EFFECT OF SUPPLEMENTAL POTASSIUM ON THE GROWTH AND YIELD OF RICE DIFFERING IN SALT TOLERANCE

By

TANVIR MASUM SAIKOT

Reg. No.: 04-01352

A Thesis

Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (M.S.)
IN
AGRICULTURAL CHEMISTRY

Semester: January–June, 2010

Approved By:

....

(Professor Dr. Md. Abdur Razzaque)
Department of Agricultural Chemistry
Sher-e-Bangla Agricultural University,
Dhaka-1207
Supervisor

....

(Professor Md. Shahjahan Miah)
Department of Agricultural Chemistry
Sher-e-Bangla Agricultural University,
Dhaka-1207
Co-supervisor

....

Professor Dr. Rokeya Begum
Chairman
Examination Committee

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka – 1207
PABX: 9110351 & 9144270-79

CERTIFICATE

This is to certify that the thesis entitled "EFFECT OF SUPPLEMENTAL POTASSIUM ON THE GROWTH AND YIELD OF RICE DIFFERING IN SALT TOLERANCE" submitted to the *DEPARTMENT OF AGRICULTURAL CHEMISTRY*,, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of *MASTER OF SCIENCE (M.S.) in AGRICULTURAL CHEMISTRY*, embodies the results of a piece of *bona fide* research work carried out by TANVIR MASUM SAIKOT, Registration. No. 04-01352, under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma in any other institution.

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

Dated: 16.10.2011
Dhaka, Bangladesh

(Professor Dr. Md. Abdur Razzaque)
Department of Agricultural Chemistry
Sher-e-Bangla Agricultural University,
Dhaka, Bangladesh
Supervisor

DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENT

All praises are due to the Almighty Allah, the great, the gracious, merciful and supreme ruler of the universe to complete the research work and thesis successfully for the degree of Master of Science (MS) in Agricultural Chemistry.

I express the deepest sense of gratitude, sincere appreciation and heartfelt indebtedness to my reverend research supervisor Professor Dr. Md. Abdur Razzaque, Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, innovative suggestion, constant supervision and inspiration, valuable advice and helpful criticism in carrying out the research work and preparation of this manuscript.

I deem it a proud privilege to acknowledge my gratefulness, boundless gratitude and best regards to my respectable co-supervisor Professor Md. Shahjahan Miah, Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka for his valuable advice, constructive criticism and factual comments in upgrading the research work.

Special appreciation and warmest gratitude are extended to my esteemed teachers Professor Md. Azizur Rahman Mazumder,, Professor Dr. Rokeya Begum, Associate Professor Dr. Noor Jahan Begum, Assistant professor Md. Ariful Islam, Assistant professor Md. Sirajul Islam Khan and Assistant professor Md. Tazul Islam Chowdhury, Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka who provided creative suggestions, guidance and constant inspiration from the beginning to the completion of the research work. Their contribution, love and affection would persist in my memory for countless days.

I express my heartiest thanks to my dearest friends Ahsan habib, Md. Ali Ahmed, Sharifur Rahman Khandakar, Anis-Ur-Rahman and Md. Ashraful Alam, Sher-e-Bangla Agricultural University, Dhaka for their endless and active co-operation during the entire period of the research.

I express my special thanks to my classmates Md. Zahirul Islam, Md. Ayatullah and Md. Moksadul Islam for their extended help during the research period.

I also express my special thanks to Md. Abdus Salam, Section Officer, Lab. Assistants of the Department of Agricultural Chemistry and Soil Science and other office staffs of the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka for their extended and heartiest helps in completing the chemical analysis and other works during the research work.

I express my unfathomable tributes, sincere gratitude and heartfelt indebtedness from my core of heart to my parents S. M. A. Mannan and Masuma Akter, whose blessing, inspiration, sacrifice, and moral support opened the gate and paved to way of my higher study.

I want to say thanks, to all of my classmates and friends, for their active encouragement and inspiration.

October, 2011 Tanvir Masum Saikot

ABSTRACT

A pot culture experiment was conducted to study the reclamation of salinity by potassium supplementation on growth and yield of rice. The experiment was completed using two varieties namely Pokkali and BRRI dhan 29, four salinity levels (0, 4, 8 and 12 dS m^{-1}) and 4 supplemental K levels (80, 100, 120, 140 kg K_2O ha^{-1}). Plant height , root dry weight, shoot dry weight, total dry matter, effective number of tiller $hill^{-1}$, panicle length, number of filled grain $panicle^{-1}$, 1000 grain weight and grain yield $hill^{-1}$ of the rice varieties were studied. Significant varietal differences were found in plant height, shoot dry weight, total dry matter, effective number of tiller $hill^{-1}$, panicle length, number of filled grain $panicle^{-1}$, 1000 grain weight and grain yield $hill^{-1}$ except the root dry weight where Pokkali is better than BRRI Dhan 29. All of the growth and yield parameters decreased with increasing salinity. With increasing potassium level all of the growth and yield parameters increased up to 120 kg K_2O ha^{-1}, then slightly decreased at 140 kg K_2O ha^{-1}. The yield is significantly increased with the increasing level of potassium. In considering the interaction effect of variety and potassium treatments, the highest results were shown at 120 kg K_2O ha^{-1} in Pokkali . The effect of different K levels at different salinity levels, the values of both growth and yield parameters increased with increasing of potassium level at same salinity treatment except at 140 kg K_2O ha^{-1} where slight declination was observed. Interaction of variety, salinity and potassium also significantly affected all the growth and yield parameters. In most circumstances, the maximum result was in Pokkali at control salinity treatment with 120 kg K_2O ha^{-1}.

CONTENTS

(Cont'd)

(Cont'd)

(Cont'd)

(Cont'd)

(Cont'd)

LIST OF TABLES

(Cont'd)

LIST OF FIGURES

(Cont'd)

(Cont'd)

(Cont'd)

LIST OF ABBREVIATIONS

Abbreviated Form	Elaborated Form
EC	Electrical Conductivity
dS	Deci. Siemens
ha^{-1}	Per hectare
m^{-1}	Per meter
$hill^{-1}$	Per hill
L^{-1}	Per Litre
$panicle^{-1}$	Per panicle
g	Gram
kg	Kilogram
et al.	and others
mmol	Milli mole
BRRI	Bangladesh Rice Research Institute
LSD	Least Significant Difference
TSP	Triple Super Phosphate

CHAPTER I

INTRODUCTION

Soil salinity is a major problem in arid and semi-arid regions, where rainfall is insufficient to leach salts and excess sodium ions down and out of the root zone. These areas often have high evaporation rates, which can encourage an increase in salt concentration at the soil surface through capillary rise. The presence of a cemented hardpan at varying depths and insufficient precipitation for leaching often adds to the problem. At present, out of 1.5 billion hectares (ha) of cultivated land around the world, about 77 million hectares (5 %) is affected by excess salt content (Sheng et al., 2008). Incidentally, most of the developing and underdeveloped countries of South and Southeast Asia, Africa and South America are the worst affected by this salinity. A large bulk of about 320 million hectares of land in South and South East Asia is under the grip of salinity (Alam, 2001).

Among the environmental factors, salinity is one of the major constraint to food, feed and industrial raw material production because it limits crop yields and restricts the use of land previously uncultivated. In many arid and semi-arid regions, good soils are scarce with their overall productivity declining because of soil degradation by salinity and lack of proper soil and water management practices. Most salt-affected lands are found in the arid, semi-arid and coastal regions of sub-humid areas and are low in crop production (IAEA, 1995).

Soil or water salinity is one of the major stresses that severely limits crop production. Salinity has three potential effects on plants: lowering of the water potential, specific ion toxicity (sodium and chloride) and interference in the uptake of essential nutrients (Flowers and Flowers, 2005). The adverse effects of salinity on plant growth and yield are of a multifarious nature, *i.e.* they may be due to reduced cell expansion and leaf area (Ashraf, 1998) or to a reduced supply of photosynthates to the growing tissues (Munns, 1993). The deleterious effects of salinity on plant growth are associated with the low osmotic potential of soil solution, thereby causing water stress, nutritional imbalance and specific ion toxicity or a combination of these factors (Marschner, 1995).

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

Nutrient management is a vital component of the scientific package of agriculture technology to fight salinity. However, the use of potassium is very much lower than recommended levels. The acquisition of K^+ is concerned due to physiological similarities between Na^+ and K^+ (Noaman, 2004). The capacity of plants to counteract salinity stress will strongly depend on the status of their K^+ nutrition. Potassium is essential to all plants and in most terrestrial plants K^+ is the major cationic inorganic nutrient and it also enhances several enzyme functions. Potassium acts to balance the charge in the cytoplasm of the cell, where K^+ is the dominant counter ion for the large excess of negative charge on proteins and nucleic acids (Yang *et al.*, 2004). Potassium contributes more than Na^+, Cl^- and glycinebetaine in osmotic adjustment under saline conditions and activates the crucial enzymatic reactions such as formation of pyruvate. It is also a substantial contributor to osmotic pressure of the vacuole and thereby maintains cell turgor (Ashraf and Sarwar, 2002).

Rice (*Oryza sativa* L.) is a salt-sensitive crop. However, because of its ability to grow well in standing water, it is recommended as a desalinization crop (Bhumbla and Abrol, 1978). Yeo and Flowers (1982) reported varietal differences in rice for salinity tolerance. Salt seems to affect rice during pollination, decrease seed setting and grain yield (Maloo, 1993). Finck (1977) suggested that deficiency of K and Ca elements might play a significant role in plant growth depression in many saline soils. Reducing sodium and chloride uptake into rice while maintaining potassium uptake would aid growth under saline condition (Koyama *et al.*, 2001).

As saline soil generally has higher concentration of Na and Mg than K and Ca, high ionic imbalances may impair the selectivity of root membranes. This may result in passive accumulation of Na in root and shoot. Addition of K to a saline culture solution or soil has been found to increase the dry weight and K content of shoots with a corresponding decrease in Na content in rice. According to Yoshida (1981) rice is sensitive to salinity especially during early seeding growth and flowering. Therefore, maintaining a low Na/ K ratio on the soil during these two critical stages may benefit the rice plants. Two yield parameters, tiller number per plant and spike-let number per panicle, have proved most sensitive to salinity and are highly significantly correlated to final seed yield in rice cultivar under salt stress (Zeng and Shannon, 2000). The present study was aimed to investigate the effect of different levels of K application on the growth and yield of two salt tolerant and salt-sensitive rice varieties.

