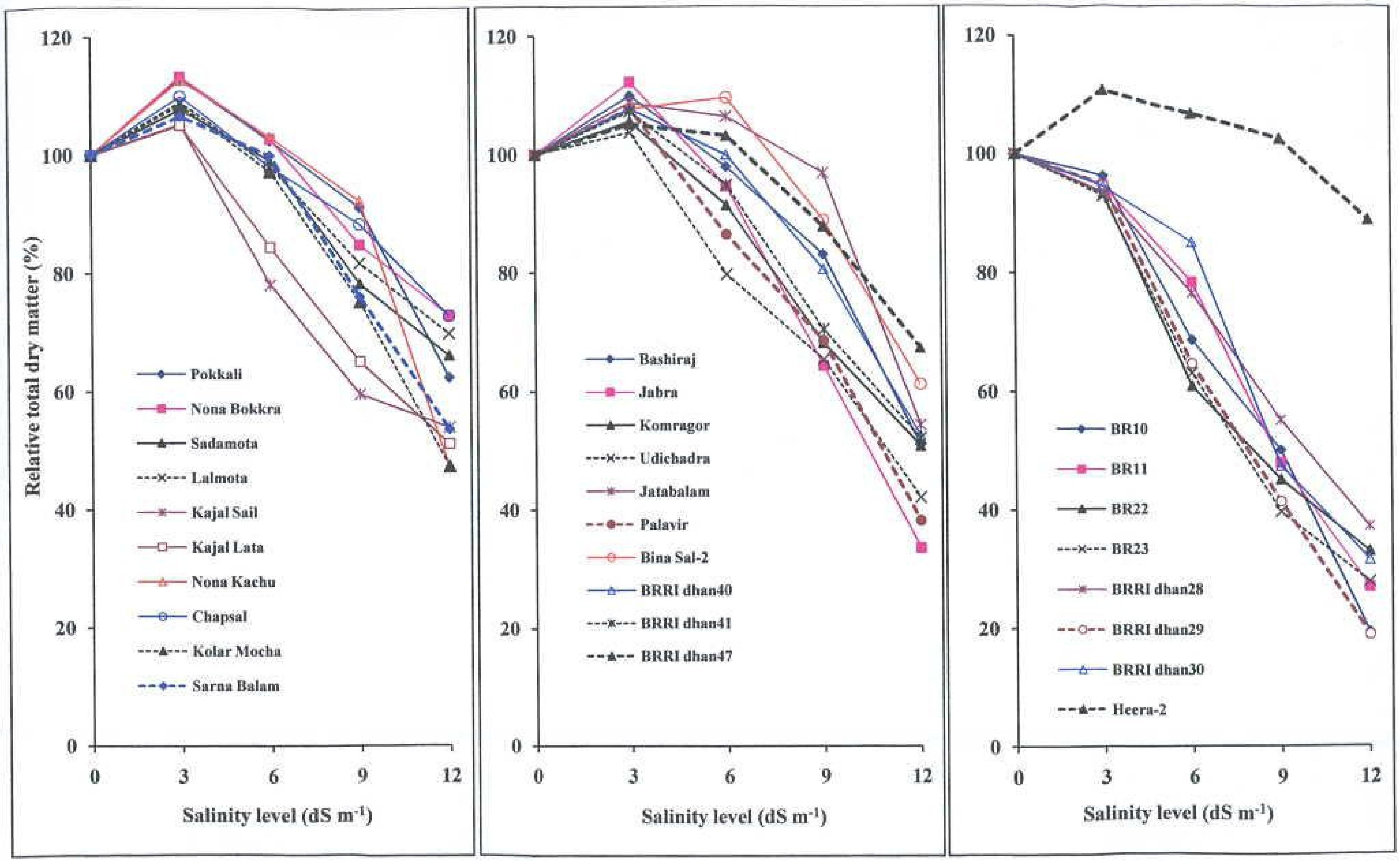

Figure 16. The effect of different salinity levels on total dry matter (TDM) of 28 rice cultivars

Concentration of Na^+, K^+, Ca^{2+} and Mg^{2+} in shoots of rice seedlings

4.6 Concentration of Na^+

The concentration of Na^+ in seedlings of different cultivars/genotypes of rice differed significantly due to the application of different levels of salinity (Figure 17). The highest concentration of Na^+ was found in cultivars BRRI dhan29 and BRRI dhan30 (1.38%) followed by BR 23 (1.283%) and BRRI dhan 28 (1.237%) where the cultivars Bashiraj, BINA Sal-2 and Nona Bokkra contained the lowest concentration of Na^+ (0.95%) which was statistically same to the cultivars Komragor, Lalmota and BRRI dhan47 (Figure 17). Other cultivars showed the intermediate values. (Appendix 5).

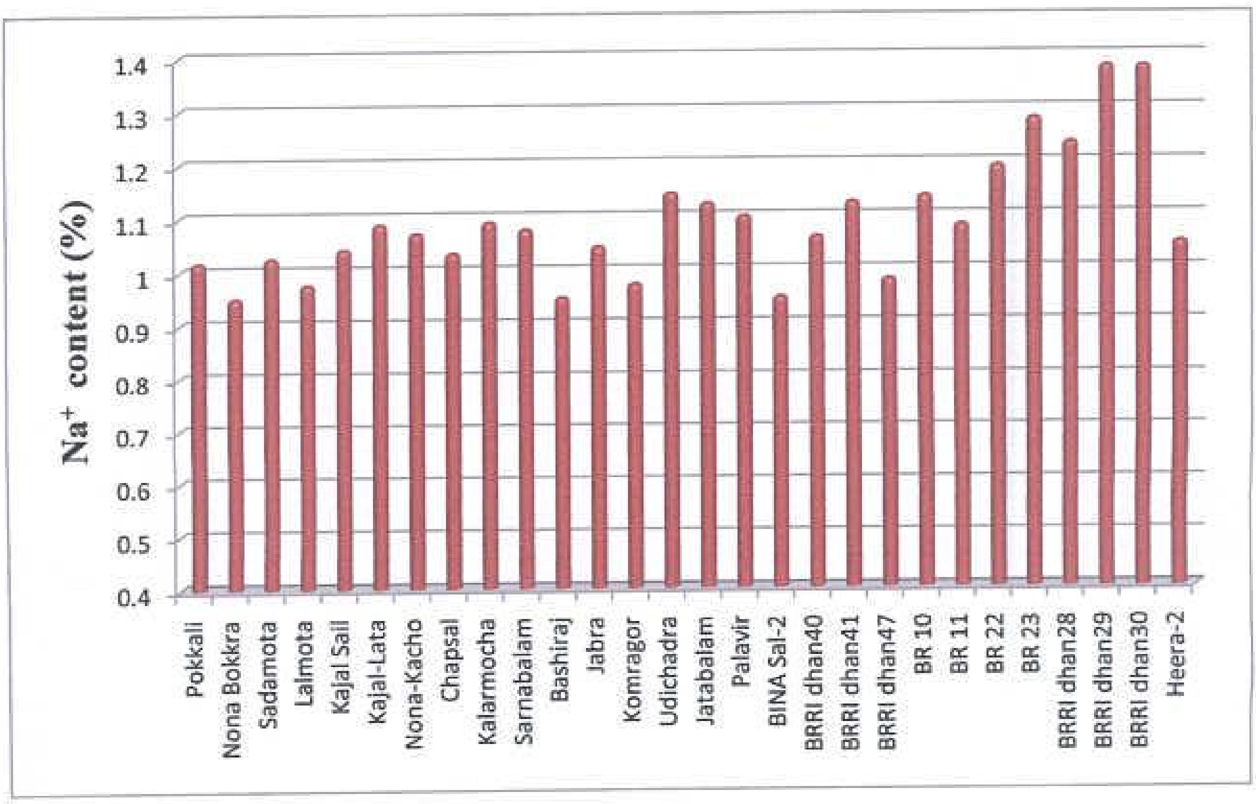

Figure 17. The effect of cultivar on Na^+ content of rice (mean of 5 salinity levels)

The concentration of Na^+ in seedlings of different rice cultivars/lines was significantly influenced due to the increase of salinity levels (Figure 18). The highest concentration of Na^+ (2.345%) was observed at the highest salinity level (12 dS m^{-1}) and it was the lowest (0.361%) at control treatment (Appendix 6).

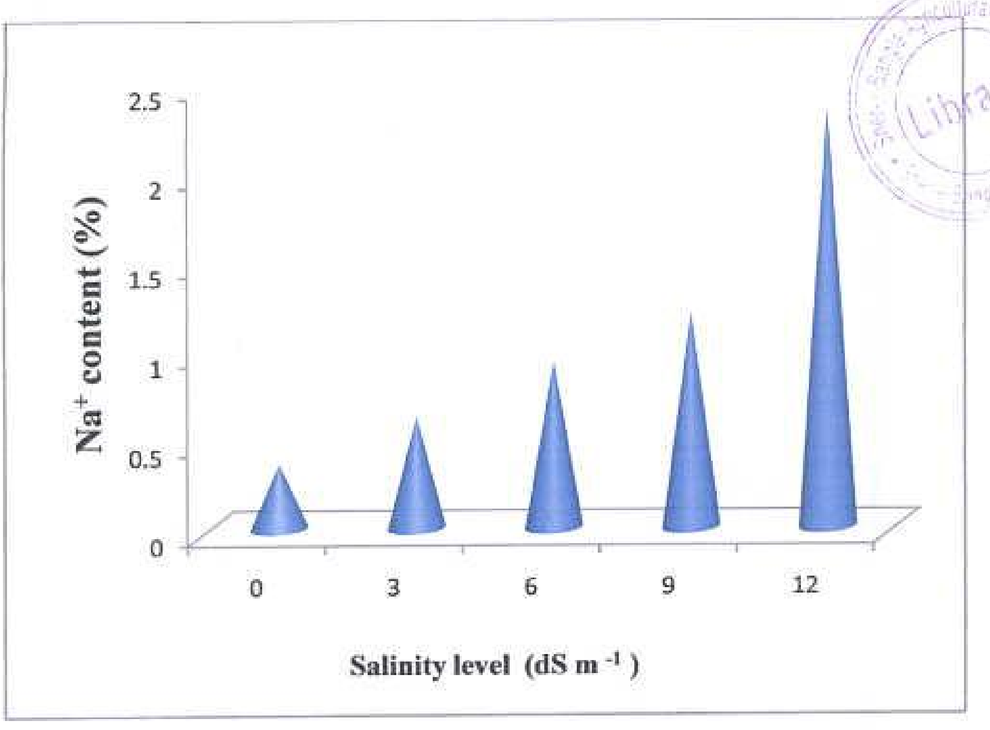

Figure 18. The effect of salinity on effective tillers hill^{-1} (mean of 28 rice cultivars)

On the basis of Figure 19, it was noted that the Na^+ content (%) increased slowly in cultivars Lalmota, Bashiraj, BINA Sal-2, BRRI dhan47, Nona Bokkra, Pokkali, and Heera-2 with the increase in salinity upto 12 dS m^{-1} level while it increased sharply in cultivars BRRI dhan29, BRRI dhan30 and BR 10. The highest percentage of Na^+ content was recorded in BRRI dhan29 (2.79 %) followed by BRRI dhan30 (2.77 %) and BR 10 (2.64 %) and Jota Balam (2.55 %) also showed higher values at 12 dS m^{-1} than others (Appendix 7).

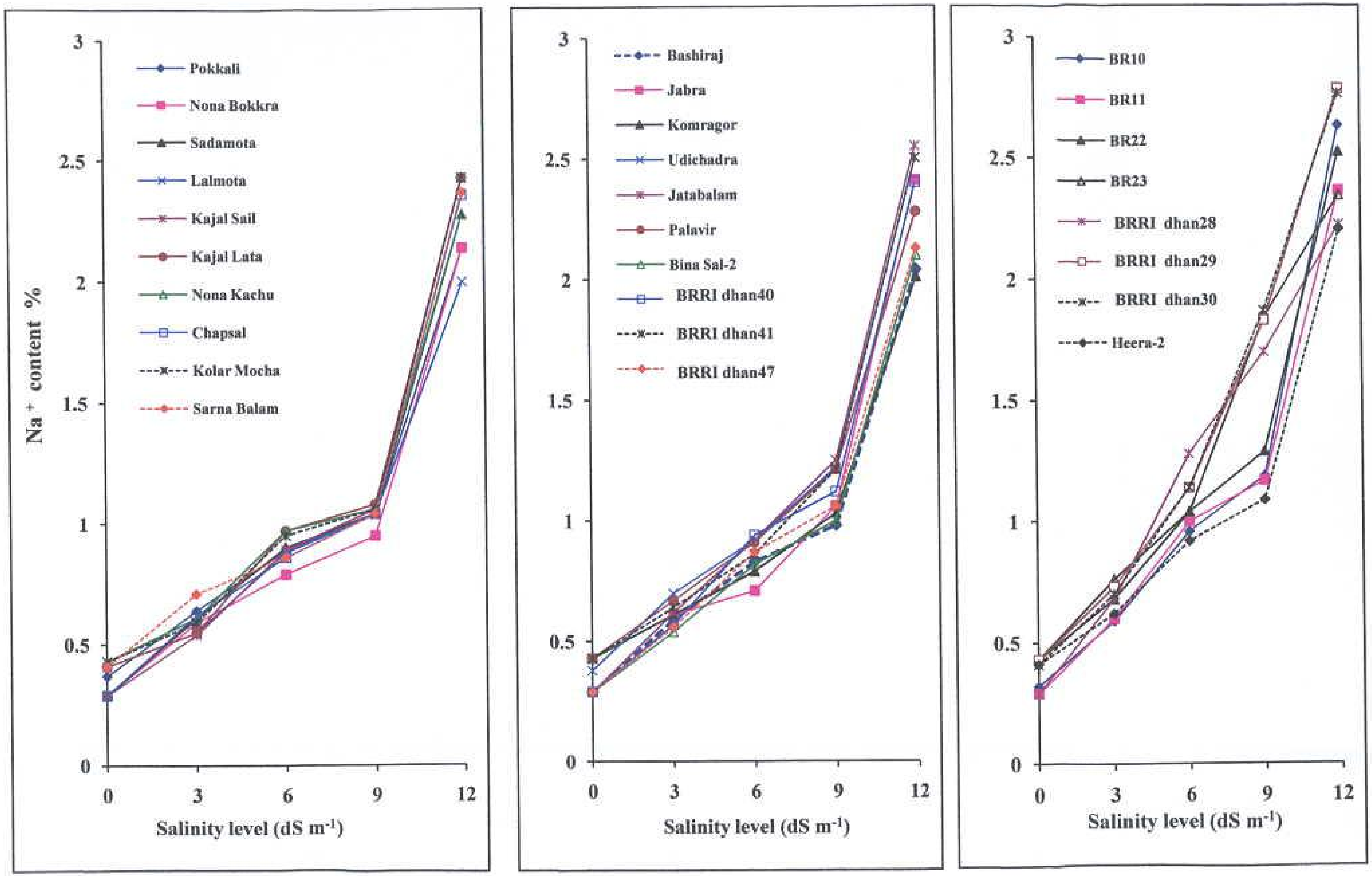

Figure 19. The effect of different salinity levels on Na^+ content (%) of 28 rice cultivars

Salt tolerance in plants is generally associated with low uptake and accumulation of Na^+, which is mediated through the control of influx and/ or by active efflux from the cytoplasm to the vacuoles and also back to the growth medium (Jacoby, 1999). It is well established that Na^+ moves passively through a general cation channel from the saline growth medium into the cytoplasm of plant cells (Marschner, 1995; Jacoby, 1999; Mansour *et al.*, 2003) and the active transport of Na^+ through Na^+/H^+ antiports in plant cells is also evident (Shi *et al.*, 2003). Cha-um *et al.* (2005) and Fageria (2003) also found similar results.

Dionisio and Tobita (2000) and Pushpam and Rangasamy (2004) reported that an increase in salinity level increased the content of Na^+.

4.7 Concentration of K^+

The results on the mean effect of different levels of salinity indicate that the K^+ concentration in shoots of different rice cultivars seedling significantly differed (Figure 20). The cultivar Heera-2 contained the highest concentration of K^+ (1.128%) followed by BRRI dhan47 (1.111%) and BINA Sal-2 (1.074%); and the cultivar Jabra contained the lowest amount of K^+ (0.916%) which was statistically similar to the cultivars BR 11, BRRI dhan29, BRRI dhan30 and Pokkali (Appendix 5).