The research work was designed and planned with the following objectives:

- To study the various growth parameters of rice under salinity with K^+ supplementation.
- To observe the various yield components of rice under different levels of salinity with supplementation by different levels of K^+.

CHAPTER II

REVIEW OF LITERATURE

Rice is the staple food in many parts of the world. It is sensitive to various environmental factors *viz*. variety, soil, nutrient availability, temperature, humidity, light intensity and moisture for proper growth and yield. Many researches have been conducted on various aspects of rice in different countries. A lot of work has been done on potassium effects on different crops in normal soils, but a little information is available regarding K fertilization effects paddy yield in salt affected soils. Literature regarding the studies on 'Reclamation of salinity by potassium supplementation on yield and nutrient content of rice' are also scanty in Bangladesh. The 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. The salts interfered with the absorption of K^+ and Ca^{2+} and significantly ($P \leq 0.05$) decreased their uptake in rice cultivars. Addition of K and Si either alone or in combination significantly ($P \leq 0.05$) inhibited the uptake and transport of Na^+ from roots to shoots and improved dry matter yields under NaCl conditions. Potassium uptake, K^+/Na^+ ratios, and Ca^{2+} and Si uptake were also significantly ($P \leq 0.05$) increased by the addition of K and/or Si to the root medium. In this study, K and Si-enhanced salt tolerance in rice cultivars was ascribed to decreased Na^+ concentration and increased K^+ with a resultant improvement in K^+/Na^+ ratio, which is a good indicator to assess plant tolerance to salt stress.

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

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

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.

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

Din *et al.* (2001) conducted a pot experiment at salinity levels of 1.6, 6.0 and 12 dS m^{-1} with 50 mg kg^{-1} K_2SO_4 as soil application and 0.5% K_2SO_4 soultion as foliar spray on rice. He concluded that foliar and soil application of K increased significantly the number of tillers plant^{-1}, plant height, number of grains plant^{-1}, paddy and straw yield and grain to straw ratio in saline conditions. He also found that with foliar and soil application of potassium, the concentration of N and P increased in rice shoot and straw in saline conditions. He also found that foliar application of K increased the K^+ concentration in rice shoot and straw compared to soil application.

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.

Kandil *et al.* (2010) conducted three field experiments at El-Sirw Agricultural Research Station, Damietta during 1999, 2000 and 2001 under saline soil. The field experiments were laid out in split-split plot design with four replications. The main plots were devoted to four irrigation treatments *i.e.* continuous flooding (I1), water withholding for 12 days at 15 days after transplanting (DAT) (I2), at 25 DAT (I3) and at 35 DAT (I4). The sub plots were allocated to the three rice cultivars viz. Sakha 101, Sakha 102 and Giza 178. Three K rates 0, 48 and 46 kg K_2Oha^{-1} was randomized in the sub-sub-plots. The growth characteristic like leaf area index (LAI), dry matter productions (DM) g/m^2, chlorophyll content, heading date were studied along with the chemical traits i. e Na and K contents of shoot as well as Na/K ratio. It was observed that water stress at any growth stage significantly decreased LAI, DM and chlorophyll content and delayed the heading date. Similarly water stress increased Na and K contents (%) in shoots while it had no effect on Na/K ratio. Varietal differences were found significant in all studied characters. Giza 178 had the superiority in this concern as compared to other varieties while Sakha 102 was found inferior in all parameters under these conditions. K rates significantly increased LAI, DM, chlorophyll content and K% up to 48 kg K_2O/ha while lessen Na% and Na/K ratio and hastened the heading date. The interaction between irrigation treatments and varieties affected LAI, DM, chlorophyll content and heading date while the interactive effects of irrigation and K rates had significant effect on LAI, while cultivars and K rates significantly affected DM and chlorophyll content.

Mehdi *et al.* (2007) conducted a field experiment to evaluate the response of rice crop to potassium fertilization in saline-sodic soil during 2005. Soil samples were collected before transplanting of rice crop and analysed for physical and chemical properties of the soil. In this experiment five rates of K_2O (0, 25, 50, 75 and 100 kg ha^{-1}) were applied in the presence of basal doses of N and P_2O_5 i.e., 110 and 90 kg ha^{-1}, respectively. Whole of P, K and ½ of N were applied at the time of rice transplanting. Twelve and half kg ha^{-1} $ZnSO_4$ was also applied 15 days after rice transplanting. The remaining half of N was applied 30 days after rice transplanting. The system of layout was Randomized Complete Block Design with four replications. The net plot size was 6x4 m. Fertilizer sources of NPK were urea, TSP and SOP, respectively. Rice salt tolerant line PB-95 was used as test crops. The data of growth parameters and yield was recorded and samples of paddy and straw were collected treatment-wise and analysed for N, P and K contents. Soil samples after harvesting the crop were also collected, processed and analysed for the changes in the extractable soil K. The results showed that increasing rates of potassium fertilizer increased the number of tillers m^{-2}, plant height (cm), 1000-paddy weight and paddy as well as straw yield significantly. Maximum paddy (3.24 t ha^{-1}) and straw (3.92 t ha^{-1}) yields were obtained in T_5 (100 kg K_2O ha^{-1}) which was at par with T_4 (75 kg K_2O ha^{-1}). With increasing rates of potassium fertilizer, concentration of potassium in paddy and straw increased significantly. After harvesting the crop, the extractable potassium contents of soil increased from that of the original soil. It was concluded from the results that there was an increase of 30.65% in paddy over control by applying potassium (100 kg K_2O ha^{-1}) in saline-sodic soil.

Qadar (1995) grew rice cv. CSR 10 in pots at pH 8.0, 9.4, 9.8 or 10.0 and were given 0 or 60 kg/ha P and/or K. He found that increasing sodicity stress (pH 8.0, 9.4, 9.8 and 10.0 achieved by using sodium bicarbonate) adversely affected growth with delayed initiation of tillering and reduced the grain filling period. Total and filled grains per panicle, 1000-grain weight and grain yield were significantly lowered even at pH 9.4. There was a marked increase in Na concentration with a decrease in K and Ca in shoots at 30 day after transplanting and at maturity. P and Mg were slightly higher in the shoot in response to sodicity stress. P and K application at pH 10.0 ameliorated the adverse effect of sodicity by early initiation of tillering and flowering and had a positive effect on the yield attributes and grain yield. This also resulted in a decrease in Na and improvement in the P and K status of shoot. It was concluded that the amount of available P and K in the soil which was adequate for plant growth and development at lower sodicity levels, however became inadequate at higher sodicity.

Song and Fujiyama (1996) grew rice cv. Yamabiko hydroponically subjected to Na-salinization (addition of 80 mmol Na kg^{-1}) were given 0-50 mmol K kg^{-1}. They found that addition of 10 mmol K increased growth by decreasing the content of Na and increasing the K content of the plants. Higher K concentrations decreased growth compared with the optimum rate, such that plant Dry Weight (DW) at the highest K rate was similar to that with 80 mmol Na alone. Growth of the plants was best in control (unsalinized) plants. Total cation content increased with increasing K concentration, due to increased plant K content. A close relationship was observed among the osmotic potential of the solution, cumulative transpiration, and dry weight among the K treatments. Addition of K suppressed the uptake of other cations by rice in the order of Na > Mg > Ca, with a very small suppression for Ca and Mg. The depression of Na uptake by K could be due to the antagonism between the two cations. The addition of K resulted in a decrease of the uptake concentration (UC) of Na and an increase of that of K, but did change the UC of Ca and Mg. Transport of Na and Ca to the tops of rice palnts was not affected by the addition of K, while that of Mg increased with K addition.

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.

Zayed *et al*. (2007) conducted two field experiments at the experimental farm of El Sirw Agriculture Research Dammiatta prefecture, Egypt during 2005 and 2006 seasons. The study aimed to investigate the effect of various potassium rates; Zero, 24, 48 and 72 Kg K_2O ha^{-1}, on growth, sodium, potassium leaf content and their ratio at heading, grain yield and yield components of three hybrids: SK2034H, SK2046H and SK2058H and three varieties; Giza 177, Giza 178 and Sakha 104. The economic values were also estimated. The experimental soil was clayey with salinity levels of 8.5 and 8.7 dS/m in the first and second seasons, respectively. The experiments were performed in a split plot design with four replications. The main plots were devoted to the tested rice varieties, while potassium rates were distributed in the sub plots. The studied varieties varied significantly in their growth parameters, Na^+ and K^+ leaf content at heading as well as ratio, yield components and their economic values. SK2034H surpassed the rest varieties without any significant differences with SK2046H. SK2058H didn't show advantage over Giza 178 or Sakha 104. Giza 177 was the worst under such conditions. Increasing potassium rate significantly improved all studied traits leading to high grain yield. Furthermore, potassium succeeded to reduce Na^+, lower Na^+/K^+ ratio and raised K^+ resulted in considerable salinity withstanding. The hybrids of SK2034H and SK2046H as well as the salt sensitive rice variety Giza 177 were the most responsive cultivars for potassium fertilizer up to 72 kg K_2O /ha. Consequently, the economic estimates SK2034H had the higher net return and the high potassium level of 72 kg K_2O ha^{-1} gave the highest values of economic parameters under the tested saline soil conditions.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted under pot-culture at the net house of the department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207 to study the effect of supplemental K for amelioration of salinity and improve the growth and nutrients content of two selected rice varieties during Boro season (December-June) of the year 2008-09. Soils of different salinity levels (0, 4, 8 and 12 dS m^{-1}) were prepared artificially.

3.1 Design of the experiment:

Three factorial experiment was laid out in Completely Randomized Design (CRD) with three replications.

Factor 1: Rice Variety- 2 (Pokkali and BRRI dhan 29)

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

Factor 3: K^+ level- 4 (80, 100, 120, 140 kg K_2O ha^{-1})

Treatment combinations = 2 x 4 x 4 = 32

Replication: 3

3.2 Pot collection

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

3.3 Collection and preparation of soil

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

3.4 Seedbed preparation

Two separate wet seedbeds were prepared for two varieties of rice. Required amount of fertilizers were applied one day prior to sowing of seeds in the seed beds.

3.5 Seed soaking

Previously collected seeds of Pokkali and BRRI dhan 29 were soaked with water for 48 hours and then washed thoroughly in fresh water, and incubated for sprouting separately.