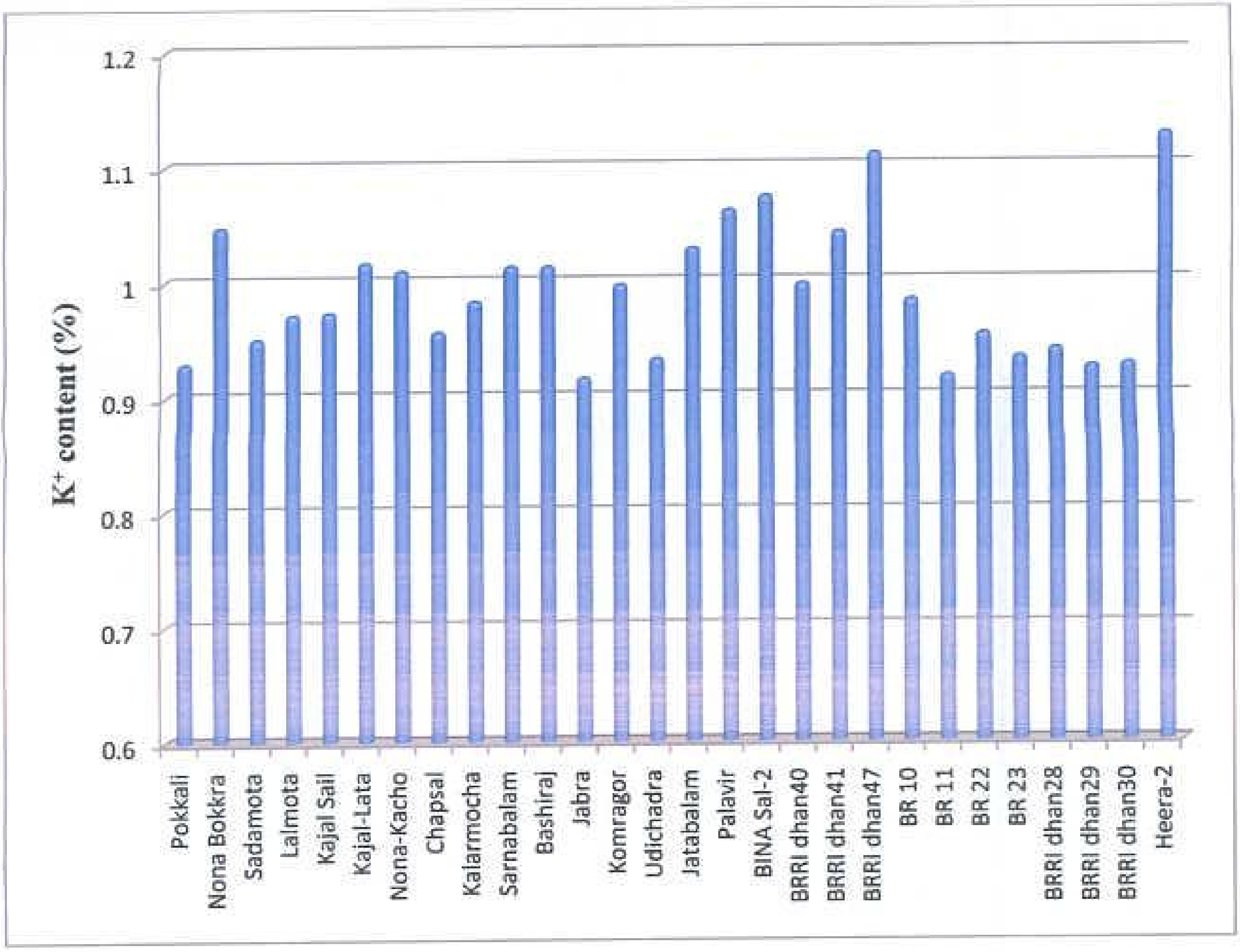

Figure 20. The effect of cultivar on K^+ content (%) of rice (mean of 5 salinity levels)

The results presented in Figure 21 show that the K^+ content in seedlings of different rice cultivars/lines varied significantly due to the application of different levels of salinity. It appeared that the content of K^+ in shoots of rice seedlings decreased with increase in salinity levels. The highest amount of K^+ (1.861%) was found at control treatment and it was the lowest (0.403%) at 12 dS m^{-1} level of salinity (Appendix 6).

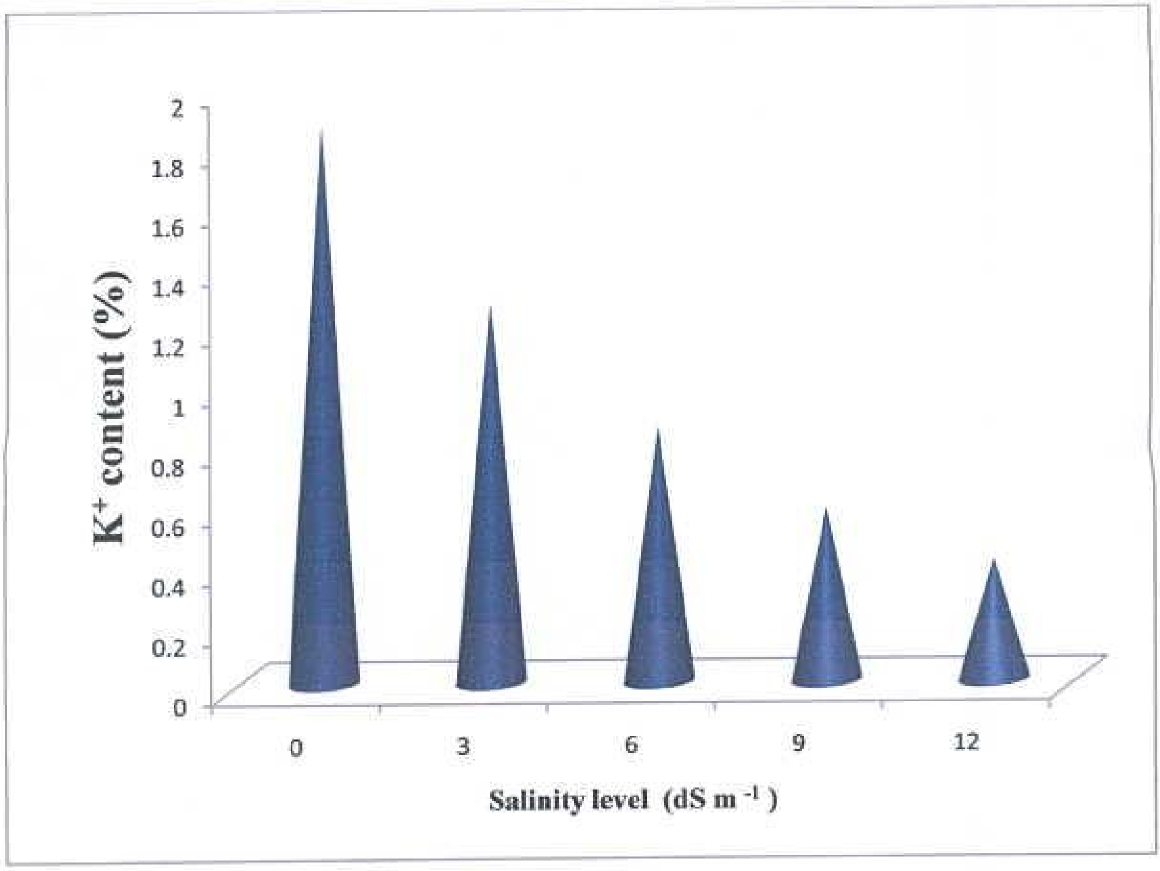

Figure 21. The effect of salinity on K^+ content (%) of rice (mean of 28 rice cultivars)

The combined effect of cultivar and salinity significantly changed the potassium concentration. The K^+ content (%) decreased slowly in cultivars Heera-2, BRRI dhan47, BINA Sal-2, Lalmota, Nona Bokkra, Pokkali, and Chapsal with the increase in salinity levels while it decreased sharply in cultivars BR 23, BR 22, BRRI dhan29 and BR 22 (Figure 22). At 12 dS m^{-1} the highest K^+ content (0.51 %) was found in cultivars BRRI dhan47 and Heera-2, followed by BINA Sal-2 (0.47%), Pokkali (0.45 %) and Chapsal (0.44 %). The lowest percentage of K^+ content was recorded in BR 23 (0.29 %) followed by BR 22 (0.30 %) and BRRI dhan29 (0.31 %) at 12 dS m^{-1} (Appendix 7).

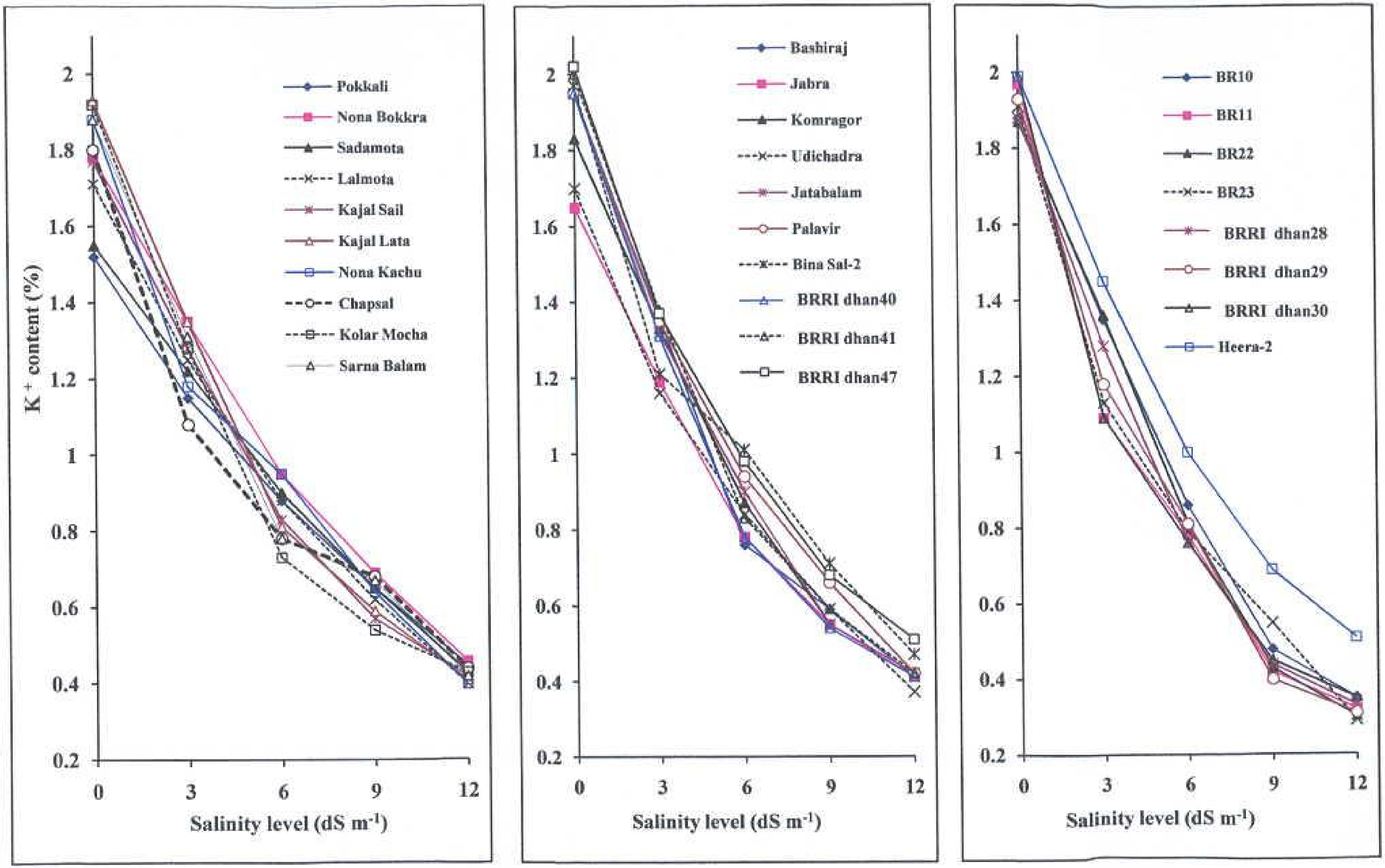

Figure 22. The effect of different salinity levels on K^+ content (%) of 28 rice cultivars

Cha-um *et al.* (2005) conducted an investigation with an objective to evaluate the effective salt-tolerance defense mechanisms in aromatic rice varieties. Pathumthani 1 (PT1), Jasmine (KDML105), and Homjan (HJ) aromatic rice varieties were chosen as plant materials. Rice seedlings photoautotrophically grown *in-vitro* were treated with 0, 85, 171, 256, 342, and 427 mM NaCl in the media. Data, including sodium ion (Na^+) and potassium ion (K^+) accumulation, osmolarity, chlorophyll pigment concentration, and the fresh and dry weights of seedlings were collected after salt-treatment for 5 days. Na^+ in salt-stressed seedlings gradually accumulated, while K^+ decreased, especially in the 342-427 mM NaCl salt treatments.

4.8 Concentration of Ca^{2+}

Results presented in Appendix 5 showed that there was a significant variation on Ca^{2+} content in shoots of different rice cultivars due to the mean effect of different salinity levels. The cultivar Udichadra had the highest concentration of Ca^{2+} (0.533%) followed by BR22 (0.517%), BR 10 (0.513%) and BR 23 (0.509%) and the cultivar Kajal Lata contained the lowest amount of Ca^{2+} (0.39%) {Figure 23}.

It is apparent from the results that the Ca^{2+} content in rice seedlings of different cultivars increased with increase in the levels of salinity (Figure 24). The highest content of Ca^{2+} (0.634%) was found in rice shoots at 12 dS m^{-1} level of salinity and the lowest (0.273%) was at control treatment (Appendix 6).

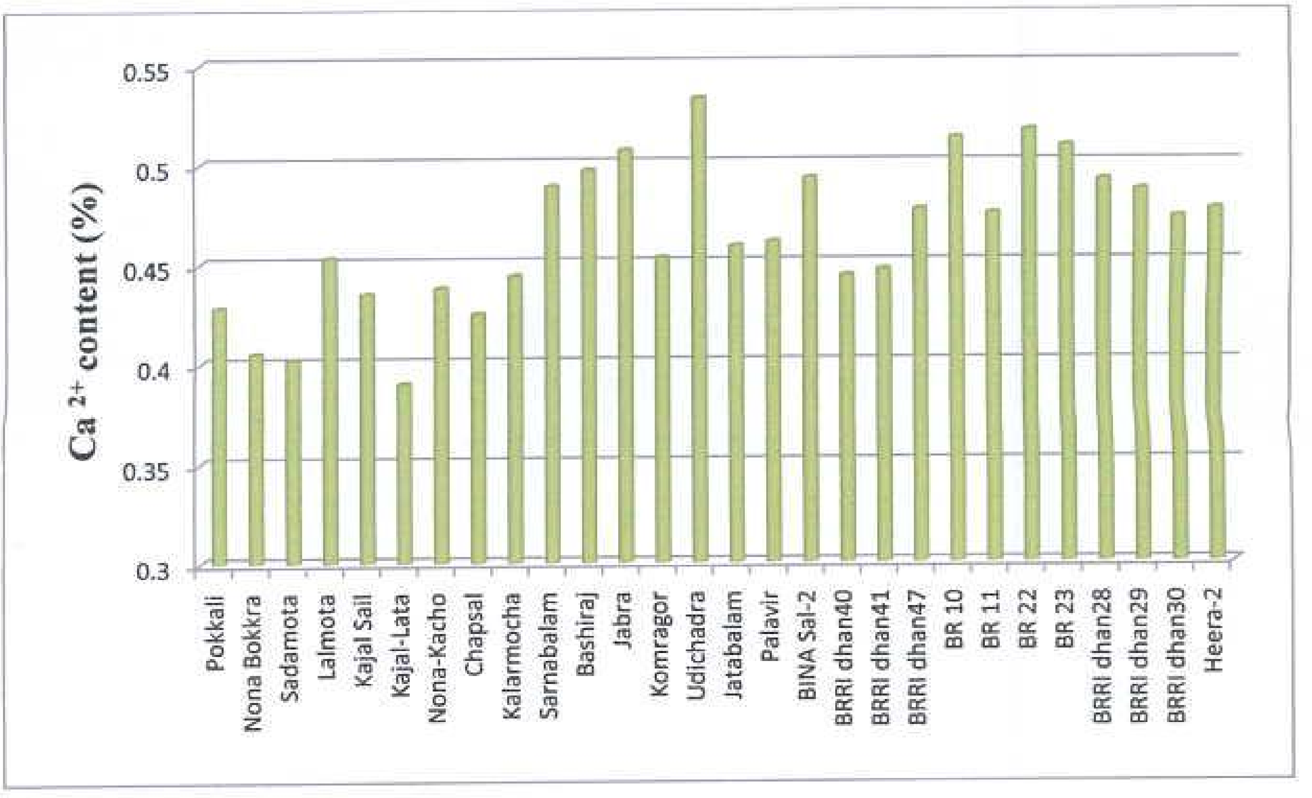

Figure 23. The effect of cultivar on Ca^{2+} content (%) of rice (mean of 5 salinity levels)

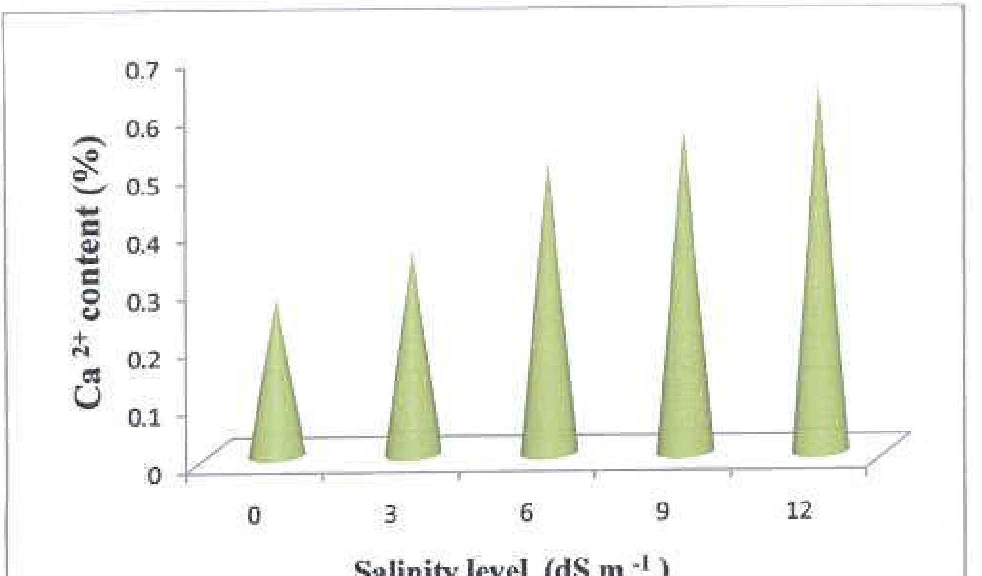

Figure 24. The effect of salinity on Ca^{2+} content (%) of rice plant (mean of 28 rice cultivars)

On the basis of Figure 25, it was noted that the Ca^{2+} content (%) increased with the increase in salinity upto 12 dS m^{-1} level. It increased sharply in cultivars Udichadra, Bashiraj, Sarna Balam and BR 10. At 12 dS m^{-1} the highest percentage of Ca^{2+} content was recorded in Udichadra (0.75 %) followed by Bashiraj (0.73 %) and Sarna Balam (0.72 %).and lowest Ca^{2+} content was showed by Kajal lata (0.51 %) followed by Nona Bokkra (0.54 %), BRRI dhan47 (0.65 %) and BINA Sal-2 (0.67 %) at same salinity level (Appendix 7). This is controverst to the findings of Qadar (1995) where he found that increasing sodicity stress decrease the Ca in shoots.