3.6 Sowing of seeds in seedbed

Sprouted seeds of the two varieties were sown in the wet seed bed separately.

3.7 Pot preparation for transplanting the rice seedlings

The chemical fertilizers *i.e.,* Urea, Triple Supper Phosphate (TSP), Muriate of Potash (MOP) and Gypsum were added for N, P, K and S in all the pot soils at the rate of 100 kg N, 60 kg P_2O_5, 80 kg K_2O and 20 kg S ha^{-1}, respectively. The whole amount of TSP, MOP, Gypsum and $1/3^{rd}$ of urea were applied before the final preparation of the pots. According to the treatment rate, the whole amount of supplemental K (as KCl) was also added in the respective pots. Thereafter the pots containing soil were moistened with water. Five weeks old seedlings of selected rice cultivars were transplanted in the respective pots. Two weeks after transplanting the salt solutions were applied in each pot according to the treatments. To avoid osmotic shock, salt solutions were added in three equal installments on alternate days until the expected conductivity was reached. The electric conductivity (EC) of each pot was measured everyday with a EC meter and necessary adjustments were made by adding water. The remaining $2/3^{rd}$ urea were top dressed at two equal divisions after 25 and 50 days of transplanting.

3.8 Intercultural operations

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

3.9 Data collection of growth and yield parameters

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

3.9.1 Plant height

The plant height (cm) was measured from the surface level of the growth media to the tip of the longest leaf at different days after transplanting (DAT) and before harvesting.

3.9.2 Number of effective tiller hill^{-1}

Effective tiller number hill^{-1} was counted at maturity.

3.9.3 Shoot dry weight

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

3.9.4 Root dry weight

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

3.9.5 Total dry matter

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

3.9.6 Panicle length (cm)

In case of more than 8 effective tillers hill^{-1}, average panicle length (cm) was calculated by taking the lengths of 8 panicles hill^{-1} which were selected randomly. In case of less than 10 effective tiller hill^{-1}, average panicle length (cm) was calculated by taking the lengths of all the panicles hill^{-1}.

3.9.7 Number of grain panicle^{-1}

In case of more than 8 effective tillers hill^{-1}, average number of filled grain was calculated by counting the number of filled grain of 8 panicles hill^{-1} which was selected randomly. In case of less than 8 effective tiller hill^{-1}, average number of filled grain was calculated by counting the number of filled grain of all the panicles hill^{-1}.

3.9.8 Thousand grain weights (g)

Thousand grain weight hill^{-1} was taken.

3.9.9 Grain yield hill^{-1} (g)

The grain yield of the hill which had effective tiller was recorded by weighing after proper drying the grain.

CHAPTER IV

RESULTS AND DISCUSSION

The different growth and yield parameters studied including plant height, root dry weight, shoot dry weight and total dry matter, number of effective tiller, panicle length, number of filled grain panicle^{-1}, grain yield hill $^{-1}$ and thousand grain weight of the selected two rice cultivars in view to evaluate their response to potassium supplementation at different salinity levels. To evaluate the varietal performance the absolute (Dewey,1960) values of different morphological characters and yield parameters have been taken into consideration and presented hereunder.

The results are discussed parameter wise under the following heads:

4.1 Plant height

4.1.1 Effects of variety

Varietal effect on plant height (cm) was statistically significant due to the combined effect of different salinity and supplemental K levels (Figure 1) at different days after transplanting (DAT). The plant height was highest (92.38, 107.68, 117.9 and 120.80 cm) in Pokkali at 30 DAT, 45 DAT, at flowering and at harvest and the shortest plant (47.16, 51.79, 57.72 and 58.05 cm) was obtained in BRRI Dhan 29 at different date respectively.

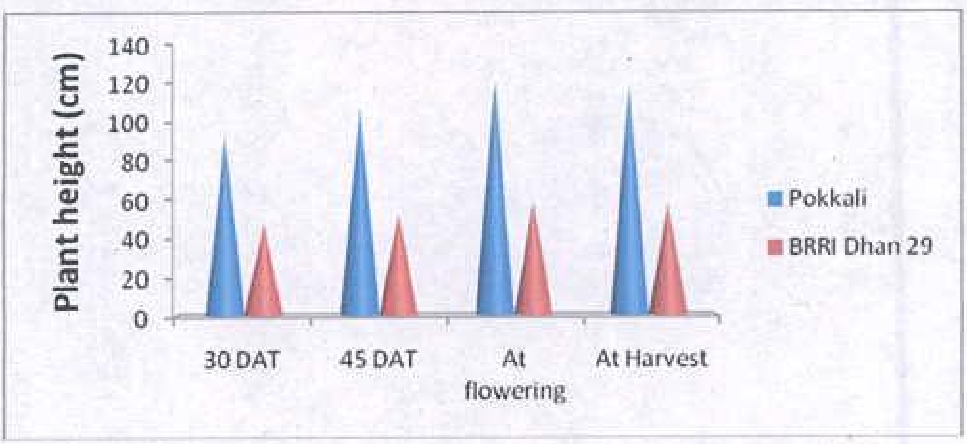


Figure 1.The Effect of variety on plant height of rice at different days after transplantation (DAT) due to the combined effect of different salinity and K levels

But the difference between the tallest and the shortest plant was very high and it seems to be due to inherent genetical characters (Appendix-1).

4.1.2 Effects of salinity

The average plant height of the selected rice varieties decreased as the levels of salinity increased due to the mean effect of different supplemental K levels (Figure 2) at different days after transplanting (DAT). The absolute plant height was highest (82.91, 101.7, 117 and 118.9 cm) at 30 DAT, 45 DAT, at flowering and at harvest by 0 dSm^{-1} and the shortest plant (48.25, 44.08, 35.07 and 30.90 cm) was obtained by 12 dSm^{-1} at 30, 45 DAT, at flowering and at harvest (Appendix 2).

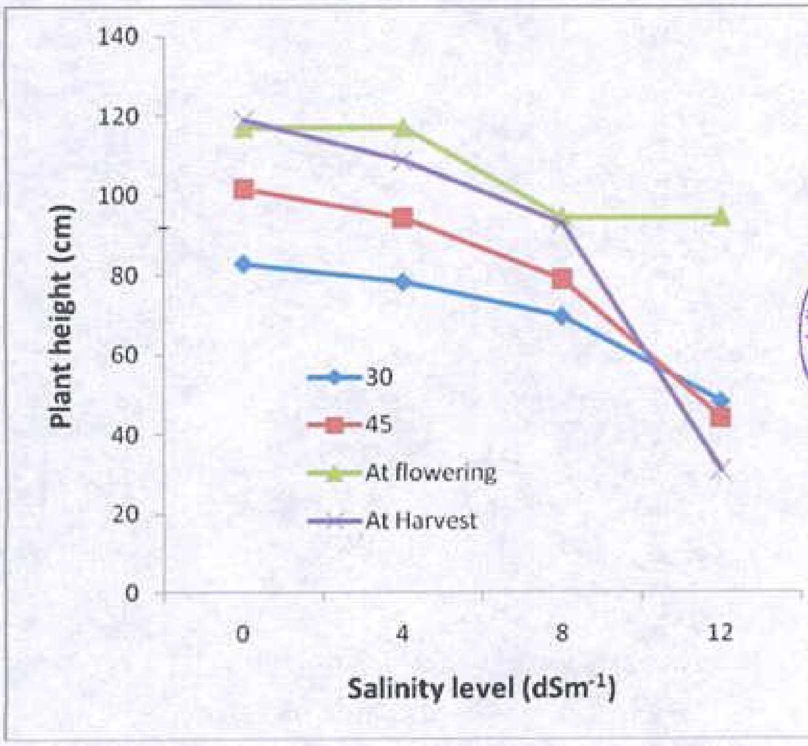


Figure 2. The effect of salinity level on plant height of rice at different days after transplantation (mean of 2 cultivars and 4 K levels)

4.1.3 Effects of potassium (K)

The plant height of rice increased with increasing the K levels over all the levels of salinity (Figure 3). The plant height was highest (72.54 , 83.17, 96.47 and 98.32 cm) at 30, 45 DAT, at flowering and at harvest by 120, 140, 120 and 120 kg K_20 ha^{-1}

respectively and the shortest plant (63.80, 74.11, 74.79 and.80.49 cm) was obtained 80 kg K_20 ha^{-1} (Figure 3 & Appendix 3).

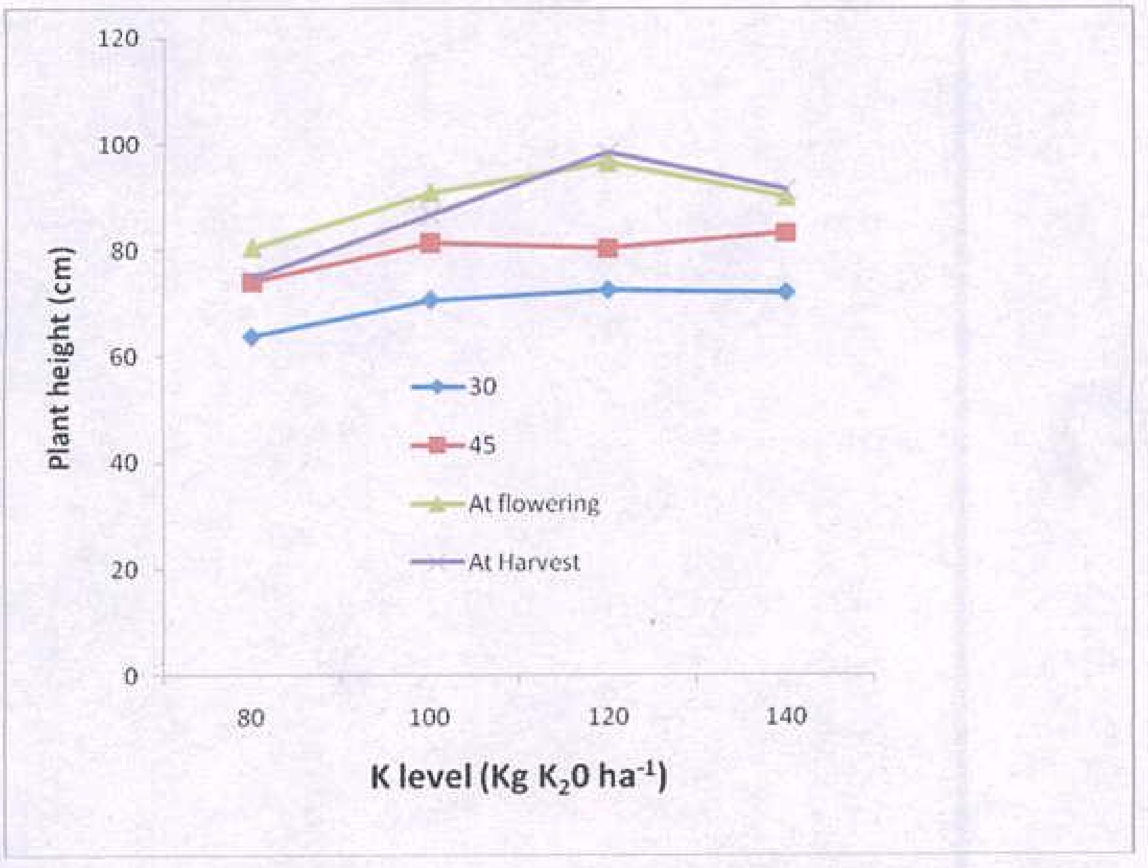


Figure 3. The effect of different potassium levels on plant height of rice at different days after transplantation (mean of 2 cultivars and 4 salinity levels)

4.1.4 Interaction effect of variety and salinity

The plant height of two rice varieties significantly decreased with increasing the salinity levels over all the levels of supplemental K (Table 1). The plant height was highest (107.67, 131.14, 146.29 and 148.24 cm) at 30, 45 DAT, at flowering and at harvest by 0 dSm^{-1} in Pokkali which was statistically identical with 4 and 8 dSm^{-1} salinity levels and the shortest plant (30.73, 20.70, 0.00 and 0.00 cm) was obtained by 12 dSm^{-1} in BRRI Dhan 29 at 30, 45 DAT, at flowering and at harvest.

Table 1. The effect of different salinity levels on plant height of two selected rice varieties (mean of 4 K levels)

Variety	Salinity level (dSm^{-1})	Plant height (cm) at different DAT			
		30	45	At flowering	At Harvest
Pokkali	0	107.67 a	131.14 a	146.29 a	148.24 a
	4	104.50 a	124.15 a	142.35 a	135.32 a
	8	91.60 ab	108.00 a	124.45 a	126.24 a
	12	65.75 bc	67.45 b	70.13 b	61.80 b
BR29	0	58.15 cd	72.30 b	87.61 b	89.50 b
	4	52.18 cd	64.42 b	80.12 b	81.87 b
	8	47.59 cd	49.75 b	64.47 b	59.53 b
	12	30.73 d	20.70 c	0.00 c	0.00 c
Significant level		**	**	**	**
$LSD_{0.05}$		2.05	2.57	2.98	4.14
CV (%)		7.37	5.07	4.12	5.50

** 1 % level of Significance

4.1.5 Interaction effect of variety and potassium

The effect of different K levels on plant height of the two rice varieties was significant where plant height increased with increasing the K levels (Table 2). The absolute plant height was highest (96.43, 114.93, 130.02 and 132.42 cm) at 30, 45 DAT, at flowering and harvest by 100 and 120 kg K_20 ha^{-1} respectively in Pokkali variety and the shortest plant (42.74, 45.81, 51.76 and 46.55 cm) was obtained by 80 kg K_20 ha^{-1} in BRRI Dhan 29 at 30, 45 DAT, at flowering and harvest which were statistically similar to all others K level respectively (Table 2).

Table 2. The effect of different K levels on plant height of two selected rice varieties (mean of 4 salinity levels)

Variety	K level (K_2O kg ha^{-1})	Plant height (cm) at different DAT			
		30	45	At flowering	At Harvest
Pokkali	80	84.85 a	102.40 a	109.21 a	103.21 b
	100	96.43 a	114.93 a	122.95 a	113.39 ab
	120	95.55 a	106.20 a	130.02 a	132.42 a
	140	92.70 a	107.21 a	121.02 a	122.58 ab
BR29	80	42.74 b	45.81 b	51.76 b	46.55 c
	100	44.94 b	47.83 b	58.65 b	60.03 c
	120	49.53 b	54.40 b	62.91 b	64.21 c
	140	51.43 b	59.12 b	58.87 b	60.10 c
Significant level		*	*	*	*
$LSD_{0.05}$		27.41	26.81	25.51	28.30
CV (%)		6.17	5.95	5.67	6.28

* 5 % level of Significance

4.1.6 Interaction effect of salinity and potassium

The effect of different K levels on plant height of rice at different salinity levels was not significant. But a positive relationship was found between K levels and plant height at all salinity levels. The plant height was highest (85.30, 103.60, 117.75 and 119.76 cm) at 30, 45 DAT, at flowering and at harvest by 140, 80, 80 and 120 kg K_20 ha^{-1} respectively in 0 dSm^{-1} salinity and the shortest plant (37.20, 38.93, 15.21 and 0.00 cm) was obtained by 80 kg K_20 ha^{-1} in 12 dSm^{-1} at 30, 45 DAT, at flowering and at harvest (Table 3).

Table 3. Interaction effect of different salinity and supplemental K levels on plant height of rice varieties (mean of 2 varieties)

Salinity level (dSm^{-1})	K level (K_2O kg ha^{-1})	Plant height (cm)			
		30	45	At flowering	At Harvest
0	80	81.40 ab	103.60 a	117.75 a	119.58 a
	100	80.65 ab	100.06 a	117.70 a	119.71 a
	120	84.30 ab	100.78 a	117.31 a	119.76 a
	140	85.30 a	102.43 a	115.05 a	116.43 ab
4	80	74.03 abc	86.91 a-c	105.06 ab	106.80 a-c
	100	80.06 ab	93.71 ab	110.03 ab	94.21 c
	120	77.08 ab	97.63 ab	116.93 a	119.01 a
	140	82.18 ab	98.90 ab	112.91 ab	114.36 a-c
8	80	62.58 b-d	66.98 c	83.93 c	73.16 d
	100	71.40 a-d	85.61 a-c	98.25 a-c	99.98 a-c
	120	74.30 a-c	79.03 bc	101.23 a-c	101.98 a-c
	140	70.11 a-d	83.86 a-c	94.43 bc	96.41 bc
12	80	37.20 e	38.93 d	15.21 e	0.00 f
	100	50.63 de	46.13 d	37.25 d	32.93 e
	120	54.48 c-e	43.75 d	50.40 d	52.51 e
	140	50.66 de	47.48 d	37.40 d	38.16 e
Significant level		*	*	*	*
$LSD_{0.05}$		19.75	19.05	18.13	20.11
CV (%)		6.17	5.95	5.66	6.28

* 5 % level of Significance

4.1.7 Interaction effect of variety, salinity and potassium

The plant height of the two rice varieties vary significantly due to the interaction effect of different salinity and K levels (Table 4). Here, the plant height of the two rice varieties increased progressively at all salinity levels with increasing the supplemental K levels except the highest level of K (140 kg K_2O ha^{-1}) at 12 dSm^{-1} level of salinity in Pokkali and 8 & 12 dSm^{-1} levels of salinity in BRRI Dhan 29; where it slightly decreased. The plant height was highest (111.90, 132.90, 148.5 and 149.80 cm) at 30, 45 DAT, at flowering and harvest by 140, 80, 100 and 100 kg K_2O ha^{-1} respectively in 0 dSm^{-1} in Pokkali variety and the shortest plant (26.90, 0.00, 0.00 and 0.00 cm) was obtained in BRRI Dhan 29 at 12 dSm^{-1} at all K level.

Table 4. Interaction effect of different salinity and supplemental K levels on plant height of two rice varieties

Variety	Salinity level (dS m^{-1})	K level (K_2O kg ha^{-1})	Plant height (cm) at different DAT			
			30	45	At flowering	At Harvest
Pokkali	0	80	105.3 ab	132.9 a	146.0 a	148.3 a
		100	104.3 abc	131.1 a	148.5 a	149.8 a
		120	109.2 a	127.9 ab	144.8 ab	147.8 ab
		140	111.9 a	132.7 a	145.9 a	147.0 ab
	4	80	100.6 abc	116.7 a-d	135.0 abc	136.2 abc
		100	110.8 a	127.6 ab	144.5 ab	111.9 def
		120	100.2 abc	125.3 abc	145.1 ab	147.0 ab
		140	106.4 abc	127.0 ab	144.8 ab	146.1 ab
	8	80	87.59 b-e	103.6 de	125.4 bc	128.3 a-d
		100	96.30 a-d	108.7 b-e	124.4 c	126.0 b-e
		120	95.87 a-d	114.8 a-d	129.4 abc	129.8 a-d
		140	86.67 c-f	104.9 cde	118.6 cd	120.8 cde
	12	80	45.93 i-n	56.43 gh	30.43 g	0.0000 j
		100	74.37 e-h	92.27 ef	74.50 f	65.87 i
		120	76.93 d-g	56.80 gh	100.8 de	105.0 efg
		140	65.80 f-i	64.30 g	74.80 f	76.33 hi
BRRI dhan 29	0	80	47.46 g-j	74.33 fg	89.47 ef	90.83 fgh
		100	49.33 g-k	69.00 g	86.93 ef	89.63 gh
		120	54.00 g-j	73.67 fg	89.87 ef	91.73 fgh
		140	57.93 g-j	72.20 fg	84.20 ef	85.83 ghi
	4	80	37.57 i-n	57.13 gh	75.10 f	77.40 hi
		100	46.50 i-m	59.83 gh	75.60 f	76.50 hi
		120	52.73 h-k	69.97 g	88.77 ef	91.00 fgh
		140	53.57 g-j	70.77 g	81.03 ef	82.6 hi
	8	80	28.47 j-n	30.37 ij	42.50 g	18.00 j
		100	26.90 i-n	62.50 gh	72.10 f	74.00 hi
		120	32.03 h-l	43.27 hi	73.03 f	74.13 hi
		140	35.53 h-l	62.87 gh	70.27 f	72.00 hi
	12	80	26.90 mn	21.43 j	0.000 h	0.0000 j
		100	32.03 n	0.0000 k	0.000 h	0.0000 j
		120	33.4 lmn	30.70 ij	0.000 h	0.0000 j
		140	35.53 k-n	30.67 ij	0.000 h	0.0000 j
Significant level			*			
$LSD_{0.05}$			1.40			
CV (%)			15.68			

* 5 % level of Significance

From the above results it appeared that salinity depressed the plant height (Figure . 2), while the plant height increased with increasing the K levels (Figure . 3). These results are in agreement with that of Qadar (1989) who found that the supplementation of K (30 kg K_2O ha^{-1}) in sodic soil increased plant height, shoot dry weight and grain yield of rice, where these growth and yield components of rice adversely affected by increasing the sodicity. The increasing levels of K application improved plant height, tiller numbers, shoot dry weight of both salt tolerant and susceptible cultivars and this beneficial effect of K application under saline conditions may be attributed to its influence on net photosynthesis (Bohra and Doerffling , 1993).