Many researchers worked on mineral ions concentration in rice seedlings. Among them, Won *et al.* (1992) reported that increasing the levels of salinity resulted in a significant increase in Na^+ content of the shoots, while K^+ decreased. They also observed that the salt tolerant cultivars had lower Na^+ and higher K^+ contents. Lee and Senadhira (1996) found that tolerant varieties absorbed less Na^+ in shoots. They also observed that shoot K^+ concentration did not show any relationship with salinity tolerance. Pushpam and Rangasamy (2004) observed that Na^+ content increased and K^+ decrease in seedlings as the level of stress increased. Lin and Kao (2001) observed that increasing concentrations of NaCl progressively increased both Na^+ and Cl^- in rice seedling. Mandal and Singh (1999) reported that salt tolerant rice cultivars showed lower levels of sodium and higher levels of potassium in rice seedlings than in the salt sensitive cultivars, when subjected to salt stress (EC 12 and 16 dS m^{-1}) treatments.

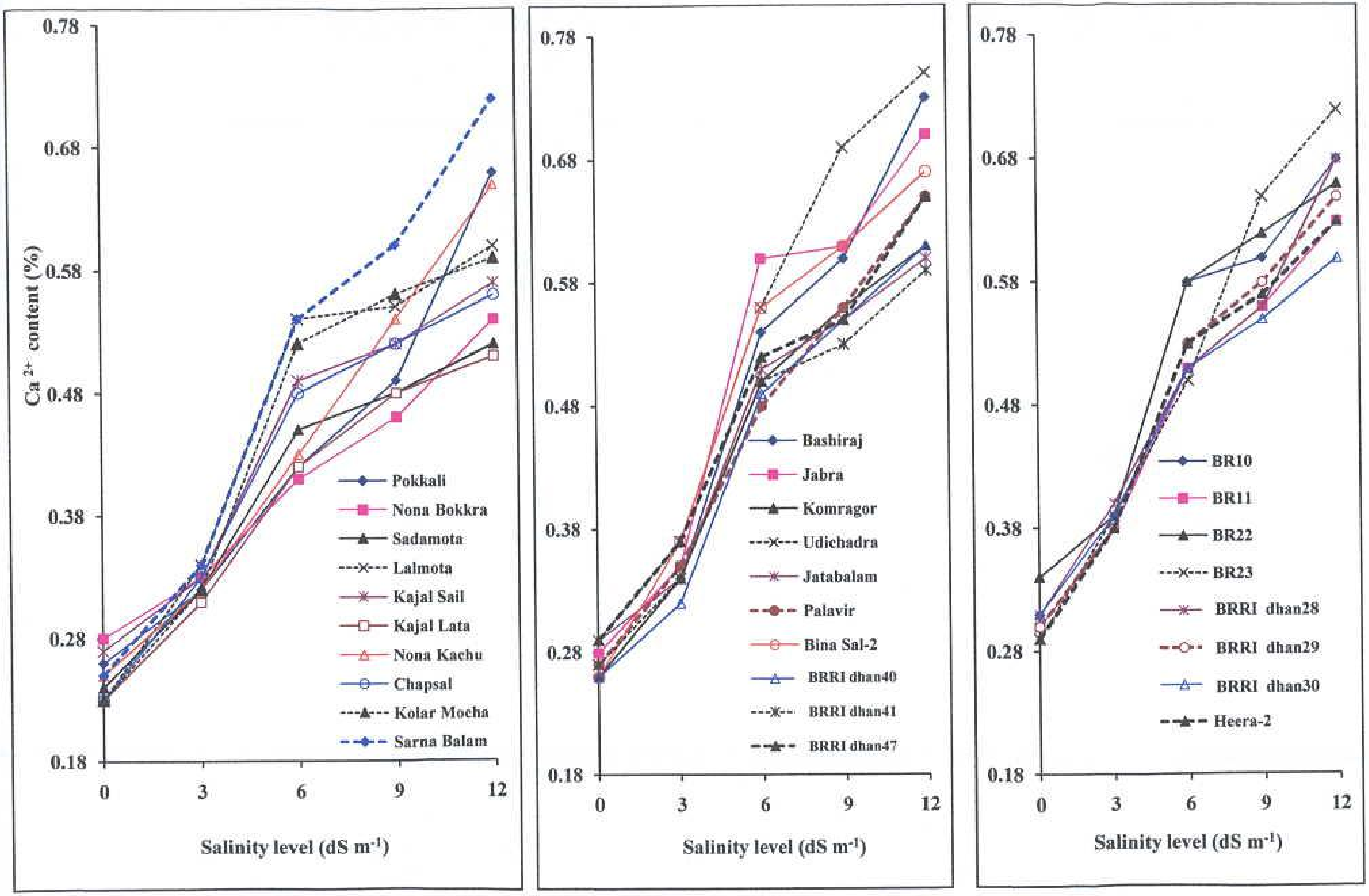

Figure 25. The effect of different salinity levels on Ca^{2+} content (%) of 28 rice cultivars

4.9 Concentration of Mg^{2+}

The concentration of Mg^{2+} in shoots of different rice cultivars differed significantly due to the mean effect of different levels of salinity (Figure 26). The results of the mean effect of different salinity levels indicate that the cultivars BRRI dhan29 and Bashiraj contained the highest amount of Mg^{2+} (0.27%) followed by BRRI dhan47 (0.269%) and BR 23 (0.266%) and the cultivars Nona Bokkra and BINA Sal-2 showed the lowest concentration of Mg^{2+} (0.225%). The concentration of Mg^{2+} in the shoots of other rice cultivars more close to each other, though significantly different (Appendix 5).

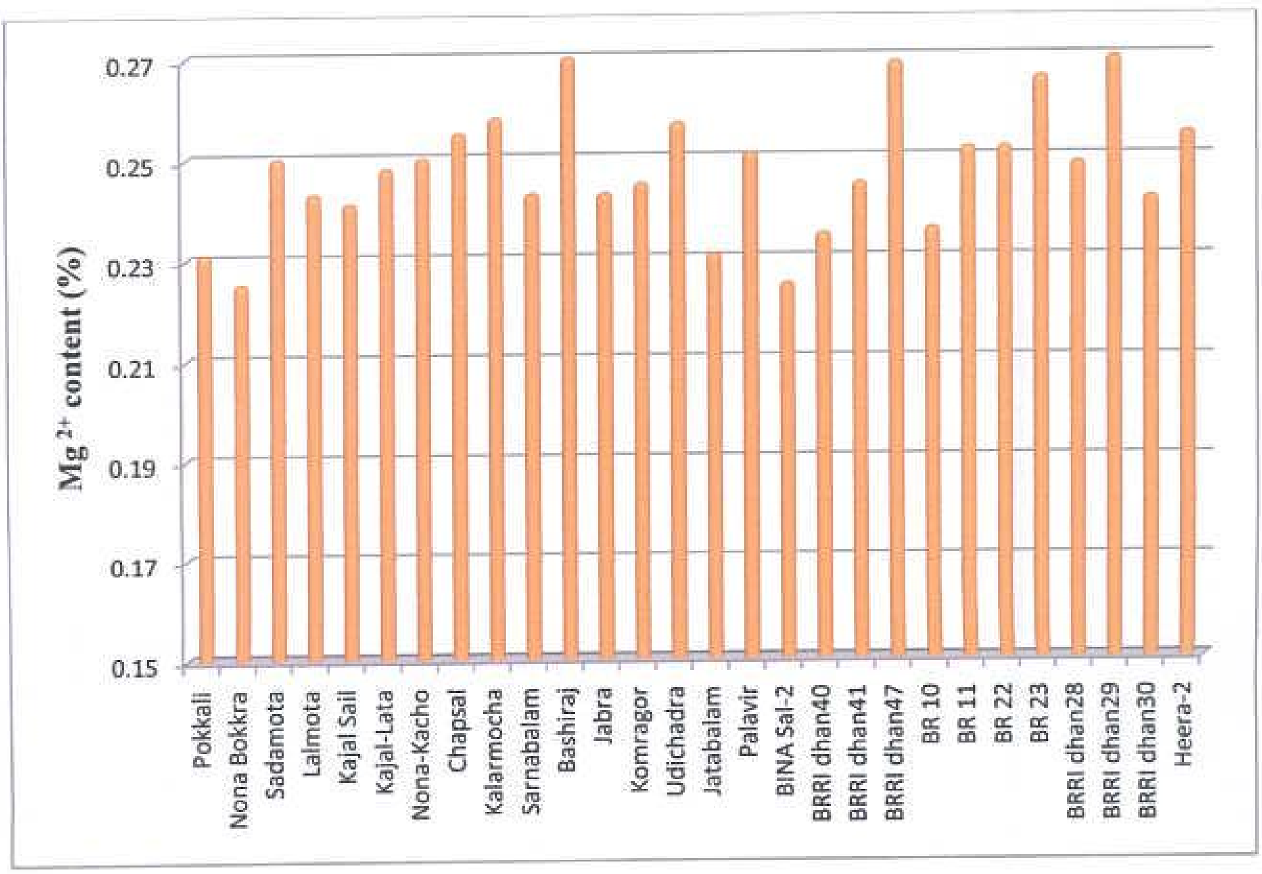

Figure 26. The effect of cultivar on Mg^{2+} content (%) of rice (mean of 5 salinity levels)

The concentration of Mg^{2+} in shoots of different rice genotypes was significantly influenced by the application of different levels of salinity and it increased with increase in salinity level (Figure 27). The highest content of Mg^{2+} (0.303%) was found in rice shoots at 12 dS m^{-1} level of salinity and it was the lowest (0.204%) at control treatment (Appendix 6).

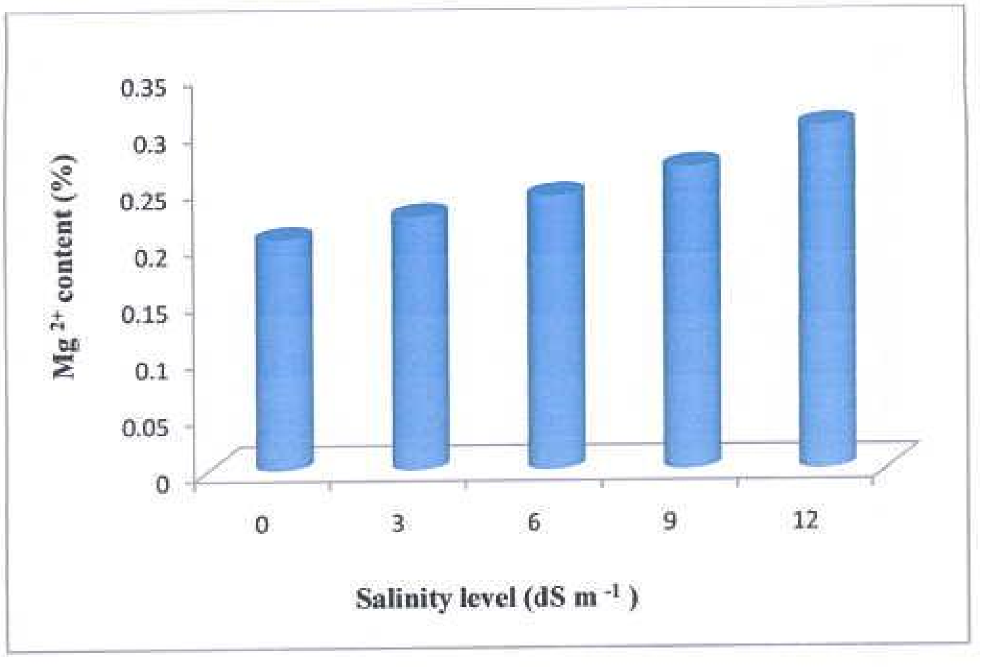

Figure 27. The effect of salinity on Mg^{2+} content (%) of rice plant (mean of 28 rice cultivars)

The content of Mg^{2+} increased slowly due to the interaction effect of cultivar and salinity in most of the cases. At 12 dS m^{-1} the highest percentage of Mg^{2+} content was recorded in Bashiraj (0.37 %) followed by BRRI dhan29 (0.35 %) and BRRI dhan47 (0.34 %). The lowest Mg^{2+} content was showed by Nona Bokkra (0.25 %) followed by BINA Sal-2 (0.26 %) at the highest salinity level (Appendix 7). Khan *et al.* (1992) conducted a greenhouse experiment and found that plant Mg^{2+} content increased upto 8 dS m^{-1} level of salinity.

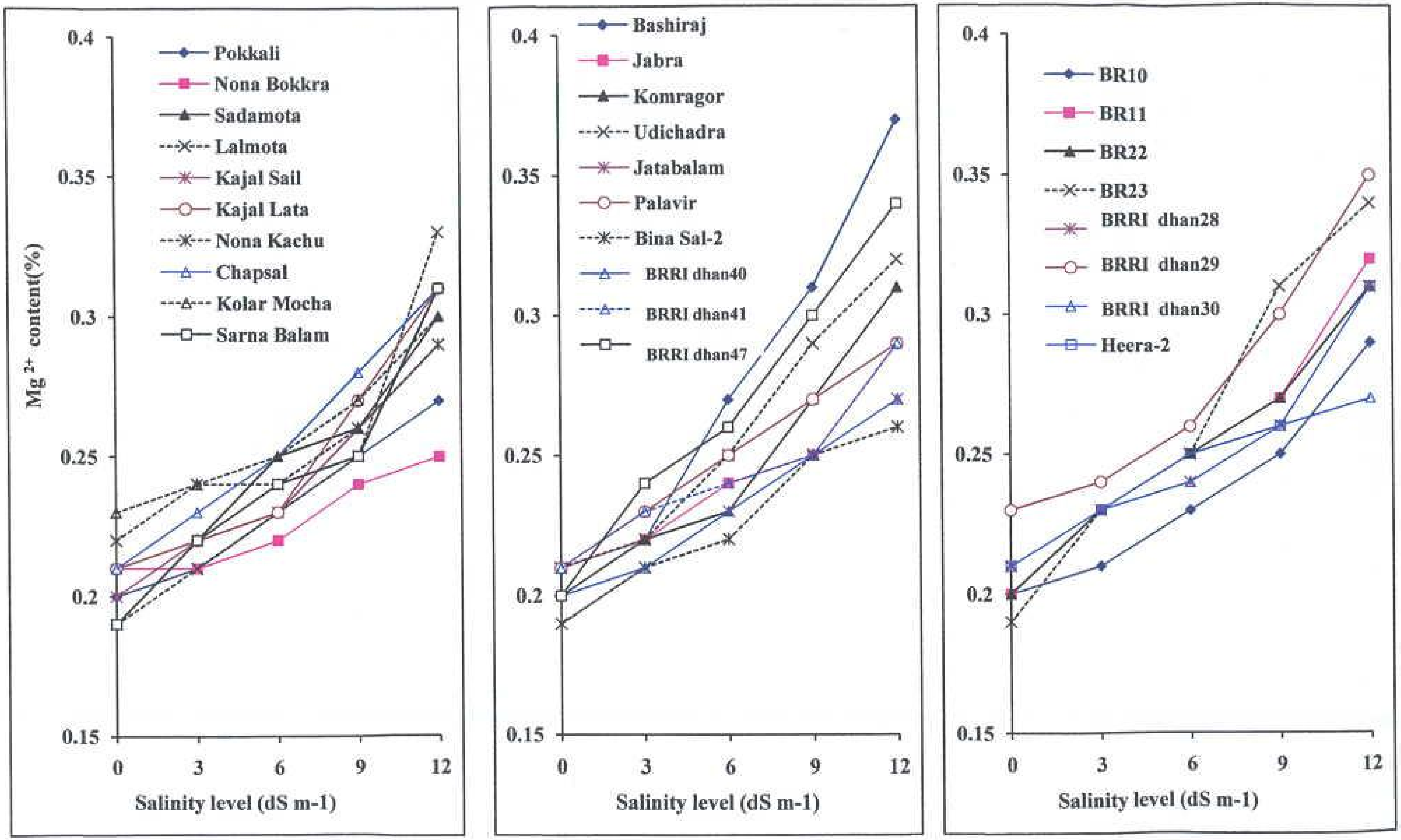

Figure 28. The effect of different salinity levels on Mg^{2+} content (%) of 28 rice cultivars

Ratio of Na^+ and K^+, Na^+ and Ca^+ and Na^+ and Mg^+

4.10 Ratio of Na^+ and K^+

Among the 28 rice genotypes/cultivars, the ratio of Na^+ and K^+ (Na/K value) differed significantly due to the mean effect of different salinity levels (Figure 29 and Appendix 8). The highest value was observed in BRRI dhan29 (3.17) followed by BRRI dhan30 (2.89) and BR 23 (2.72) and the lower values were recorded in BRRI dhan47 (1.44) followed by BINA Sal-2 (1.47) and Nona Bokkra (1.48).

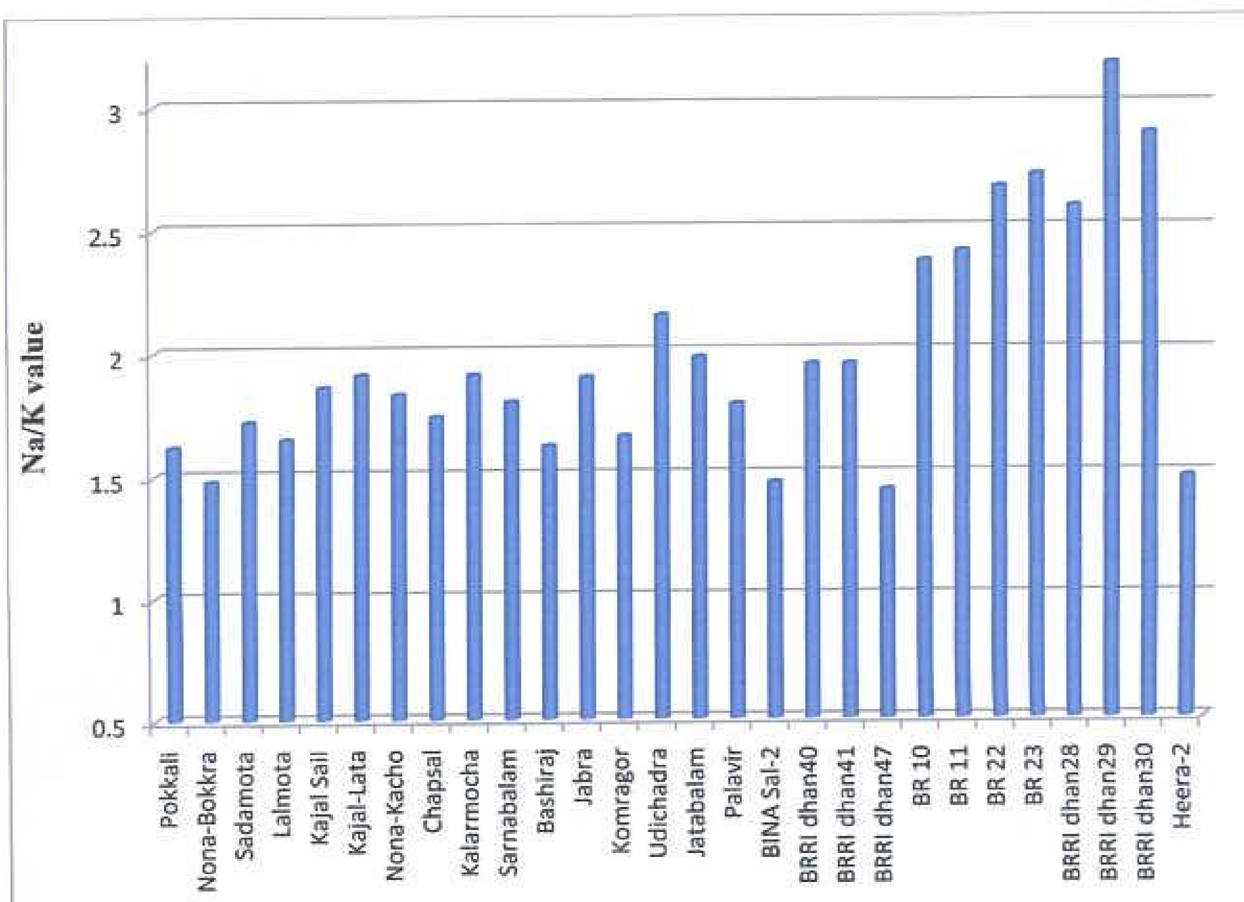

Figure 29. The effect of cultivar on ratio of Na and K content of rice (mean of 5 salinity levels)

The ratio of Na^+ and K^+ (Na/K value) of different rice cultivars significantly increased with the increase in salinity levels (Figure 30). The Na/K ratio value was highest (5.98) at 12 dS m^{-1} salinity treatment and it was lowest (0.19) at 0 dS m^{-1} level of soil salinity (Appendix 9).

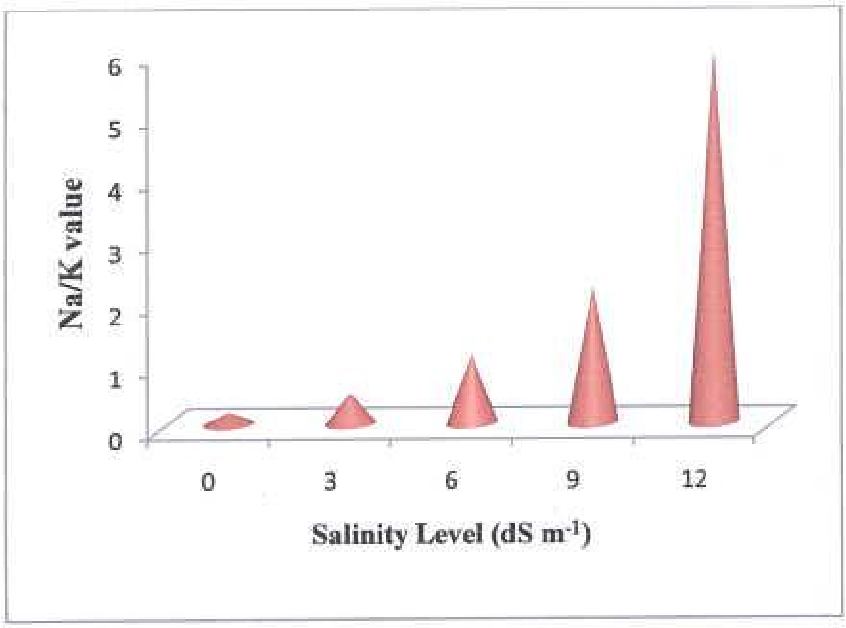

Figure 30. The effect of salinity on ratio of Na and K content of rice (mean of 28 rice cultivars)

The effect of different salinity levels on the ratio of Na and K content of different genotypes/cultivars varied significantly (Figure 31). The Na/K values slowly increased with increasing the salinity levels in cultivars BRRI dhan47 (4.2), Heera-2 (4.32), BINA Sal-2 (4.56) and Nona Bokkra (4.62) and it sharply increased with increasing salinity levels in cultivars BRRI dhan29 (9.02), BR 23 (8.06), BR 10 (7.64) (Appendix 10).

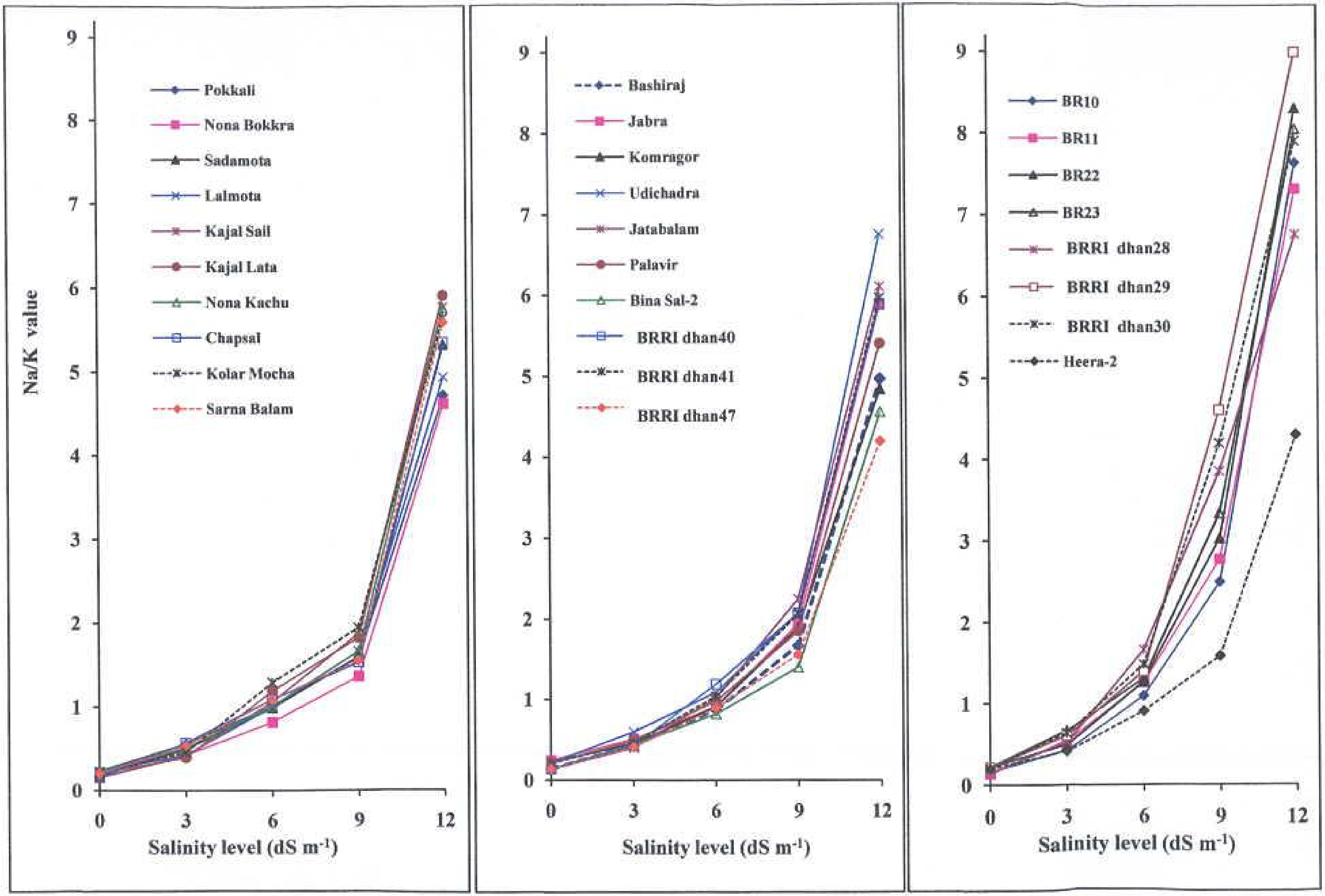

Figure 31. The effect of different salinity levels on the ratio of Na^+ and K^+ of 28 rice cultivars

Tripathy and Kar (1995) reported that the rice cultivars which are less tolerant to salinity had higher value of Na/K ratio at higher salinity than tolerant cultivars. The salt tolerant rice varieties have some mechanisms to restrict the uptake of excess Na. Girdhar (1988) reported that increase in salinity level of irrigation water increased the Na/K ratio. The ratio of Na to K in rice varieties had positive relation with salinity and negative relation with yield under saline water irrigation. Thus, the stress of salinity on yield can be predicted from Na/K ratio in plants during maximum tillering and panicle initiation stage (Ahmed *et al.,* 1989; El-Agrodi and Abou-El-Soud,1990).

4.11 Ratio of Na^+ and Ca^{2+}

The ratio of Na^+ and Ca^{2+} (Na/Ca value) differed significantly due to the mean effect of different salinity levels among the 28 rice cultivars (Figure 32). The highest value was observed in BRRI dhan30 (2.66) followed by BRRI dhan29 (2.58) and Kajal Lata (2.56) which are statistically identical. The lower values were recorded in Bashiraj (1.74) followed by BINA Sal-2 (1.76) and BRRI dhan47 (1.87) (Appendix 8).

It was found that the ratio of Na^+ and Ca^{2+} (Na/Ca value) of different rice cultivars significantly increased with the increase in salinity levels (Figure 33). The Na/Ca ratio value was highest (3.73) at 12 dS m^{-1} salinity treatment and it was lowest (1.34) at 0 dS m^{-1} level of soil salinity (Appendix 9).

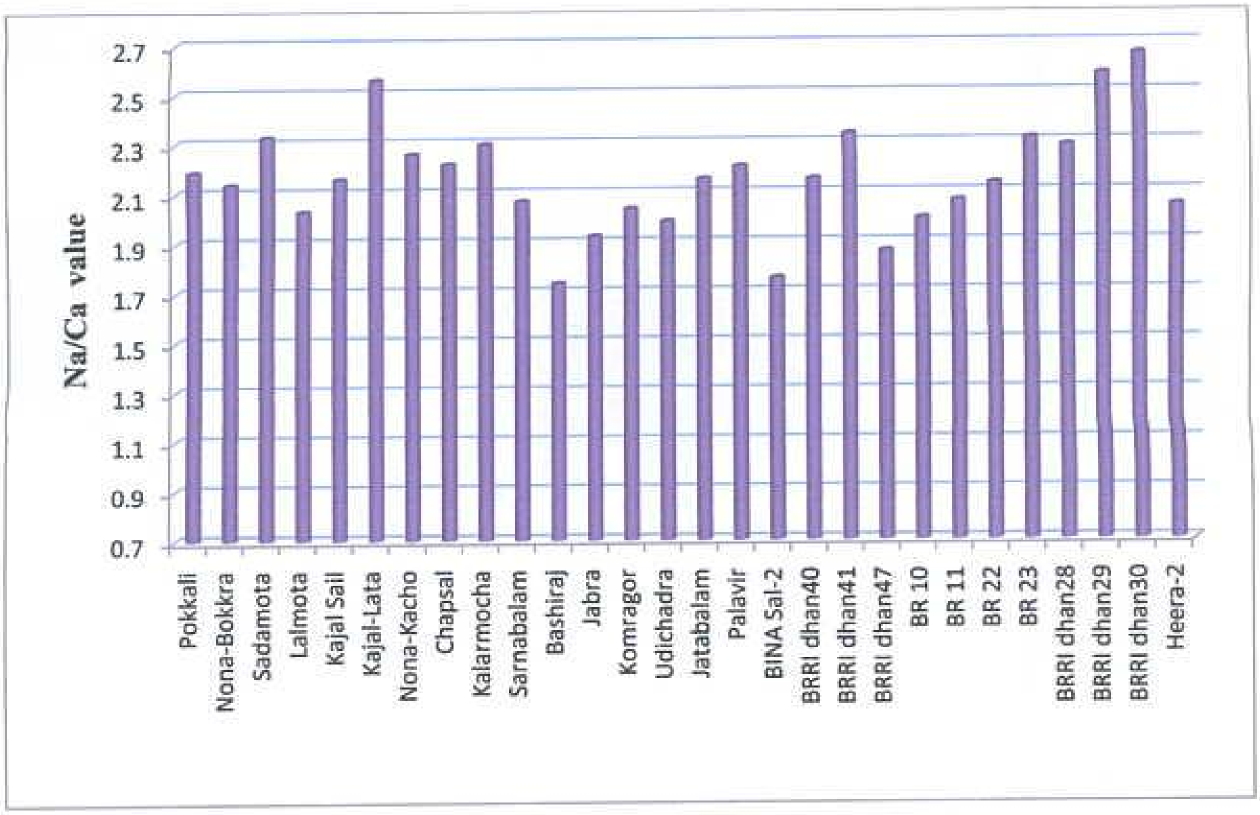

Figure 32. The effect of cultivar on the ratio of Na^+ and Ca^{2+} of rice (mean of 5 salinity levels)

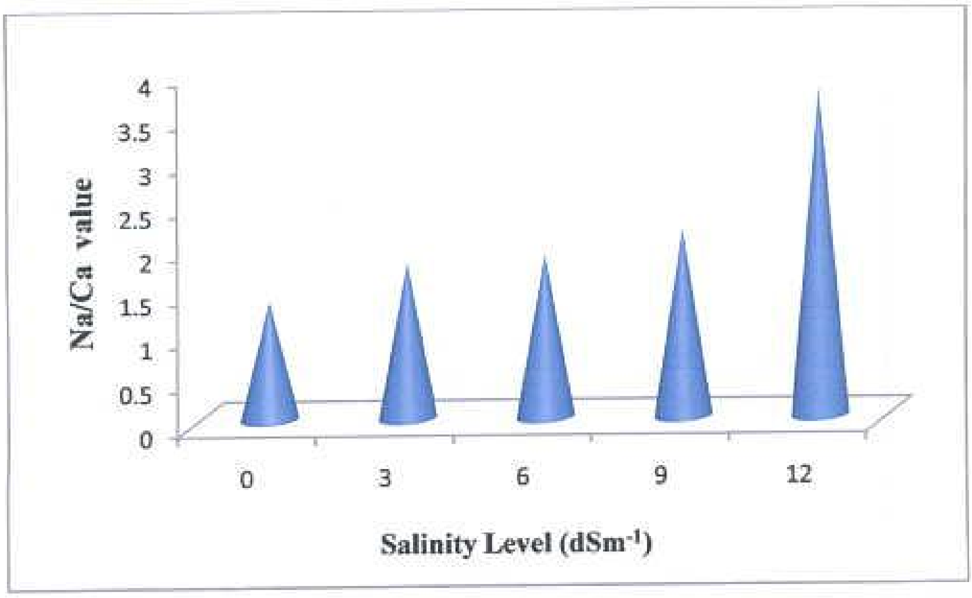

Figure 33. The effect of salinity on the ratio of Na^+ and Ca^{2+} of rice (mean of 28 rice cultivars)

The Appendix 10 showed that the different salinity levels had significant effect on ratio of Na^+ and Ca^{2+}. The ratio of Na^+ and Ca^{2+} was lower in cultivars Bashiraj (2.77), BINA Sal-2 (3.14), BRRI dhan47 (3.26). Heera-2 also showed relatively lower Na/Ca than most other cultivars. Na/Ca was higher in cultivars Kajal Lata (4.70) and BRRI dhan30 (4.59) compared to other cultivars due to increase in the level of salinity (Figure 34).