4.2 Number of effective tiller $hill^{-1}$

4.2.1 Effects of variety

The variation of effective tiller $hill^{-1}$ in two rice varieties was statistically significant due to the combined effect of different salinity and K levels (Figure 4). Considering the performance of variety, the number of effective tiller was found highest in BRRI Dhan 29 (6.91) and it was lowest (4.24) in Pokkali (Appendix 10).

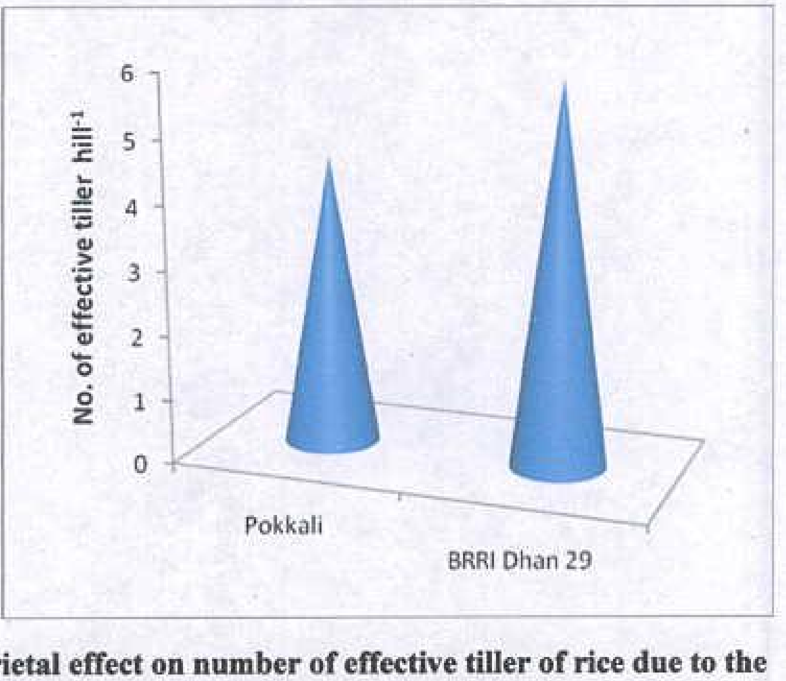


Figure 4. Varietal effect on number of effective tiller of rice due to the combined effect of different salinity and K levels

4.2.2 Effects of salinity

The effect of salinity on number of effective tiller $hill^{-1}$ of rice varieties differed significantly (Apendix 11). It decreased with increasing salinity levels (Figure 5). Number of effective tiller was highest (8.95) at 0 dSm^{-1} and it was found lowest (0.37) at 12 dSm^{-1}.

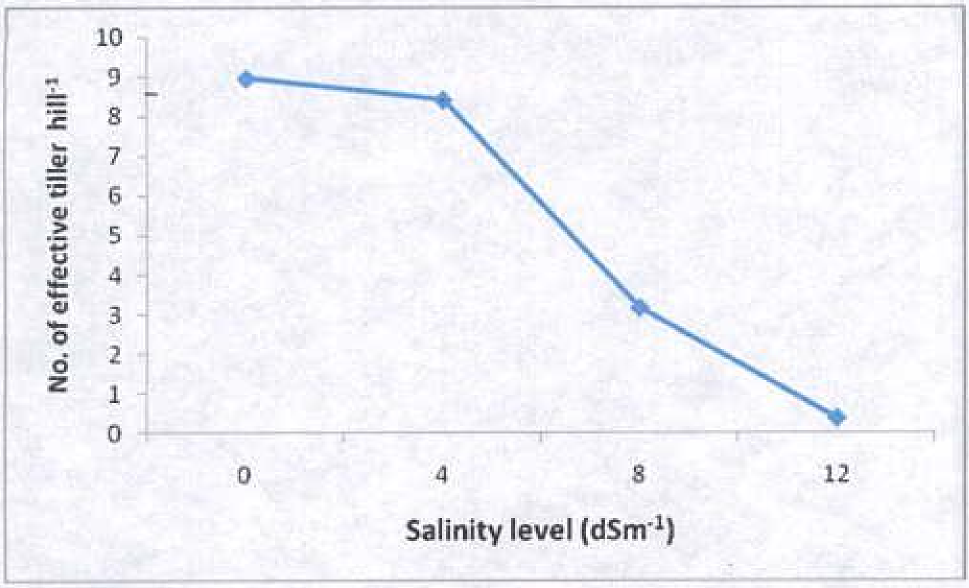


Figure 5 . The effect of different salinity levels on number of effective tiller of rice (mean of 2 cultivars and 4 K levels)

4.2.3 Effects of potassium

On the contrary of salinity, the effect of supplemental K on number of effective tiller $hill^{-1}$ of rice significantly increased due to increasing the K levels (Figure 6). Number of effective tiller $hill^{-1}$ was highest (5.95) at 140 kg K ha^{-1} and it was found lowest (4.5) at 80 kg K ha^{-1}. (Appendix 12).

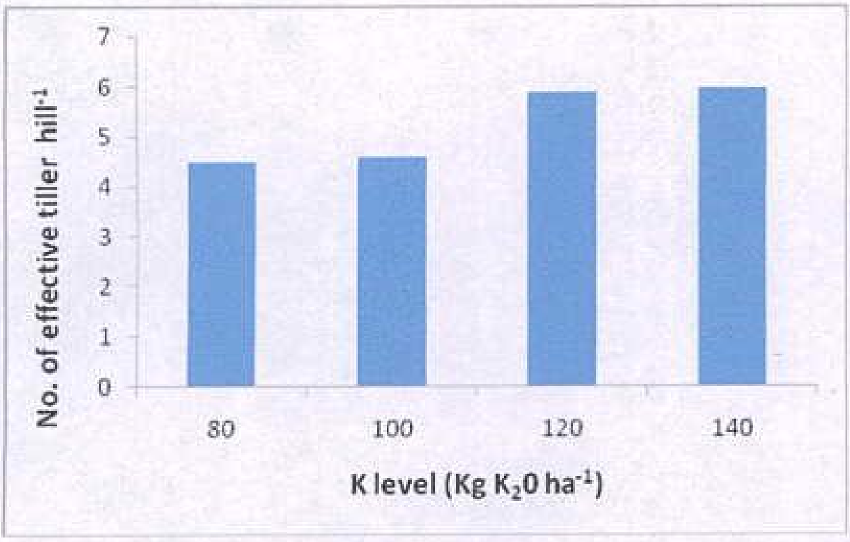


Figure 6. The effect of different K levels on number of effective tiller of rice (mean of 2 cultivars and 4 salinity levels)

4. 2.4 Interaction effect of variety and salinity

The effect of different salinity levels on number of effective tiller hill^{-1} of two rice varieties decreased significantly due to the increase in salinity levels over all the levels of K and the decreasing pattern were very sharp after 4 dSm^{-1} level of salinity (Figure 7). Number of effective tiller was highest (10.91) at 0 dSm^{-1} in BRRI Dhan 29 and it was found lowest (0.00 g) at 12 dSm^{-1} in BRRI Dhan 29 (Appendix 13).

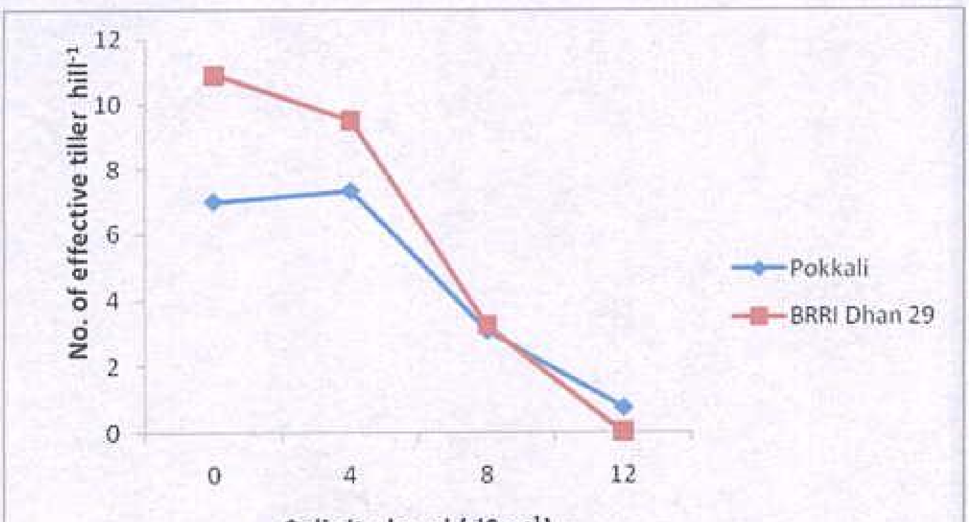


Figure 7. The effect of different salinity levels on number of effective tiller of two rice varieties (mean of 4 K levels)

4.2.5 Interaction effect of variety and potassium

The effect of different K levels was significant on effective tiller $hill^{-1}$ of two rice varieties over all the levels of different salinity (Appendix 14). The number of effective tiller of the two rice varieties increased as the application of increased levels of supplemental K (Figure 8). Number of effective tiller was highest (7.08) at 120 kg K_20 ha^{-1} in BRRI Dhan 29 and it was found lowest (3.91) at 80 kg K_20 ha^{-1} in Pokkali.