Lazof and Bernstein (1999) discussed the shortcomings of research where not only NaCl was used as the sole salinizing salt, but those studies where non-saline control treatments contain unrealistic trace amounts of Na and Cl. These investigators emphasize that trace levels of NaCl in control treatments are problematic in light of observed stimulatory effects from small additions of NaCl up to 5mM in many glycophytes. Extremely high Na/Ca ratios, on the other hand, lead to nutritional disorders and secondary stresses due to adverse affects on soil conditions. Not only is NaCl uncharacteristic of agriculturally saline environments, but experiments that use this as the sole salinizing salt create extreme ratios of Na/Ca, Na/K, Ca/Mg and Cl/NO_3 in the root media (Läuchli and Epstein, 1990).

Sodium-induced Ca^{2+} deficiency has been observed by numerous investigators when the Na^+/Ca^{2+} ratio in the solution, at a given salinity level for a particular plant, increases above a critical level (Kopittke and Menzies, 2004).

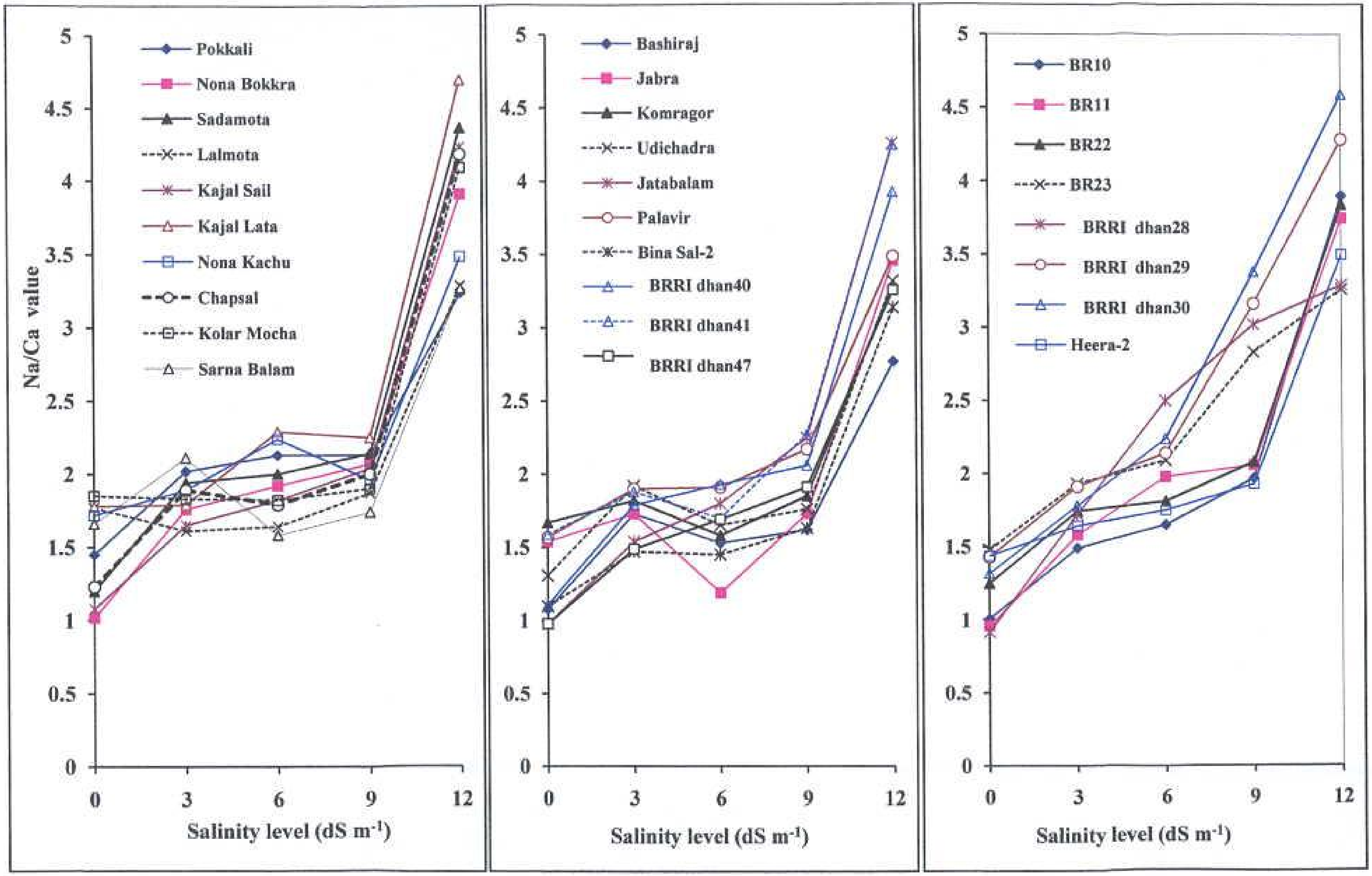

Figure 34. The effect of different salinity levels on the ratio of Na^{+} and Ca^{2+} of 28 rice cultivars

4.12 Ratio of Na^+ and Mg^{2+}

The ratio of Na^+ and Mg^{2+} (Na/Mg value) differed significantly due to the mean effect of different salinity levels among the 28 rice cultivars (Figure 35). The highest value was observed in BRRI dhan30 (5.42) followed by BRRI dhan 28 (4.70) and BRRI dhan29 (4.69). The lowest value was recorded in Bashiraj (3.17) followed by BRRI dhan47 (3.38) (Appendix 8).

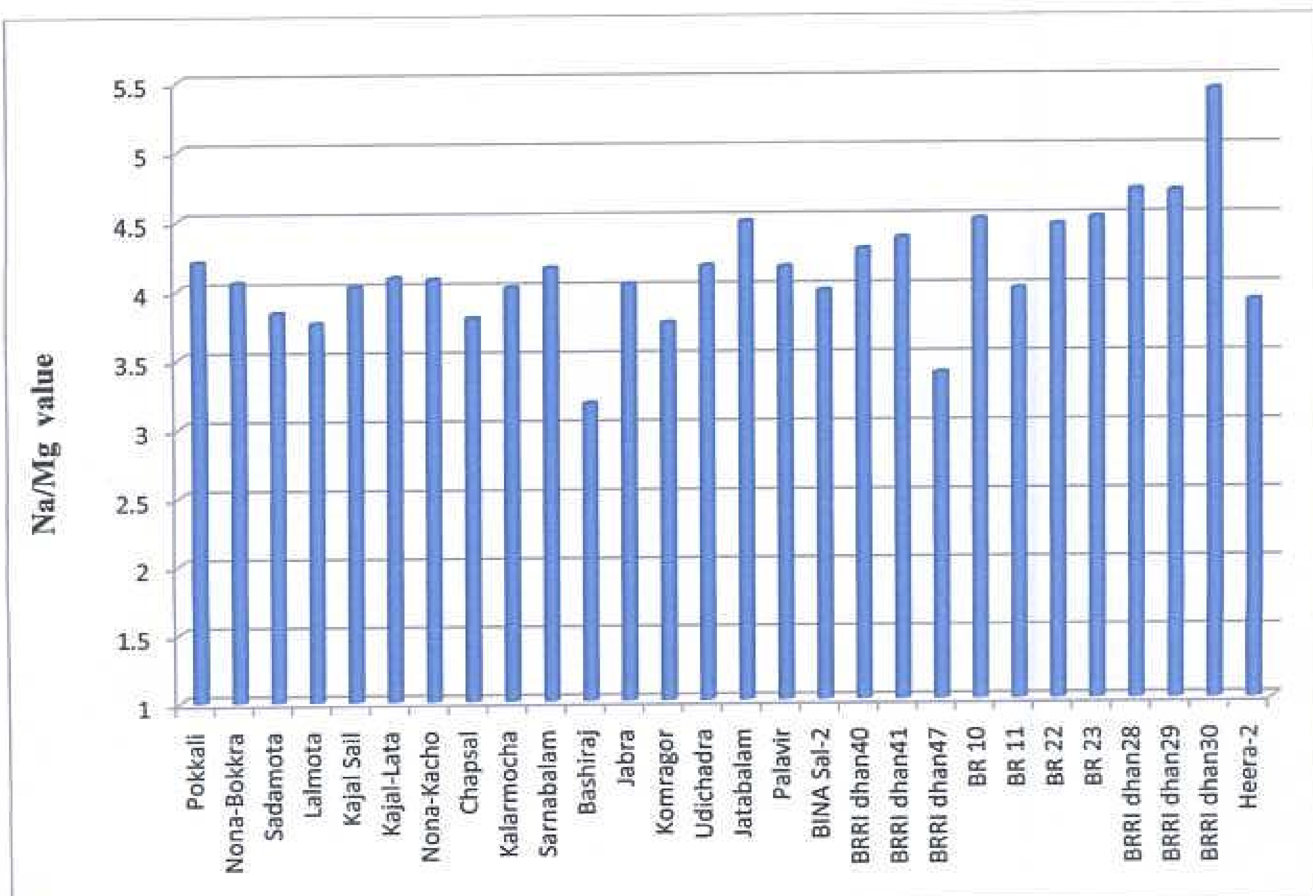

Figure 35. The effect of cultivar on the ratio of Na^+ and Mg^{2+} of rice (mean of 5 salinity levels)

The ratio of Na^+ and Mg^{2+} of different rice cultivars significantly increased with the increase in salinity levels (Figure 36). The highest Na/Mg value (7.82) was found at 12 dS m^{-1} salinity treatment and it was lowest (1.76) at the salinity level of 0 dS m^{-1} (Appendix 9).

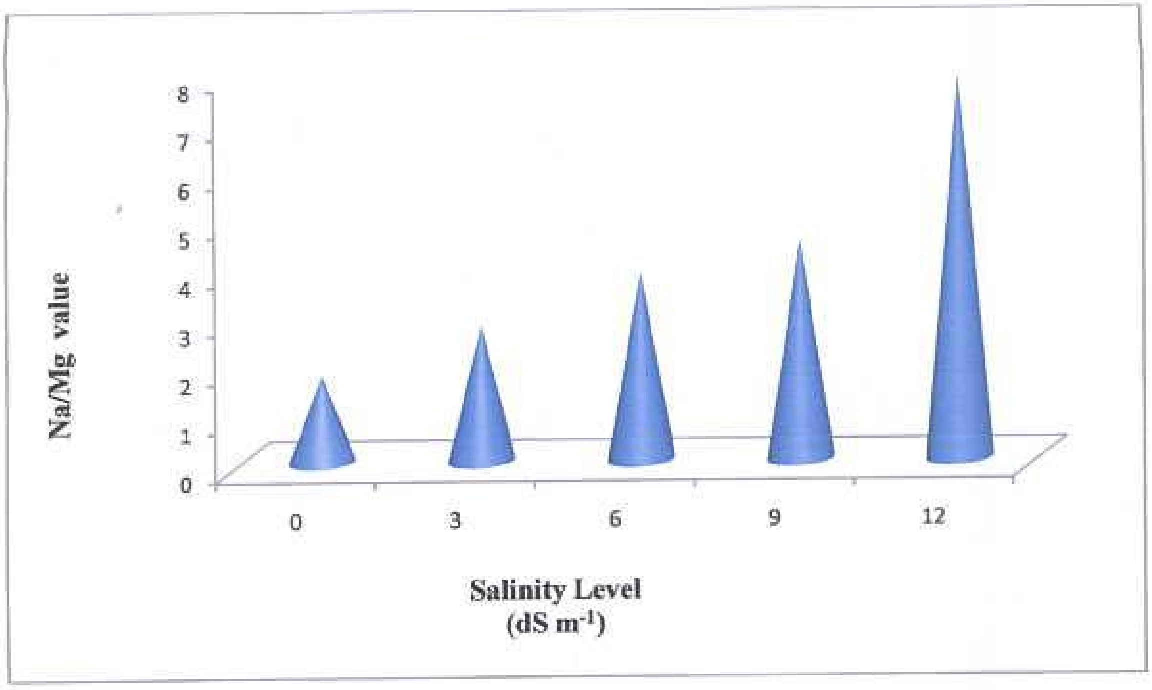

Figure 36. The effect of salinity on the ratio of Na^+ and Mg^{2+} of rice (mean of 28 rice cultivars)

The results indicate that there were sharp differences on the effect of different salinity levels on the ratio of Na^+ and Mg^{2+} of different rice Cultivars/genotypes (Figure 37). The Na/Mg slowly increased with increase in the salinity levels in cultivars Bashiraj (5.53), Lalmota (6.03) and BRRI dhan47 (6.27) and it sharply increased with increase in salinity levels in cultivars BRRI dhan30 (10.13), Jota Balam (9.46) and BR 10 (9.22) (Appendix 10).

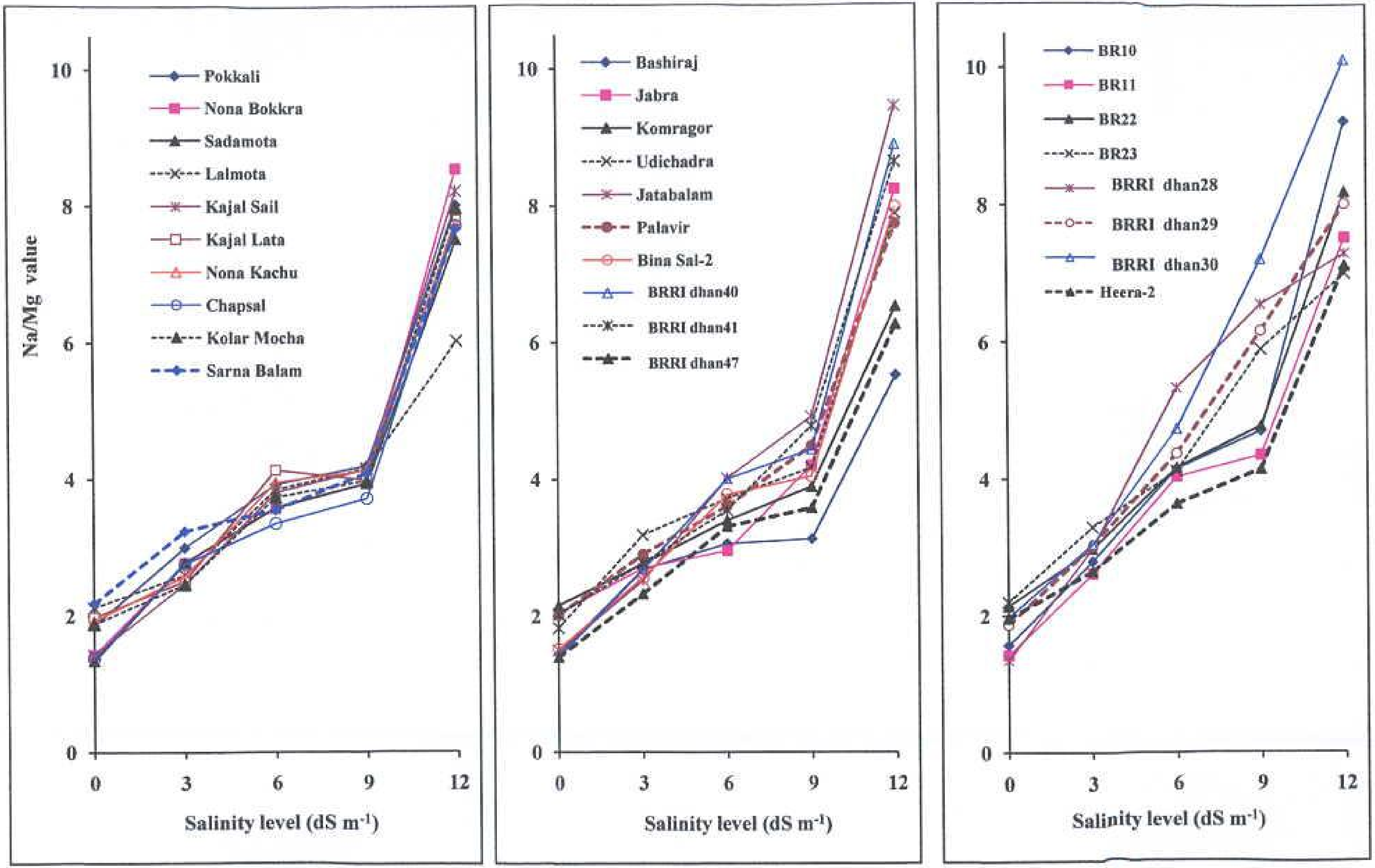

Figure 37. The effect of different salinity levels on the ratio of Na^+ and Mg^{2+} of 28 rice cultivars

Chapter 5
Summary and Conclusion

CHAPTER 5

SUMMARY AND CONCLUSIONS

An experiment was conducted at the net house of the Department of Genetics and Plant Breeding and Laboratory of Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka-1207 under pot-culture during the Aman season of the year 2010 to study the effect of salinity on germination, growth and major nutrient content of seedlings of several rice cultivars. The experiment was completed using 28 cultivars and 5 salinity levels (0, 3, 6, 9 and 12 dS m^{-1}). Data were taken on percent germination, seedling height, root dry weight, shoot dry weight, total dry matter, major nutrient contents (% content of Na^+, K^+, Ca^+ and Mg^{2+}) and ratios of Na^+ & K^+, Na^+ & Ca^{2+} and Na^+ & Mg^{2+}.