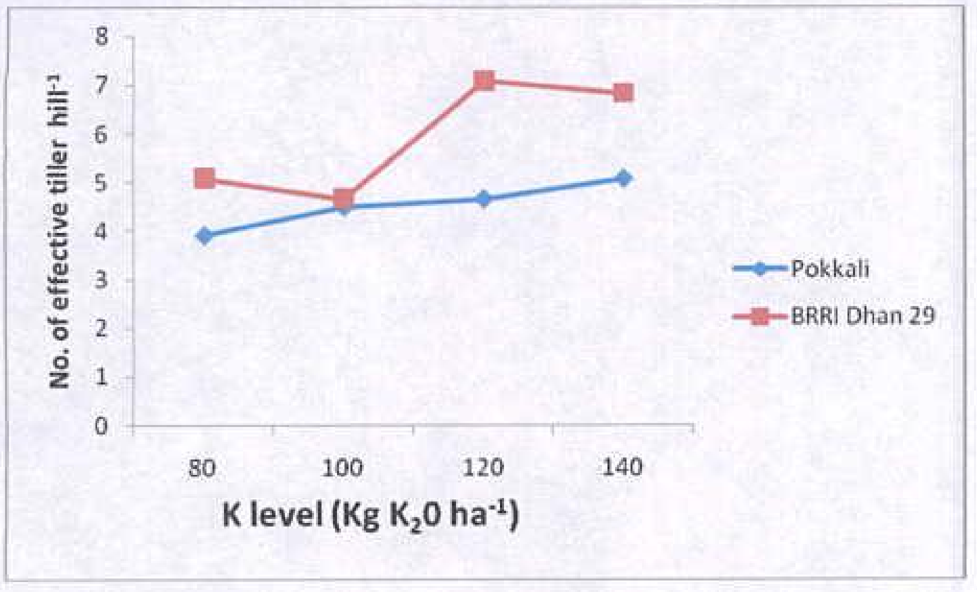


Figure 8. The effect of different K levels on number of effective tiller of two rice varieties (mean of 4 salinity levels)

4.2.6 Interaction effect of salinity and potassium

The average number of effective tiller $hill^{-1}$of the rice varieties increased as the levels of both K and salinity was increased except 0 and 4 salinity levels with 140 Kg K_20 ha^{-1} (Figure 9). It was significant interaction (Appendix 15). Number of effective tiller was highest (10.50) at 120 kg K_20 ha^{-1} at 4 dSm^{-1} and it was found lowest (0.16) at 80 kg K_20 ha^{-1} at 12 dSm^{-1}.

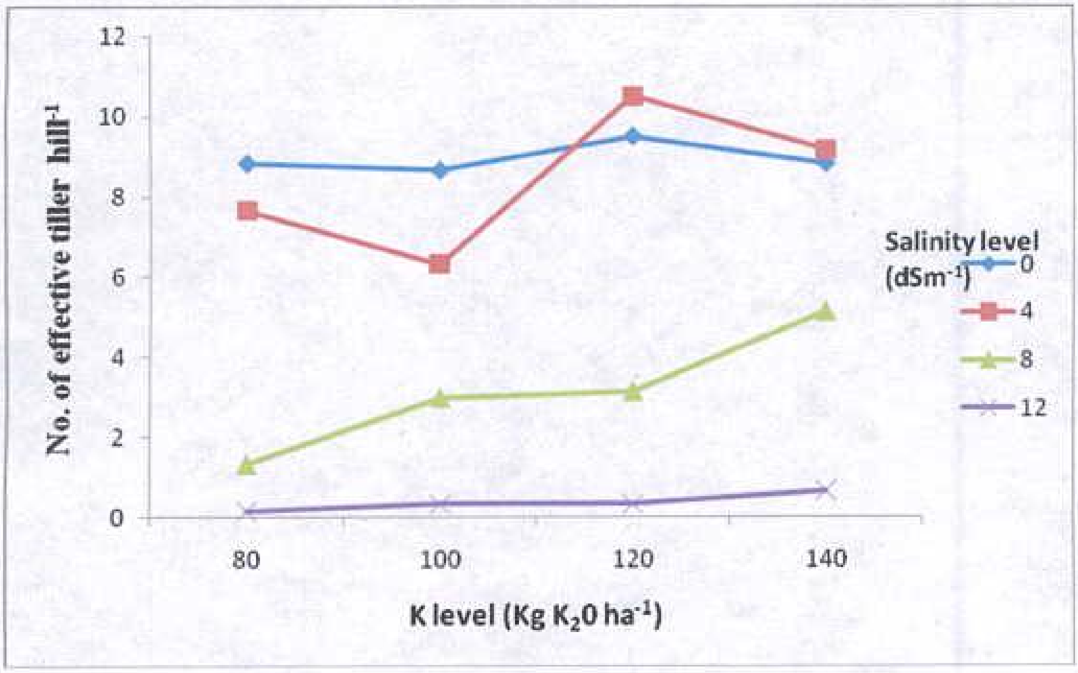


Figure 9. Interaction effect of different salinity and supplemental K levels on number of effective tiller of rice (mean of 2 varieties)

4.2.7 Interaction effect of variety, salinity and potassium

The results presented in Table 5 show that the interaction effect of different salinity and K levels significantly influenced effective tiller hill^{-1} of the two rice varieties. The number of effective tiller hill^{-1} increased progressively with increase in K levels except the highest levels of K (140 kg K_2O ha^{-1}) at 0 and 4 dSm^{-1} level of salinity in Pokkali and at 4 salinity in BRRI Dhan 29 where it decreased slightly. Number of effective tiller was highest (12.33) at 120 kg K_2O ha^{-1} at 4 dSm^{-1} in BRRI Dhan 29 and it was found lowest (0.00 or no yield) at all K level at 12 dSm^{-1} in BRRI Dhan 29.

These results corroborate with that of Qadar (1998) who found that application of P or P + K fertilizers at sodic soil significantly increased effective tiller hill^{-1} of rice cultivars.

Table 5. Interaction effect of different salinity and supplemental K levels on number of effective tiller of two rice varieties

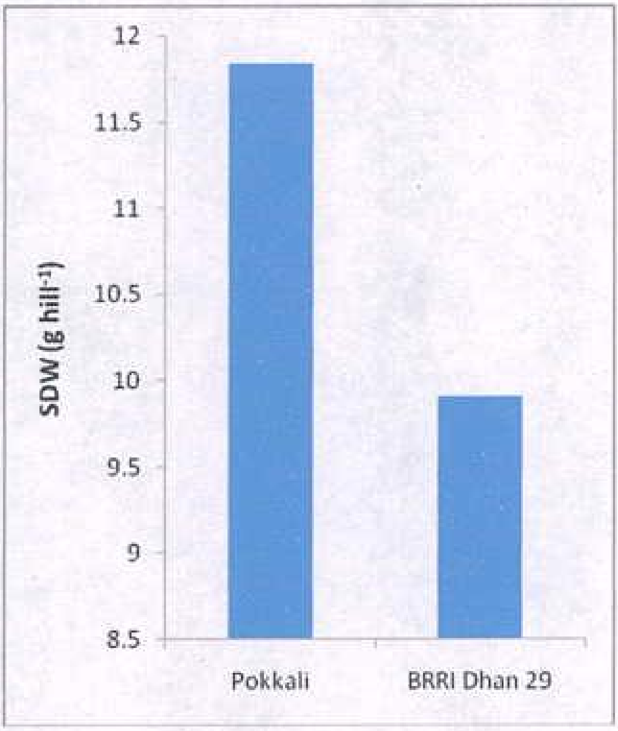
Variety	Salinity level (dS m^{-1})	K level (K_2O kg ha^{-1})	No. of Effective Tiller
Pokkali	0	80	7.333 c-g
		100	7.000 c-g
		120	7.667c-f
		140	6.000 d-g
	4	80	6.000 d-g
		100	6.333 d-g
		120	8.667 b-e
		140	8.333 b-e
	8	80	2.00 hij
		100	4.00 ghi
		120	1.667 hij
		140	4.667 fgh
	12	80	0.3333 j
		100	0.6667 ij
		120	0.6667 ij
		140	1.333 hij
BRRI dhan 29	0	80	10.33 abc
		100	10.33 abc
		120	11.33 ab
		140	11.67 ab
	4	80	9.333 a-d
		100	6.333 d-g
		120	12.33 a
		140	10.00 abc
	8	80	0.6667 ij
		100	2.00 hij
		120	4.667 fgh
		140	5.667 efg
	12	80	0.0000 j
		100	0.0000 j
		120	0.0000 j
		140	0.0000 j
Significant level			**
$LSD_{0.05}$			2.12
CV (%)			3.7

** 1 % level of Significance

4.3 Shoot dry weight

4.3.1 Effects of variety

While considering the performance of variety, the shoot dry weight (SDW) $hill^{-1}$ was found highest in Pokkali (11.84 g) and it was lowest (9.90 g) in BRRI Dhan 29 due to the mean effect of salinity and K level (Figure 10 & Appendix 4).



38899
2.3.15

Figure 10. Varietal effect on shoot dry weight (SDW) of two rice varieties due to the combined effect of different salinity and K levels

4.3.2 Effects of salinity

The effect of different salinity significantly decreased the shoot dry weight (SDW) $hill^{-1}$ of rice due to increasing the salinity levels (Figure 11). The shoot dry weight (SDW) $hill^{-1}$ was found highest (18.86 g) at 0 dSm^{-1} and it was lowest (1.46 g) at 12 dSm^{-1} (Apendix-5).

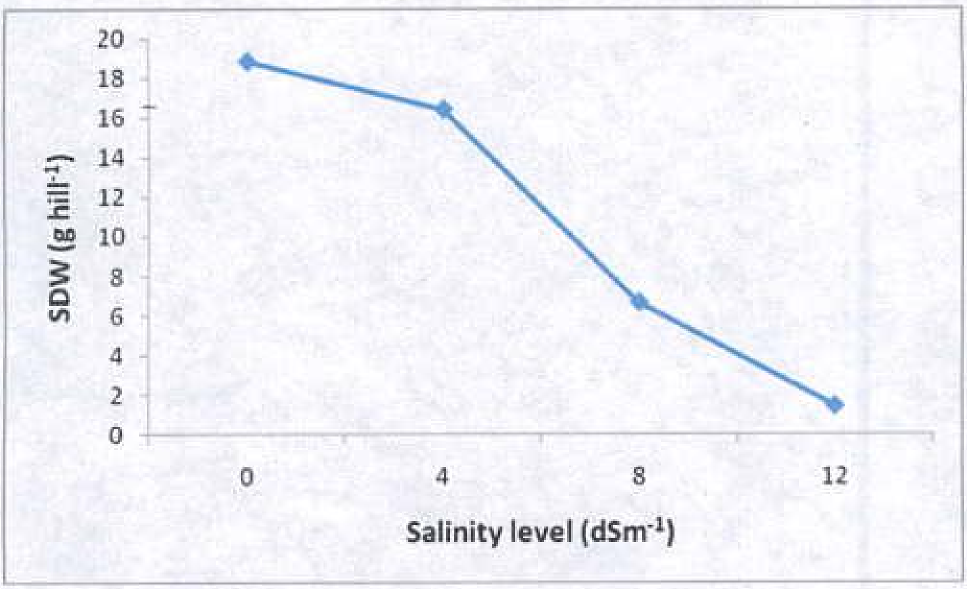


Figure 11. The effect of different salinity levels on shoot dry weight (SDW) of two rice varieties (mean of 2 cultivars and 4 K levels)

4.3.3 Effects of potassium

The application of K significantly increased the shoot dry weight (SDW) hill^{-1} with increasing K levels over all the levels of salinity. SDW hill^{-1} was found highest (12.92 g) at 120 kg K ha^{-1} and it was lowest (9.09 g) at 80 kg K ha^{-1} (Figure 12 & Appendix 6).