The mean effect of different salinity levels on percent germination; seedling height, root dry weight (RDW), shoot dry weight (SDW) and total dry matter (TDM) differed significantly among the cultivars. Sadamota followed by Lalmota, BINA Sal-2 and BRRI dhan47 showed higher germination percentage while it was lowest in BRRI dhan29. The cultivars Heera-2, Sadamota, Jotabalam, Chapsal, Pokkali and BINA Sal-2 were among the cultivars produced higher seedling height. On the other hand, cultivars BR 23 showed the lowest performance followed by BR 22. The higher % relative RDW values were observed in Nona Bokkra , Heera-2, Pokkali, Jotabalam and BRRI dhan47 while the lower values were recorded in BRRI dhan28 followed by BRRI dhan29 and BR 22. The

% relative TDM were observed higher in Heera-2, Nona Bokkra, Chapsal, Pokkali, BINA Sal-2, Jotabalam, BRRI dhan47 and Lalmota and the lowest amount was found in BRRI dhan29 .

The effect of different levels of salinity on germination, seedling height, root dry weight, shoot dry weight and total dry matter (mean of 28 rice cultivars) was found significant at 1% level. The percent germination, root dry weight, shoot dry weight and total dry matter decreased with increasing salinity levels. In case of all above mentioned parameters, highest values were recorded in 3 dS m^{-1} and lowest at 12 dS m^{-1} except percent germination which showed highest value at control saline level (0 dS m^{-1}).

On the basis of the results of this experiment; germination, seedling height, root dry weight, shoot dry weight and total dry matter varied significantly due to the interaction effect of cultivar and salinity. The percent germination increased in cultivars Lalmota, Kolarmocha, Nona-Kachu, BRRI dhan47, Bashiraj and Heera-2 with the increase in salinity upto 6 dS m^{-1} level while it decreased sharply in cultivars BRRI dhan28, BRRI dhan29 and BRRI dhan30 . The % relative seedling height was found to decrease slowly with the increase in salinity levels in cultivars Heera-2, Sadamota, Chapsal and Pokkali and it sharply decreased in cultivar BR 23. Relative root dry weight (%) slowly decreased with increasing the salinity levels in genotypes/cultivars Heera-2, Nona Bokkra, Pokkali, BRRI dhan47 and Jatabalam and it sharply decreased with increasing salinity levels in cultivars Kajal Sail and BRRI dhan29 . The cultivars Heera-2, Chapsal, BINA Sal-2, Nona Bokkra, Lalmota, Jotabalam and Pokkali produced higher % relative SDW and the cultivars BRRI dhan29 followed by BR 23, BR 10, BR 22, BR 11, BR 30 and BRRI dhan28 contained the lower relative SDW. The % relative SDW was less affected in cultivars Heera-2, Chapsal, Lalmota and Nona Bokkra and it was severely affected in cultivars BR 23 and BRRI dhan29. The % relative TDM yield slowly decreased with increase in the salinity levels in cultivars Heera-2, Chapsal and Nona Bokkra and it decreased sharply with increase in salinity levels in cultivars BRRI dhan29 and BR 23.

The concentration of Na^+, K^+, Ca^{2+} and Mg^{2+} in shoots of rice seedlings of different rice cultivars differed significantly due to the application of different levels of salinity. The highest concentration of Na^+ was found in cultivars BRRI dhan29 and BRRI dhan30 followed by BR 23 and BRRI dhan28 where the cultivars Bashiraj, BINA Sal-2, Nona Bokkra, Komragor, Lalmota and BRRI dhan47 contained the lower concentrations of Na^+. The highest amount of K^+ content was found in Heera-2, followed by BRRI dhan47 and BINA Sal-2; and the cultivar Jabra contained the lowest amount of K^+ which was statistically similar to the cultivars BR 11, BRRI dhan29, BRRI dhan30 and Pokkali. The cultivar Udichadra had the highest concentration of Ca^{2+} followed by BR 22, BR 10 and BR 23 and the cultivar Kajal Lata contained the lowest amount of Ca^{2+}. The cultivars BRRI dhan29 and Bashiraj contained the highest amount of Mg^{2+} followed by BRRI dhan47 and BR 23 and the cultivars Nona Bokkra and BINA Sal-2 showed the lowest concentration. The highest value of the ratio of Na^+ and K^+ was observed in BRRI dhan29 followed by BRRI dhan30 and BR 23 and the lower values were recorded in BRRI dhan47 followed by BINA Sal-2 and Nona Bokkra. The highest Na/Ca value was observed in BRRI dhan30 followed by BRRI dhan29 and Kajal Lata and lowest value was recorded in Bashiraj followed by BINA Sal-2 and BRRI dhan47. The highest ratio of Na^{+} and Mg^{2+} was observed in BRRI dhan30 followed by BRRI dhan28 and BRRI dhan29 and the lowest value was recorded in Bashiraj followed by BRRI dhan47.

The concentration of Na^{+}, K^{+}, Ca^{2+} and Mg^{2+} in shoots of rice seedlings of different rice cultivars was significantly influenced due to the increase of salinity levels. The highest contents of Na^{+}, Ca^{2+} and Mg^{2+} were observed at the highest salinity level (12 dS m^{-1}) and it was the lowest at control treatment. The content of K^{+} in shoots of rice seedlings decreased with increase in salinity levels. The highest amount of K^{+} was found at control treatment and it was the lowest at 12 dS m^{-1}. The Na/K, Na/Ca and Na/Mg values were highest at 12 dS m^{-1} salinity treatment and lowest at 0 dS m^{-1} level of soil salinity.

The concentration of Na^{+}, K^{+}, Ca^{2+} and Mg^{2+} differed significantly due to the interaction effect of cultivar and salinity. Na^{+} content (%) increased slowly in cultivars Lalmota, Bashiraj, BINA Sal-2, BRRI dhan47, Nona Bokkra, Pokkali, and Heera-2 with the increase in salinity level while it increased sharply in cultivars BRRI dhan29 , BRRI dhan30 and BR 10. In cultivars Heera-2, BRRI dhan47, BINA Sal-2, Lalmota, Nona Bokkra, Pokkali, and Chapsal; the K^{+} content (%) decreased slowly with the increase in salinity level while it decreased sharply in cultivars BR 23, BR 22, BRRI dhan29 and BR 22. At 12 dS m^{-1} the highest percentage of Ca^{2+} content was recorded in Udichadra and lowest Ca^{2+} content was showed by Kajal lata followed by Nona Bokkra, BRRI dhan47 and BINA Sal-2. At 12 dS m^{-1}, the highest percentage of Mg^{2+} content was recorded in Bashiraj followed by BRRI dhan29 and BRRI dhan47. The lowest Mg^{2+} content was showed by Nona Bokkra followed by BINA Sal-2. The Na/K values slowly increased with increasing the salinity levels in cultivars BRRI dhan47, Heera-2, BINA Sal-2 and Nona Bokkra and it sharply increased with increasing salinity levels in cultivars BRRI dhan29 , BR 23, BR 10. The ratio of Na^{+} and Ca^{2+} was lower in cultivars Bashiraj , BINA Sal-2, BRRI dhan47 and higher in cultivars Kajal Lata and BRRI dhan30 compared to other cultivars due to increase in the level of salinity. The Na/Mg slowly increased with increase in the salinity levels in cultivars Bashiraj, Lalmota and BRRI dhan47 and it sharply increased with increase in salinity levels in cultivars BRRI dhan30, Jota Balam and BR 10.

From the above results, it can be concluded that, rice cultivars vary in their ability to tolerate adverse saline conditions. Among the 28 cultivars, Nona Bokkra, Bashiraj, Heera-2, BINA Sal-2, BRRI dhan47, Pokkali and Sadamota showed prominent tolerance against salinity while BRRI dhan29 , BRRI dhan30 , BR 10, BR 23, Kajal Lata and BRRI dhan28 are the most susceptible ones.

Based on the results the following recommendations can be made –

- The tolerant and susceptible seedlings may be selected for the study on yield and other characters for inspecting the mechanism of salinity tolerance in rice.
- Plant breeders may adopt the technique of selection or screening the genotypes in developing salt tolerant rice cultivar.

Chapter 6
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CHAPTER 6

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Chapter 7
Appendices

CHAPTER 7

APPENDICES

Appendix 1: The effect of cultivars on germination and morphological characters of rice seedlings (each value is a mean of 5 salinity levels)

Sl. No.	Cultivars	Germination (%)	Relative seedling height (%)	Relative root dry wt. (%)	Relative shoot dry wt. (%)	Relative total dry matter (%)
1.	Pokkali	88.33 d-i	94.21 bc	97.07 a	92.85 bc	93.76 bc
2.	Nona Bokkra	91.33 a-e	87.89 ef	100.2 a	93.77 bc	94.74 b
3.	Sadamota	94.67 a	95.33 b	83.82 cd	91.51 c-e	90.17 ef
4.	Lalmota	94.33 ab	82.28 hi	77.83 ef	93.51 bc	91.69 c-f
5.	Kajal Sail	85.33 g-j	82.12 hi	71.43 gh	80.85 i	79.38 kl
6.	Kajal Lata	86.00 f-j	88.23 ef	84.44 c	80.42 i	81.13 jk
7.	Nona Kacho	88.00 e-i	80.97 i	90.62 b	91.14 c-e	91.03 de
8.	Chapsal	85.00 h-j	94.21 bc	90.55 b	94.50 b	93.81 bc
9.	Kolar mocha	87.33 e-i	87.21 e-g	75.84 e-g	88.76 e-g	85.65 h
10.	Sarnabalam	88.33 d-i	86.84 e-g	86.73 bc	87.43 f-h	87.24 gh
11.	Bashiraj	89.33 c-h	92.28 b-d	79.33 de	91.94 b-d	88.45 fg
12.	Jabra	89.67 c-g	84.52 gh	77.59 ef	82.04 i	81.01 jk
13.	Komragor	89.67 c-g	91.89 cd	73.74 fg	86.52 gh	83.22 ij
14.	Udichadra	90.00 b-f	85.65 fg	72.33 gh	82.63 i	78.22 l
15.	Jatabalam	91.00 a-e	95.09 bc	96.47 a	92.87 bc	93.29 b-d
16.	Palavir	88.33 d-i	85.20 f-h	71.16 gh	82.77 i	80.23 kl
17.	BINA Sal-2	93.00 a-c	94.17 bc	90.82 b	94.01 bc	93.57 b-d
18.	BRRI dhan40	89.00 c-h	89.91 de	84.45 c	89.83 d-f	88.31 fg
19.	BRRI dhan41	91.00 a-e	87.09 e-g	82.67 cd	85.66 h	84.96 hi
20.	BRRI dhan47	92.67 a-d	92.49 b-d	95.69 a	92.14 b-d	92.75 b-d
21	BR 10	84.33 i-k	74.92 jk	66.38 ij	67.01 l	66.94 o
22.	BR 11	85.00 h-j	76.75 jk	64.73 i-k	70.73 k	69.67 n
23.	BR 22	84.33 i-k	74.32 k	62.32 jk	67.53 l	66.51 o
24.	BR 23	80.67 k	71.30 l	64.42 i-k	64.92 l	64.71 op
25.	BRRI dhan28	82.33 jk	77.67 j	60.25 k	76.30 j	72.54 m
26.	BRRI dhan29	74.00 l	74.89 jk	61.62 jk	64.77 l	64.01 p
27.	BRRI dhan30	76.67 l	81.95 hi	68.17 hi	72.97 k	71.83 mn
28.	Heera-2	91.00 a-e	100.0 a	99.59 a	102.5 a	101.8 a
Significant level		**	**	**	**	**
$LSD_{(0.05)}$		3.83	2.93	4.35	2.55	2.29
CV (%)		4.84	4.71	7.54	4.17	3.81

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

** Significant at 0.01 level of probability

Appendix 2: The effect of different salinity levels on germination and morphological characters of rice seedlings (each value is a mean of 28 rice cultivars)

Salinity level (dS m^{-1})	Germination (%)	Relative seedling height (%)	Relative root dry wt. (%)	Relative shoot dry wt. (%)	Relative total dry matter (%)
0	93.45 a	100.0 a	100.0 a	100.0 b	100.0 b
3	92.56 a	101.5 a	103.7 a	105.3 a	105.0 a
6	90.18 b	88.42 b	87.08 b	91.54 c	90.44 c
9	86.37 c	77.22 c	66.02 c	73.02 d	71.31 d
12	75.06 d	63.09 d	41.46 d	51.86 e	49.49 e
Significant level	**	**	**	**	**
$LSD_{(0.05)}$	1.62	3.72	5.29	1.37	4.65
CV (%)	4.84	4.71	7.54	4.17	3.81

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

** Significant at 0.01 level of probability

Appendix 3: **Collected absolute data of effect of salinity on germination, seedling height, root dry weight, shoot dry weight and total dry matter of 28 rice cultivars**

Cultivars	Salinity (dS m^{-1})	Germination (%)	Seedling height (cm)	Root dry wt. (g/plant)	Shoot dry wt. (g/plant)	Total dry matter (g/plant)
1. Pokkali	0	91.67	41.83	0.018	0.064	0.082
	3	91.67	43.43	0.020	0.073	0.093
	6	91.67	39.07	0.019	0.065	0.084
	9	86.67	37.47	0.017	0.057	0.075
	12	80.00	35.20	0.012	0.039	0.051
2. Nona Bokkra	0	98.33	58.43	0.017	0.087	0.104
	3	96.67	60.60	0.020	0.099	0.118
	6	95.00	51.03	0.019	0.088	0.107
	9	88.33	46.27	0.016	0.072	0.088
	12	78.33	40.33	0.013	0.063	0.076
3. Sadamota	0	98.33	40.93	0.011	0.055	0.066
	3	98.33	43.27	0.012	0.059	0.071
	6	96.67	39.00	0.010	0.055	0.065
	9	95.00	36.90	0.008	0.044	0.051
	12	85.00	34.87	0.006	0.038	0.043
4. Lalmota	0	96.67	53.07	0.009	0.058	0.067
	3	98.33	53.37	0.010	0.062	0.073
	6	98.33	39.57	0.008	0.058	0.066
	9	93.33	38.50	0.005	0.050	0.055
	12	85.00	33.80	0.004	0.043	0.047
5. Kajalsail	0	91.67	61.57	0.021	0.115	0.135
	3	91.67	57.27	0.023	0.119	0.142
	6	88.33	48.23	0.013	0.093	0.106
	9	86.67	45.27	0.009	0.072	0.081
	12	68.33	40.37	0.008	0.065	0.073
6. Kajal Lata	0	91.67	32.73	0.011	0.049	0.060
	3	91.67	35.17	0.012	0.051	0.063
	6	91.67	28.40	0.011	0.040	0.051
	9	85.00	24.00	0.008	0.031	0.039
	12	70.00	23.83	0.005	0.026	0.031
7. Nona Kachu	0	91.67	50.63	0.019	0.095	0.114
	3	95.00	50.13	0.022	0.106	0.128
	6	93.33	42.40	0.021	0.096	0.117
	9	90.00	35.30	0.016	0.089	0.105
	12	70.00	26.53	0.008	0.046	0.054
8. Chapsal	0	91.67	51.10	0.021	0.094	0.115
	3	93.33	52.00	0.024	0.103	0.127
	6	90.00	48.50	0.019	0.094	0.113
	9	81.67	45.57	0.017	0.085	0.102
	12	68.33	43.50	0.014	0.070	0.084
9. Kolarmocha	0	93.33	54.87	0.040	0.127	0.167
	3	95.00	55.00	0.044	0.137	0.181
	6	93.33	46.33	0.034	0.128	0.162
	9	86.67	42.27	0.025	0.101	0.125
	12	68.33	38.90	0.010	0.069	0.079
10. Sarna Balam	0	91.67	42.47	0.016	0.051	0.067
	3	91.67	43.17	0.017	0.054	0.071
	6	91.67	40.77	0.016	0.051	0.067
	9	90.00	35.63	0.012	0.039	0.051
	12	76.67	22.33	0.008	0.030	0.036

Appendix-3: Contd.

Cultivars	Salinity (dS m^{-1})	Germination (%)	Seedling height (cm)	Root dry wt. (g/plant)	Shoot dry wt. (g/plant)	Total dry matter (g/plant)
11. Bashi Raj	0	91.67	58.00	0.036	0.094	0.130
	3	95.00	60.57	0.039	0.104	0.143
	6	93.33	56.00	0.032	0.095	0.127
	9	88.33	51.33	0.022	0.085	0.108
	12	78.33	41.67	0.013	0.053	0.066
12. Jabra	0	93.33	58.87	0.027	0.092	0.119
	3	93.33	61.53	0.030	0.104	0.134
	6	93.33	58.40	0.023	0.090	0.113
	9	88.33	43.33	0.017	0.060	0.077
	12	80.00	26.60	0.008	0.032	0.040
13. Komra Gor	0	91.67	59.17	0.047	0.136	0.183
	3	93.33	62.40	0.051	0.143	0.193
	6	91.67	57.10	0.042	0.126	0.167
	9	91.67	50.67	0.024	0.101	0.125
	12	80.00	42.43	0.010	0.083	0.093
14. Udi Chadra	0	93.33	40.33	0.038	0.051	0.089
	3	93.33	42.33	0.039	0.053	0.092
	6	95.00	35.90	0.028	0.043	0.071
	9	91.67	30.50	0.021	0.037	0.058
	12	76.67	23.57	0.012	0.026	0.037
15. Jota Balam	0	95.00	61.43	0.019	0.149	0.168
	3	96.67	63.43	0.021	0.162	0.183
	6	95.00	61.33	0.020	0.159	0.179
	9	93.33	58.13	0.019	0.144	0.163
	12	75.00	47.73	0.012	0.080	0.092
16. Pala Vir	0	95.00	53.93	0.027	0.097	0.124
	3	91.67	55.40	0.027	0.107	0.134
	6	90.00	48.50	0.020	0.087	0.107
	9	88.33	40.17	0.014	0.071	0.085
	12	76.67	31.67	0.008	0.039	0.047
17. BINA Sal-2	0	96.67	42.27	0.018	0.128	0.146
	3	95.00	44.83	0.020	0.137	0.157
	6	93.33	45.00	0.019	0.141	0.160
	9	95.00	37.67	0.015	0.115	0.130
	12	85.00	29.13	0.009	0.080	0.089
18. BRRI dhan40	0	91.67	32.13	0.023	0.058	0.081
	3	93.33	34.10	0.024	0.063	0.087
	6	91.67	28.43	0.023	0.058	0.081
	9	88.33	25.50	0.016	0.049	0.065
	12	80.00	24.17	0.010	0.031	0.042
19. BRRI dhan41	0	95.00	35.77	0.019	0.059	0.078
	3	96.67	36.83	0.021	0.063	0.084
	6	91.67	31.27	0.017	0.057	0.074
	9	91.67	28.03	0.013	0.042	0.055
	12	80.00	23.63	0.009	0.032	0.041
20. BRRI dhan47	0	95.00	36.17	0.023	0.112	0.135
	3	96.67	37.43	0.025	0.117	0.142
	6	95.00	35.23	0.024	0.115	0.139
	9	91.67	31.83	0.022	0.097	0.119
	12	85.00	26.53	0.017	0.074	0.091

Appendix-3: Contd.

Cultivars	Salinity (dS m^{-1})	Germination (%)	Seedling height (cm)	Root dry wt. (g/plant)	Shoot dry wt. (g/plant)	Total dry matter (g/plant)
21. BR 10	0	96.67	27.10	0.017	0.141	0.158
	3	90.00	25.67	0.015	0.137	0.152
	6	85.00	22.67	0.012	0.097	0.108
	9	80.00	15.57	0.009	0.070	0.079
	12	70.00	10.43	0.003	0.028	0.031
22. BR 11	0	96.67	39.83	0.024	0.115	0.139
	3	91.67	36.63	0.021	0.111	0.132
	6	86.67	29.83	0.016	0.093	0.109
	9	81.67	24.90	0.011	0.055	0.067
	12	68.33	21.37	0.005	0.033	0.038
23. BR 22	0	95.00	39.00	0.020	0.083	0.103
	3	88.33	37.57	0.017	0.080	0.096
	6	83.33	28.17	0.013	0.050	0.063
	9	83.33	24.00	0.009	0.038	0.046
	12	71.67	15.97	0.004	0.030	0.034
24. BR 23	0	91.67	43.10	0.022	0.093	0.115
	3	85.00	40.83	0.018	0.089	0.107
	6	81.67	28.53	0.015	0.057	0.072
	9	76.67	24.13	0.010	0.036	0.045
	12	68.33	16.93	0.005	0.027	0.032
25. BRRI dhan28	0	95.00	32.77	0.016	0.052	0.068
	3	91.67	33.50	0.013	0.051	0.063
	6	83.33	24.13	0.009	0.043	0.052
	9	75.00	21.10	0.007	0.031	0.037
	12	66.67	15.63	0.004	0.022	0.025
26. BRRI dhan29	0	85.00	32.50	0.019	0.067	0.086
	3	80.00	30.00	0.017	0.065	0.082
	6	75.00	25.60	0.014	0.042	0.056
	9	68.33	20.10	0.006	0.030	0.036
	12	61.67	13.40	0.003	0.014	0.016
27. BRRI dhan30	0	88.33	35.47	0.028	0.092	0.120
	3	81.67	34.30	0.025	0.089	0.114
	6	76.67	30.83	0.021	0.082	0.102
	9	71.67	25.07	0.014	0.043	0.057
	12	65.00	19.60	0.008	0.030	0.038
28. Heera-2	0	93.33	30.43	0.019	0.065	0.084
	3	95.00	33.13	0.021	0.072	0.093
	6	93.33	33.80	0.020	0.070	0.090
	9	90.00	30.37	0.018	0.068	0.086
	12	83.33	23.90	0.016	0.059	0.075

Appendix-4: The effect of salinity on relative seedling height, root dry weight, shoot dry weight and total dry matter of 28 rice cultivars

Cultivars	Salinity (dS m^{-1})	Relative seedling height (%)	Relative root dry wt. (%)	Relative shoot dry wt. (%)	Relative total dry matter (%)
1. Pokkali	0	100.00	100.0	100.0	100.0
	3	103.89	110.9	113.4	112.9
	6	93.41	107.5	101.0	102.4
	9	89.56	98.5	89.1	91.1
	12	84.18	68.4	60.7	62.4
2. Nona Bokkra	0	100.00	100.0	100.0	100.0
	3	103.76	115.1	113.0	113.3
	6	87.40	111.3	101.2	102.7
	9	79.18	97.1	82.5	84.8
	12	69.08	77.3	72.2	72.9
3. Sadamota	0	100.00	100.0	100.0	100.0
	3	105.83	109.1	107.3	107.6
	6	95.36	88.4	101.2	99.0
	9	90.20	70.1	79.9	78.2
	12	85.26	51.5	69.1	66.1
4. Lalmota	0	100.00	100.0	100.0	100.0
	3	100.58	111.2	106.9	108.9
	6	74.57	85.5	100.1	98.1
	9	72.57	51.9	86.4	81.7
	12	63.71	40.6	74.3	69.8
5. Kajalsail	0	100.00	100.0	100.0	100.0
	3	93.08	111.5	104.1	105.2
	6	78.35	63.5	80.9	78.1
	9	73.57	43.5	62.5	59.6
	12	65.59	38.7	56.7	54.0
6. Kajal Lata	0	100.00	100.0	100.0	100.0
	3	107.61	109.1	104.1	105.0
	6	87.09	97.2	81.6	84.4
	9	73.20	73.4	63.3	65.1
	12	73.24	42.4	53.1	51.2
7. Nona Kachu	0	100.00	100.0	100.0	100.0
	3	99.01	117.5	111.8	112.7
	6	83.75	108.9	101.8	103.0
	9	69.71	84.5	93.9	92.2
	12	52.41	42.3	48.3	47.2
8. Chapsal	0	100.00	100.0	100.0	100.0
	3	101.80	112.6	109.3	109.9
	6	94.92	90.5	99.6	98.0
	9	89.21	82.7	89.4	88.3
	12	85.15	66.8	74.1	72.8
9. Kolarmocha	0	100.00	100.0	100.0	100.0
	3	101.15	109.2	108.2	108.4
	6	84.88	84.2	101.4	97.2
	9	77.42	61.6	79.5	75.2
	12	71.27	24.2	54.7	47.4
10. Sarna Balam	0	100.00	100.0	100.0	100.0
	3	101.68	108.5	105.9	106.5
	6	95.99	100.1	99.9	100.0
	9	83.92	75.1	76.4	76.1
	12	52.60	49.9	54.9	53.7

Appendix-4: Contd.

Cultivars	Salinity ($dS\ m^{-1}$)	Relative seedling height (%)	Relative root dry wt. (%)	Relative shoot dry wt. (%)	Relative total dry matter (%)
11. Bashi Raj	0	100.00	100.0	100.0	100.0
	3	104.42	108.4	110.7	110.0
	6	96.55	89.9	101.1	98.0
	9	88.50	62.2	91.3	83.2
	12	71.86	36.2	56.7	51.0
12. Jabra	0	100.00	100.0	100.0	100.0
	3	104.53	109.8	113.0	112.3
	6	99.21	85.4	97.5	94.7
	9	73.66	63.1	64.9	64.4
	12	45.21	29.6	34.8	33.6
13. Komra Gor	0	100.00	100.0	100.0	100.0
	3	105.49	107.8	104.9	105.6
	6	96.53	88.8	92.4	91.5
	9	85.65	50.6	74.3	68.1
	12	71.73	21.4	61.0	50.8
14. Udi Chadra	0	100.00	100.0	100.0	100.0
	3	105.01	102.7	104.6	103.8
	6	89.08	72.9	85.0	79.8
	9	75.70	55.3	73.0	65.4
	12	58.43	30.6	50.6	42.1
15. Jota Balam	0	100.00	100.0	100.0	100.0
	3	103.25	112.2	108.3	108.7
	6	99.84	106.9	106.3	106.4
	9	94.63	101.8	96.2	96.9
	12	77.70	61.4	53.6	54.4
16. Pala Vir	0	100.00	100.0	100.0	100.0
	3	102.73	100.1	110.0	107.8
	6	90.00	74.2	90.1	86.6
	9	74.55	51.9	73.2	68.6
	12	58.72	29.6	40.6	38.2
17. BINA Sal-2	0	100.00	100.0	100.0	100.0
	3	106.09	111.4	107.3	107.8
	6	106.52	105.7	110.2	109.6
	9	89.25	83.7	90.0	89.0
	12	68.98	53.3	62.6	61.3
18. BRRI dhan40	0	100.00	100.0	100.0	100.0
	3	106.27	107.4	108.2	107.9
	6	88.56	100.2	100.6	100.4
	9	79.33	70.6	84.6	80.7
	12	75.38	44.1	55.8	52.6
19. BRRI dhan41	0	100.00	100.0	100.0	100.0
	3	103.05	108.8	106.8	107.3
	6	87.62	89.3	96.6	94.9
	9	78.52	68.0	71.2	70.5
	12	66.26	47.3	53.7	52.1
20. BRRI dhan47	0	100.00	100.0	100.0	100.0
	3	103.52	108.5	104.5	105.2
	6	97.43	104.2	103.0	103.2
	9	88.08	92.9	86.9	87.9
	12	73.36	72.9	66.3	67.4

Appendix-4: Contd.

Cultivars	Salinity (dS m^{-1})	Relative seedling height (%)	Relative root dry wt. (%)	Relative shoot dry wt. (%)	Relative total dry matter (%)
21. BR 10	0	100.00	100.0	100.0	100.0
	3	94.86	90.2	97.1	96.4
	6	83.77	69.8	68.6	68.7
	9	57.45	54.2	49.6	50.1
	12	38.51	17.7	19.7	19.5
22. BR 11	0	100.00	100.0	100.0	100.0
	3	92.04	88.6	96.3	94.9
	6	75.22	67.2	80.7	78.4
	9	62.73	47.1	48.2	48.0
	12	53.76	20.7	28.4	27.1
23. BR 22	0	100.00	100.0	100.0	100.0
	3	96.30	83.2	96.0	93.5
	6	72.55	64.9	59.9	60.9
	9	61.84	43.3	45.5	45.1
	12	40.91	20.1	36.2	33.1
24. BR 23	0	100.00	100.0	100.0	100.0
	3	94.79	82.6	95.7	93.0
	6	66.29	71.4	61.4	63.1
	9	56.02	44.9	38.4	39.6
	12	39.38	23.3	29.1	27.9
25. BRRI dhan28	0	100.00	100.0	100.0	100.0
	3	102.26	79.4	97.8	93.6
	6	73.79	56.5	82.8	76.6
	9	64.41	41.8	59.2	55.2
	12	47.86	23.4	41.6	37.3
26. BRRI dhan29	0	100.00	100.0	100.0	100.0
	3	92.34	88.3	97.0	94.9
	6	78.78	73.7	62.2	64.7
	9	62.05	31.8	44.2	41.4
	12	41.35	14.2	20.5	19.0
27. BRRI dhan30	0	100.00	100.0	100.0	100.0
	3	96.76	88.3	96.7	94.7
	6	86.93	74.0	88.7	85.2
	9	70.69	50.1	46.8	47.5
	12	55.32	28.5	32.7	31.7
28. Heera-2	0	100.00	100.0	100.0	100.0
	3	109.39	111.0	110.7	110.7
	6	111.13	105.7	107.2	106.8
	9	100.30	96.7	104.1	102.4
	12	79.27	84.6	90.4	89.1
Significant level	**	**	**	**	**
CV (%)	4.84	4.71	7.54	4.17	3.81

** Significant at 0.01 level of probability

Appendix-5: The effect of cultivars on Na^+, K^+, Ca^{2+} and Mg^{2+} concentration in shoots of rice seedlings [each value is a mean of 5 salinity levels (0, 3, 6, 9 & 12 dSm^{-1})]

Cultivars	Na^+ (%)	K^+ (%)	Ca^{2+} (%)	Mg^{2+} (%)
1. Pokkali	1.016 de	0.929 ef	0.428 i-l	0.231 m
2. Nona Bokkra	**0.950 e**	1.047 a-e	0.405 kl	**0.225 n**
3. Sadamota	1.024 de	0.950 c-f	0.402 kl	0.250 f-h
4. Lalmota	0.975 e	0.971 c-f	0.453 d-j	0.243 ij
5. Kajal Sail	1.041 c-e	0.973 c-f	0.435 h-k	0.241 k
6. Kajal Lata	1.087 b-e	1.016 a-f	**0.390 l**	0.248 h
7. Nona Kacho	1.070 c-e	1.009 a-f	0.438 h-k	0.250 f-h
8. Chapsal	1.033 de	0.956 c-f	0.425 j-l	0.255 e
9. Kolarmocha	1.091 b-e	0.983 c-f	0.444 g-k	0.258 d
10. Sarnabalam	1.077 c-e	1.013 a-f	0.489 a-g	0.243 jk
11. Bashiraj	**0.950 e**	1.013 a-f	0.497 a-d	**0.270 a**
12. Jabra	1.045 c-e	**0.916 f**	0.507 a-c	0.243 ij
13. Komragor	0.975 e	0.997 b-f	0.453 d-j	0.245 i
14. Udichadra	1.144 b-e	0.933 d-f	**0.533 a**	0.257 de
15. Jatabalam	1.125 b-e	1.029 a-f	0.459 d-j	0.231 m
16. Palavir	1.101 b-e	1.062 a-d	0.461 c-j	0.251 fg
17. BINA Sal-2	**0.950 e**	1.074 a-c	0.493 a-e	**0.225 n**
18.BRRI dhan40	1.063 c-e	0.998 b-f	0.444 g-k	0.235 l
19. BRRI dhan41	1.127 b-e	1.043 a-f	0.447 e-k	0.245 i
20. BRRI dhan47	0.983 e	1.111 ab	0.477 b-h	0.269 b
21 BR 10	1.138 b-e	0.984 c-f	0.513 ab	0.236 l
22. BR 11	1.084 c-e	0.918 ef	0.475 b-i	0.252 f
23. BR 22	1.194 b-d	0.954 c-f	0.517 ab	0.252 f
24. BR 23	1.283 ab	0.934 d-f	0.509 ab	0.266 c
25. BRRI dhan28	1.237 a-c	0.941 d-f	0.492 a-f	0.249 gh
26. BRRI dhan29	**1.380 a**	0.926 ef	0.487 a-g	**0.270 a**
27. BRRI dhan30	**1.380 a**	0.928 ef	0.473 b-i	0.242 jk
28. Heera-2	1.051 c-e	**1.128 a**	0.477 b-h	0.255 e
Significant level	**	**	**	**
$LSD_{0.05}$	0.166	0.105	0.039	0.002
CV (%)	13.67	4.60	7.08	7.23

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

** Significant at 0.01 level of probability

Appendix-6: The effect of different salinity levels on Na^+, K^+, Ca^{2+} and Mg^{2+} concentration in shoots of rice seedlings (mean of 28 rice cultivars)

Level of salinity (dSm^{-1})	Na^+ (%)	K^+ (%)	Ca^{2+} (%)	Mg^{2+} (%)
0	0.361 e	1.861 a	0.273 e	0.204 e
3	0.625 d	1.263 b	0.352 d	0.224 d
6	0.930 c	0.849 c	0.506 c	0.242 c
9	1.198 b	0.576 d	0.561 b	0.267 b
12	2.345 a	0.403 e	0.634 a	0.303 a
Significant level	**	**	**	**
$LSD_{0.05}$	0.070	0.044	0.016	0.003
CV (%)	13.67	4.60	7.08	7.23