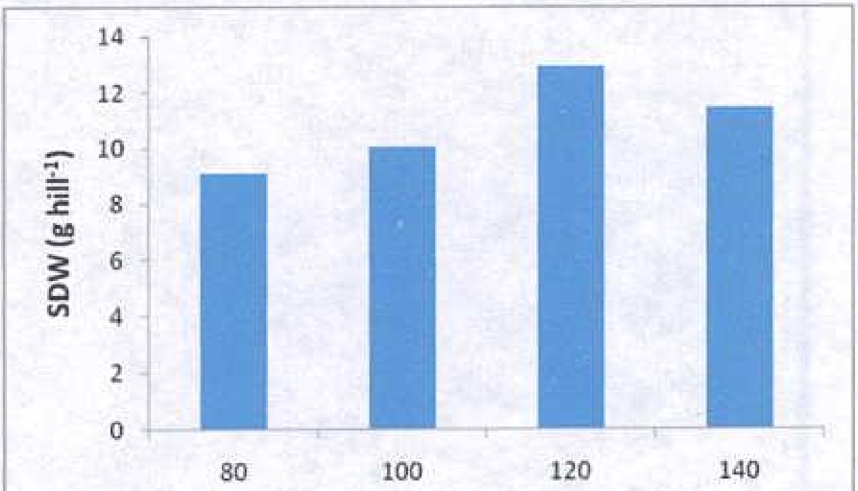


Figure 12. The effect of different K levels on shoot dry weight (SDW) of two rice varieties (mean of 2 cultivars and 4 salinity levels)

4.3.4 Interaction effect of variety and salinity

The effect of different salinity levels on shoot dry weight (SDW) $hill^{-1}$ of the two rice varieties differed significantly over all the levels of K (Figure 13). The SDW $hill^{-1}$ of the two rice varieties under study decreased as the salinity level increased (Figure 13). The SDW $hill^{-1}$ was found highest (19.03 g) at 0 dSm^{-1} in BRRI Dhan 29 and it was lowest (0.40 g) at 12 dSm^{-1} BRRI Dhan 29 (Apendix-7). Furthermore, the decreasing pattern of SDW $hill^{-1}$ very sharp with increasing the salinity levels in BRRI Dhan 29(Figure 13).

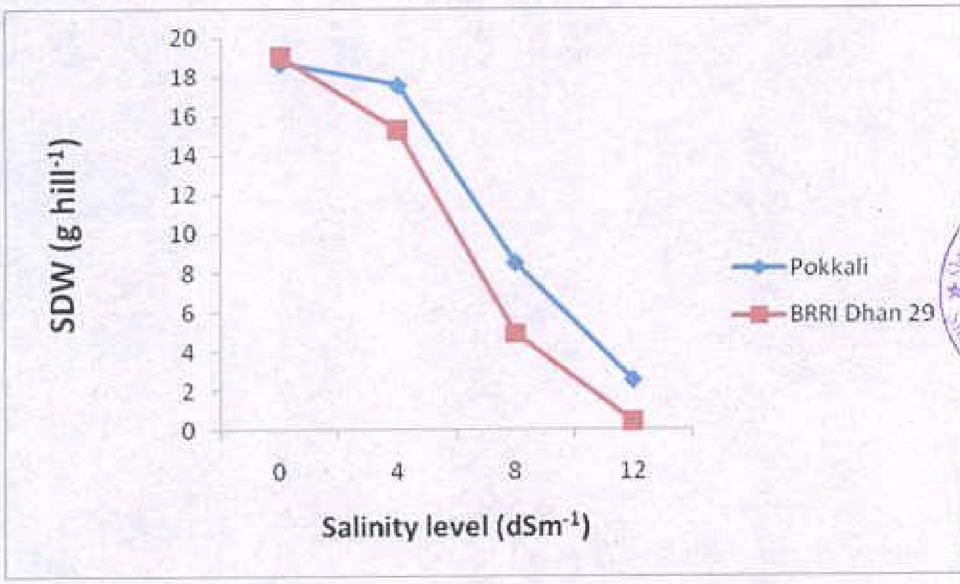


Figure 13. The effect of different salinity levels on shoot dry weight (SDW) of two selected rice varieties (mean of 4 K levels)

4.3.5 Interaction effect of variety and potassium

The effect of different supplemental K levels on shoot dry weight (SDW) $hill^{-1}$ of two rice varieties was significant over all the levels of salinity (Appendix-8). The SDW $hill^{-1}$ of the selected rice varieties increased with increasing K levels upto 120 kg K_2O ha^{-1} and thereafter it decreased (Figure 14). The SDW $hill^{-1}$ was found highest (12.87 g) at 120 kg K_2O ha^{-1} in BRRI Dhan 29 and it was lowest (7.91 g) at 80 kg K ha^{-1} in BRRI Dhan 29.

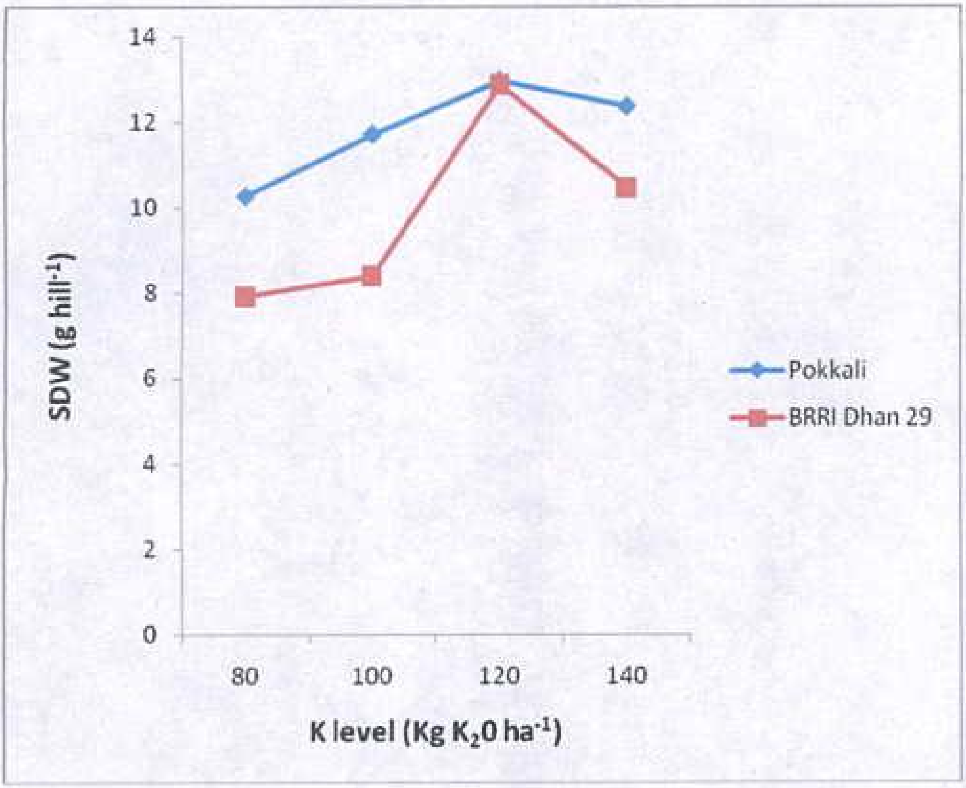


Figure 14. The effect of different K levels on shoot dry weight (SDW) of two selected rice varieties (mean of 4 salinity levels)

4.3.6 Interaction effect of salinity and potassium

The effect of different supplemental K levels on shoot dry weight (SDW) hill^{-1} of rice at all the 4 salinity levels was not significant (Appendix-9). But the SDW hill^{-1} increased at all salinity levels with increasing the supplemental K levels (Figure 15). The SDW hill^{-1} was found highest (21.39 g) at 120 kg K_2O ha^{-1} at 4 dSm^{-1} and it was lowest (0.54 g) at 80 kg K_2O ha^{-1} at 12 dSm^{-1} .