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

** Significant at 0.01 level of probability

Appendix-7: The effect of salinity on Na, K, Ca and Mg contents (%) of 28 rice cultivars

Cultivars	Salinity (dS m^{-1})	Na content (%)	K content (%)	Ca content (%)	Mg content (%)
1. Pokkali	0	0.37	1.52	0.26	0.20
	3	0.64	1.15	0.32	0.21
	6	0.89	0.88	0.42	0.23
	9	1.04	0.65	0.49	0.25
	12	2.14	0.45	0.66	0.27
2. Nona Bokkra	0	0.29	1.78	0.28	0.21
	3	0.59	1.35	0.33	0.21
	6	0.79	0.95	0.41	0.22
	9	0.95	0.69	0.46	0.24
	12	2.14	0.46	0.54	0.25
3. Sadamota	0	0.29	1.55	0.24	0.21
	3	0.61	1.22	0.32	0.22
	6	0.90	0.90	0.45	0.25
	9	1.04	0.65	0.48	0.26
	12	2.28	0.43	0.52	0.30
4. Lalmota	0	0.41	1.71	0.23	0.19
	3	0.55	1.25	0.34	0.21
	6	0.88	0.88	0.54	0.23
	9	1.04	0.62	0.55	0.25
	12	2.00	0.40	0.60	0.33
5. Kajalsail	0	0.29	1.77	0.27	0.20
	3	0.54	1.28	0.33	0.22
	6	0.89	0.83	0.49	0.23
	9	1.06	0.57	0.52	0.26
	12	2.43	0.42	0.57	0.29
6. Kajal Lata	0	0.41	1.93	0.23	0.21
	3	0.55	1.35	0.31	0.22
	6	0.97	0.81	0.42	0.23
	9	1.08	0.59	0.48	0.27
	12	2.43	0.41	0.51	0.31
7. Nona Kachu	0	0.43	1.88	0.25	0.22
	3	0.61	1.18	0.32	0.24
	6	0.97	0.95	0.43	0.24
	9	1.06	0.64	0.54	0.26
	12	2.28	0.40	0.65	0.29
8. Chapsal	0	0.29	1.80	0.23	0.21
	3	0.62	1.08	0.33	0.23
	6	0.86	0.78	0.48	0.25
	9	1.04	0.68	0.52	0.28
	12	2.36	0.44	0.56	0.31
9. Kolarmocha	0	0.43	1.92	0.23	0.23
	3	0.59	1.28	0.32	0.24
	6	0.95	0.73	0.52	0.25
	9	1.06	0.54	0.56	0.27
	12	2.43	0.43	0.59	0.30
10. Sarna Balam	0	0.41	1.88	0.25	0.19
	3	0.71	1.31	0.34	0.22
	6	0.86	0.78	0.54	0.24
	9	1.04	0.67	0.60	0.25
	12	2.37	0.42	0.72	0.31

Appendix-7:Contd.

Cultivars	Salinity (dS m^{-1})	Na content (%)	K content (%)	Ca content (%)	Mg content (%)
11. Bashi Raj	0	0.29	1.95	0.26	0.20
	3	0.59	1.36	0.34	0.22
	6	0.83	0.76	0.54	0.27
	9	0.98	0.59	0.60	0.31
	12	2.04	0.41	0.73	0.37
12. Jabra	0	0.43	1.65	0.28	0.21
	3	0.61	1.19	0.35	0.22
	6	0.71	0.78	0.60	0.24
	9	1.06	0.55	0.61	0.25
	12	2.41	0.41	0.70	0.29
13. Komra Gor	0	0.43	1.83	0.26	0.20
	3	0.61	1.33	0.34	0.22
	6	0.79	0.87	0.50	0.23
	9	1.03	0.55	0.56	0.27
	12	2.01	0.42	0.61	0.31
14. Udi Chadra	0	0.38	1.70	0.29	0.21
	3	0.70	1.16	0.37	0.22
	6	0.92	0.84	0.56	0.25
	9	1.22	0.59	0.69	0.29
	12	2.50	0.37	0.75	0.32
15. Jota Balam	0	0.29	1.95	0.29	0.19
	3	0.62	1.32	0.34	0.21
	6	0.92	0.90	0.51	0.23
	9	1.25	0.55	0.55	0.25
	12	2.55	0.42	0.60	0.27
16. Pala Vir	0	0.43	1.95	0.27	0.21
	3	0.67	1.35	0.35	0.23
	6	0.91	0.94	0.48	0.25
	9	1.21	0.66	0.56	0.27
	12	2.28	0.42	0.65	0.29
17. BINA Sal-2	0	0.29	1.97	0.26	0.19
	3	0.54	1.21	0.37	0.21
	6	0.82	1.01	0.56	0.22
	9	1.00	0.71	0.61	0.25
	12	2.10	0.47	0.67	0.26
18. BRRI dhan40	0	0.29	1.95	0.26	0.20
	3	0.57	1.31	0.32	0.21
	6	0.94	0.78	0.49	0.23
	9	1.12	0.54	0.55	0.25
	12	2.40	0.41	0.61	0.27
19. BRRI dhan41	0	0.43	2.00	0.27	0.21
	3	0.64	1.38	0.34	0.23
	6	0.86	0.83	0.50	0.24
	9	1.21	0.59	0.53	0.25
	12	2.50	0.42	0.59	0.29
20. BRRI dhan47	0	0.29	2.02	0.29	0.20
	3	0.56	1.37	0.37	0.24
	6	0.87	0.98	0.52	0.26
	9	1.06	0.68	0.55	0.30
	12	2.13	0.51	0.65	0.34

Appendix-7:Contd.

Cultivars	Salinity (dS m^{-1})	Na content (%)	K content (%)	Ca content (%)	Mg content (%)
21. BR 10	0	0.32	1.88	0.31	0.20
	3	0.59	1.35	0.39	0.21
	6	0.96	0.86	0.58	0.23
	9	1.19	0.48	0.60	0.25
	12	2.64	0.35	0.68	0.29
22. BR 11	0	0.29	1.97	0.30	0.20
	3	0.60	1.09	0.38	0.23
	6	1.00	0.78	0.51	0.25
	9	1.17	0.42	0.56	0.27
	12	2.37	0.32	0.63	0.32
23. BR 22	0	0.43	1.87	0.34	0.20
	3	0.68	1.36	0.39	0.23
	6	1.04	0.81	0.58	0.25
	9	1.29	0.43	0.62	0.27
	12	2.53	0.30	0.66	0.31
24. BR 23	0	0.43	1.91	0.29	0.19
	3	0.76	1.13	0.39	0.23
	6	1.04	0.79	0.50	0.25
	9	1.84	0.55	0.65	0.31
	12	2.35	0.29	0.72	0.34
25. BRRI dhan28	0	0.29	1.88	0.31	0.21
	3	0.68	1.28	0.40	0.23
	6	1.28	0.76	0.51	0.24
	9	1.70	0.44	0.56	0.26
	12	2.23	0.33	0.68	0.31
26. BRRI dhan29	0	0.43	1.93	0.30	0.23
	3	0.73	1.18	0.38	0.24
	6	1.14	0.81	0.53	0.26
	9	1.83	0.40	0.58	0.30
	12	2.79	0.31	0.65	0.35
27. BRRI dhan30	0	0.41	1.99	0.31	0.21
	3	0.70	1.09	0.39	0.23
	6	1.14	0.76	0.51	0.24
	9	1.87	0.45	0.55	0.26
	12	2.77	0.35	0.60	0.27
28. Heera-2	0	0.41	1.99	0.29	0.21
	3	0.62	1.45	0.38	0.23
	6	0.92	1.00	0.53	0.25
	9	1.09	0.69	0.57	0.26
	12	2.21	0.51	0.63	0.31
Significant level		**	**	**	**
CV (%)		13.67	4.60	7.08	7.23

** Significant at 0.01 level of probability

Appendix- 8: The effect of cultivars on ratio of Na and K, Na and Ca and Na and Mg content of rice seedlings (each value is a mean of 5 salinity levels)

Sl. No.	Cultivars	Na/K	Na/Ca	Na/Mg
1.	Pokkali	1.62 i-k	2.19 b-h	4.20 d-i
2.	Nona Bokkra	1.48 jk	2.14 e-i	4.05 f-j
3.	Sadamota	1.72 g-j	2.33 bc	3.83 ij
4.	Lalmota	1.65 h-k	2.03 h-j	3.75 jk
5.	Kajal Sail	1.86 f-i	2.16 b-i	4.02 g-j
6.	Kajal Lata	1.91 e-h	2.56 a	4.08 d-j
7.	Nona Kacho	1.83 f-i	2.26 b-e	4.07 e-j
8.	Chapsal	1.74 f-i	2.22 b-f	3.79 ij
9.	Kolar mocha	1.91 e-h	2.30 b-e	4.01 g-j
10.	Sarnabalam	1.80 f-i	2.07 f-j	4.15 d-j
11.	Bashiraj	1.62 i-k	1.74 l	3.17 l
12.	Jabra	1.90 e-h	1.93 jk	4.03 f-j
13.	Komragor	1.66 h-k	2.04 g-j	3.75 jk
14.	Udichadra	2.15 e	1.99 i-k	4.16 d-j
15.	Jatabalam	1.98 ef	2.16 b-i	4.48 b-e
16.	Palavir	1.79 f-i	2.21 b-g	4.15 d-j
17.	BINA Sal-2	1.47 jk	1.76 l	3.98 g-j
18.	BRRI dhan40	1.95 e-g	2.16 c-i	4.28 c-h
19.	BRRI dhan41	1.95 e-g	2.34 b	4.36 b-g
20.	BRRI dhan47	1.44 k	1.87 kl	3.38 kl
21	BR 10	2.37 d	2.00 i-k	4.49 b-e
22.	BR 11	2.41 d	2.07 f-j	3.99 g-j
23.	BR 22	2.67 bc	2.14 d-i	4.45 b-f
24.	BR 23	2.72 bc	2.32 b-d	4.50 b-d
25.	BRRI dhan28	2.59 cd	2.29 b-e	4.70 b
26.	BRRI dhan29	3.17 a	2.58 a	4.69 bc
27.	BRRI dhan30	2.89 b	2.66 a	5.42 a
28.	Heera-2	1.49 jk	2.05 f-j	3.90 h-j
	Significant level	**	**	**
	$LSD_{(0.05)}$	**0.2197**	**0.1480**	**0.3609**
	CV (%)	**14.71%**	**9.12%**	**11.63%**

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

** Significant at 0.01 level of probability

Appendix- 9: The effect of salinity levels on ratio of Na and K, Na and Ca and Na and Mg content of rice seedlings (each value is a mean of 28 cultivars)

Salinity level (dSm^{-1})	Na/K	Na/Ca	Na/Mg
0	0.19 e	1.34 e	1.76 e
3	0.49 d	1.77 d	2.77 d
6	1.10 c	1.85 c	3.84 c
9	2.19 b	2.13 b	4.49 b
12	5.98 a	3.73 a	7.82 a
Significant level	**	**	**
$LSD_{(0.05)}$	0.1256	0.08461	0.2064
CV (%)	14.71%	9.12%	11.63%

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

** Significant at 0.01 level of probability

Appendix-10: The effect of salinity on Na /K, Na/Ca and Ca/Mg ratio of 28 rice cultivars

Cultivars	Salinity (dS m^{-1})	Na/K	Na/Ca	Na/Mg
1. Pokkali	0	0.24	1.42	1.85
	3	0.56	2.00	3.05
	6	1.01	2.12	3.87
	9	1.60	2.12	4.16
	12	4.76	3.24	7.93
2. Nona Bokkra	0	0.16	1.04	1.38
	3	0.44	1.79	2.81
	6	0.83	1.93	3.59
	9	1.38	2.07	3.96
	12	4.65	3.96	8.56
3. Sadamota	0	0.19	1.21	1.38
	3	0.50	1.91	2.77
	6	1.00	2.00	3.60
	9	1.60	2.17	4.00
	12	5.30	4.38	7.60
4. Lalmota	0	0.24	1.78	2.16
	3	0.44	1.62	2.62
	6	1.00	1.63	3.83
	9	1.68	1.89	4.16
	12	5.00	3.33	6.06
5. Kajal sail	0	0.16	1.07	1.45
	3	0.42	1.64	2.45
	6	1.07	1.82	3.87
	9	1.86	2.04	4.08
	12	5.79	4.26	8.38
6. Kajal lata	0	0.21	1.78	1.95
	3	0.41	1.77	2.50
	6	1.20	2.31	4.22
	9	1.83	2.25	4.00
	12	5.93	4.76	7.84
7. Nona Kachu	0	0.23	1.72	1.95
	3	0.52	1.91	2.54
	6	1.02	2.26	4.04
	9	1.66	1.96	4.08
	12	5.70	3.51	7.86
8. Chap sal	0	0.16	1.26	1.38
	3	0.57	1.88	2.70
	6	1.10	1.79	3.44
	9	1.53	2.00	3.71
	12	5.36	4.21	7.61
9. Kolarmocha	0	0.22	1.87	1.87
	3	0.46	1.84	2.46
	6	1.30	1.83	3.80
	9	1.96	1.89	3.93
	12	5.65	4.12	8.10
10. Sarna Balam	0	0.22	1.64	2.16
	3	0.54	2.09	3.23
	6	1.10	1.59	3.58
	9	1.55	1.73	4.16
	12	5.64	3.29	7.65

Appendix-10: Contd.

Cultivars	Salinity (dS m^{-1})	Na/K	Na/Ca	Na/Mg
11. Bashi Raj	0	0.15	1.12	1.45
	3	0.43	1.74	2.68
	6	1.09	1.54	3.07
	9	1.66	1.63	3.16
	12	4.98	2.79	5.51
12. Jabra	0	0.26	1.54	2.05
	3	0.51	1.74	2.77
	6	0.91	1.18	2.96
	9	1.93	1.74	4.24
	12	5.88	3.44	8.31
13. Komra Gor	0	0.23	1.65	2.15
	3	0.46	1.79	2.77
	6	0.91	1.58	3.43
	9	1.87	1.84	3.81
	12	4.79	3.30	6.48
14. Udi Chadra	0	0.22	1.31	1.81
	3	0.60	1.89	3.18
	6	1.10	1.64	3.68
	9	2.07	1.77	4.21
	12	6.76	3.33	7.81
15. Jota Balam	0	0.15	1.00	1.53
	3	0.47	1.82	2.95
	6	1.02	1.80	4.00
	9	2.27	2.27	5.00
	12	6.07	4.25	9.44
16. Pala Vir	0	0.22	1.59	2.05
	3	0.50	1.91	2.91
	6	0.97	1.90	3.64
	9	1.83	2.16	4.48
	12	5.43	3.51	7.86
17. BINA Sal-2	0	0.15	1.12	1.53
	3	0.45	1.46	2.57
	6	0.81	1.46	3.73
	9	1.41	1.64	4.00
	12	4.47	3.13	8.08
18. BRRI dhan40	0	0.15	1.12	1.45
	3	0.44	1.78	2.71
	6	1.21	1.92	4.09
	9	2.07	2.04	4.48
	12	5.85	3.93	8.89
19. BRRI dhan41	0	0.22	1.59	2.05
	3	0.46	1.88	2.78
	6	1.04	1.72	3.58
	9	2.05	2.28	4.84
	12	5.95	4.24	8.62
20. BRRI dhan47	0	0.14	1.00	1.45
	3	0.41	1.51	2.33
	6	0.89	1.67	3.35
	9	1.56	1.93	3.53
	12	4.18	3.28	6.26

Appendix-10: Contd.

Cultivars	Salinity (dS m^{-1})	Na/K	Na/Ca	Na/Mg
21. BR 10	0	0.17	1.03	1.60
	3	0.44	1.51	2.81
	6	1.12	1.66	4.17
	9	2.48	1.98	4.76
	12	7.54	3.88	9.10
22. BR 11	0	0.15	0.97	1.45
	3	0.55	1.58	2.61
	6	1.28	1.96	4.00
	9	2.79	2.09	4.33
	12	7.41	3.76	7.41
23. BR 22	0	0.23	1.26	2.15
	3	0.50	1.74	2.96
	6	1.28	1.79	4.16
	9	3.00	2.08	4.78
	12	8.43	3.83	8.16
24. BR 23	0	0.23	1.48	2.26
	3	0.67	1.95	3.30
	6	1.32	2.08	4.16
	9	3.35	2.83	5.94
	12	8.10	3.26	6.91
25. BRRI dhan28	0	0.15	0.94	1.38
	3	0.53	1.70	2.96
	6	1.68	2.51	5.33
	9	3.86	3.04	6.54
	12	6.76	3.28	7.19
26. BRRI dhan29	0	0.22	1.43	1.87
	3	0.62	1.92	3.04
	6	1.41	2.15	4.38
	9	4.58	3.16	6.10
	12	9.00	4.29	7.97
27. BRRI dhan30	0	0.21	1.32	1.95
	3	0.64	1.79	3.04
	6	1.50	2.24	4.75
	9	4.16	3.40	7.19
	12	7.91	4.62	10.26
28. Heera-2	0	0.21	1.41	1.95
	3	0.43	1.63	2.70
	6	0.92	1.74	3.68
	9	1.58	1.91	4.19
	12	4.33	3.51	7.13
Significant level		**	**	**
CV (%)		14.71%	9.12%	11.63%

** Significant at 0.01 level of probability