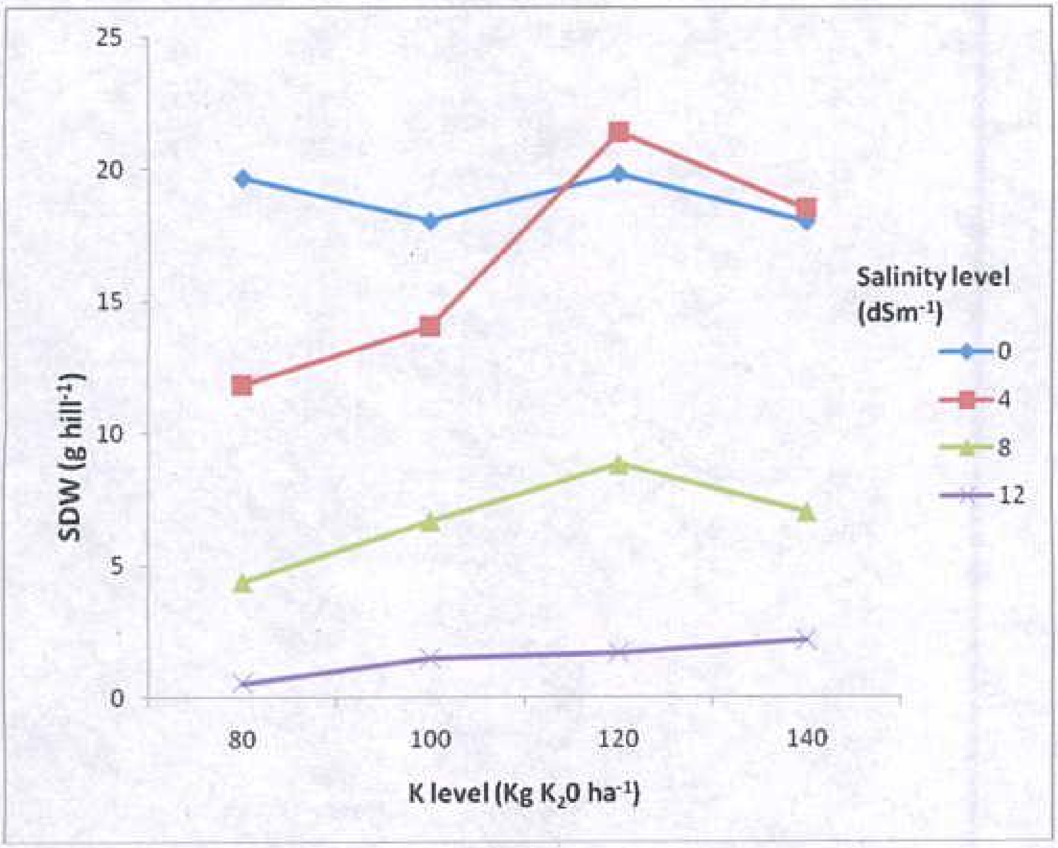


Figure 15. Interaction effect of different salinity and supplemental K levels on shoot dry weight (SDW) of rice varieties (mean of 2 varieties)

4.3.7 Interaction effect of variety, salinity and potassium

The shoot dry weight (SDW) hill^{-1} of the two selected rice varieties was significantly influenced by the interaction effect of different salinity and K levels (Table 6). The SDW hill^{-1} increased progressively of the rice varieties with increasing the K levels at all salinity levels except the highest levels of K (140 kg K_2O ha^{-1}) at 4 & 8 dSm^{-1} levels of salinity in BRRI Dhan 29; where it slightly decreased which was not statistically significant. The SDW hill^{-1} was found highest (22.33 g) at 120 kg K_2O ha^{-1} at 4 dSm^{-1} in BRRI Dhan 29 and it was lowest (0.25 g) at 80 kg K_2O ha^{-1} at 12 dSm^{-1} BRRI Dhan 29.

Table 6. Interaction effect of different salinity and supplemental K levels on shoot dry weight of two rice varieties

Variety	Salinity level (dSm^{-1})	K level (K_2O kg ha^{-1})	Shoot Dry Weight
Pokkali	0	80	19.98 ab
		100	17.9 a-d
		120	20.27 ab
		140	16.61 a-f
	4	80	12.54 b-g
		100	16.99 a-e
		120	20.45 ab
		140	20.39 ab
	8	80	7.750 g-l
		100	9.304 e-j
		120	8.163 f-l
		140	8.847 e-k
	12	80	0.823 jkl
		100	2.663 h-l
		120	2.987 h-l
		140	3.647 h-l
BRRI dhan 29	0	80	19.32 abc
		100	18.10 abc
		120	19.34 abc
		140	19.38 abc
	4	80	11.11 c-h
		100	11.14 c-h
		120	22.33 a
		140	16.63 a-f
	8	80	0.99 i-l
		100	4.027 g-l
		120	9.46 d-i
		140	5.12 g-l
	12	80	0.257 l
		100	0.3067 kl
		120	0.3733 kl
		140	0.6767 kl
Significant level			**
$LSD_{0.05}$			2.47
CV (%)			5.07

** 1 % level of Significance

From the above results it was clear that the application of supplemental K in saline conditions increased different growth characters of selected rice varieties such as plant height, shoot and root dry weights of rice. These results are in agreement with those of Mehdi *et al*., (2002) who stated that the supplementation of K (0, 20, 40, 65 and 80 mg K kg^{-1} soil) in artificially developed salinity (5.6, 8.7 and 11.5 dSm^{-1} levels) in soil of the experiment of rice the tillers, straw and grain yield significantly increased with increasing levels of K, where increasing salinity levels decreased tillers, straw and grain yield of rice. Similar results also found in the findings of Qadar (1989 and 1998); and Bohra & Doerffling (1993).

4.4 Root dry weight

4.4.1 Effects of variety

The root dry weight (RDW) $hill^{-1}$ of the two rice cultivars varied insignificantly due to the combined effect of different salinity and K levels (Figure 16). The absolute RDW was same (0.54 g) in Pokkali and in BRRI Dhan 29 (Appendix-4).

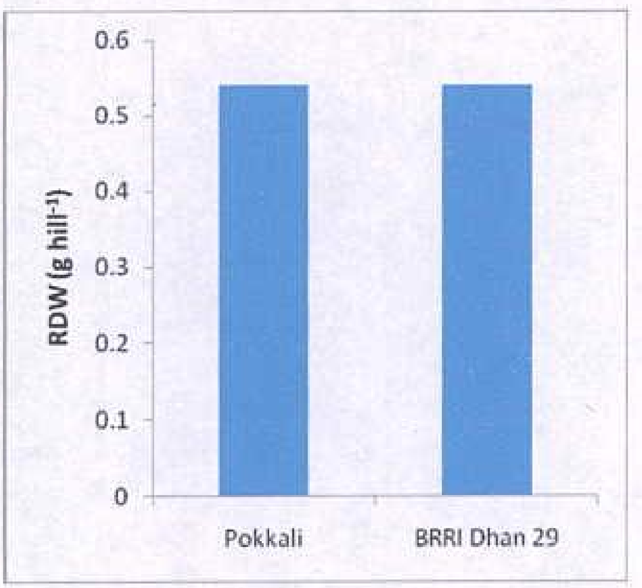


Figure 16. Varietal effect on root dry weight (RDW) of selected rice due to the combined effect of different salinity and K levels

4.4.2 Effects of salinity

The effect of salinity on root dry weight (RDW) hill^{-1} of rice varieties decreased significantly with increasing salinity levels. The absolute RDW was highest (0.88 g) in 0 dSm^{-1} and lowest (0.13 g) in 12 dSm^{-1} (Figure 17 & Appendix 5).

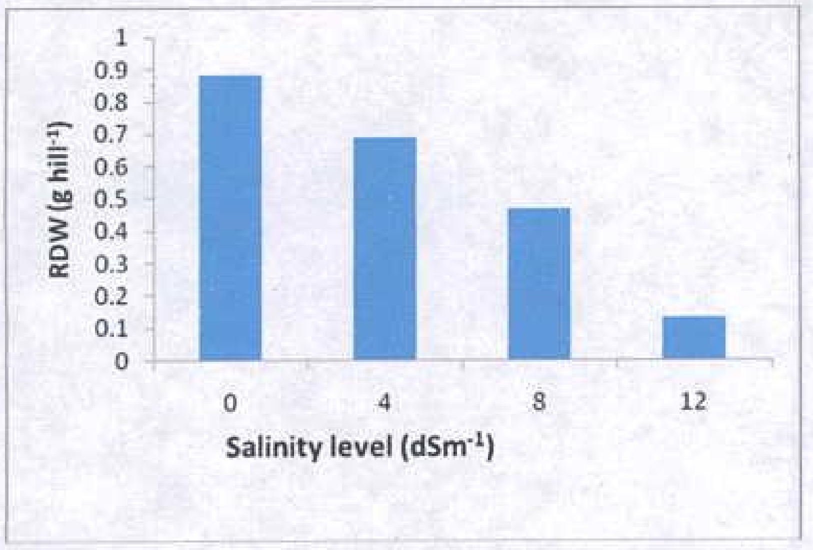


Figure 17. The effect of different salinity levels on root dry weight (RDW) of two rice varieties (mean of 2 cultivars and 4 K levels)

4.4.3 Effects of potassium (K)

On the contrary, the root dry weight (RDW) hill^{-1} of rice increased significantly with increasing the supplemental K levels. The RDW hill^{-1} was highest (0.63 g) in 140 kg K_2O ha^{-1} and the lowest (0.46 g) in 100 kg K_2O ha^{-1} (Figure 18 & Appendix 6).

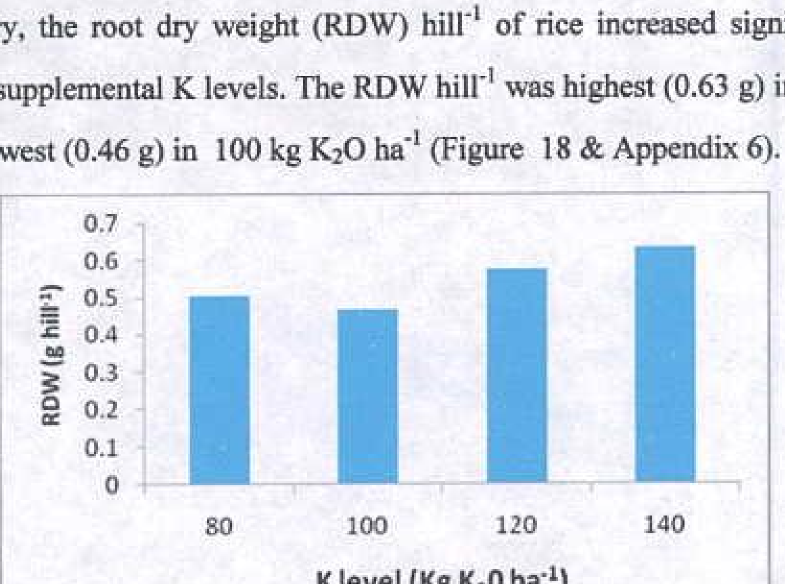


Figure 18. The effect of different K levels on root dry weight (RDW) of two rice varieties (mean of 2 cultivars and 4 salinity levels)

4.4.4 Interaction effect of variety and salinity

The Figure 19 shows that the root dry weight (RDW) $hill^{-1}$ of the rice varieties significantly decreased with increasing the salinity levels over all the levels of supplemental K. The RDW was highest (0.88 g) in 0 dSm^{-1} in Pokkali & BRRI Dhan 29 and the lowest (0.13 g) in BRRI Dhan 29 at 12 dSm^{-1}.

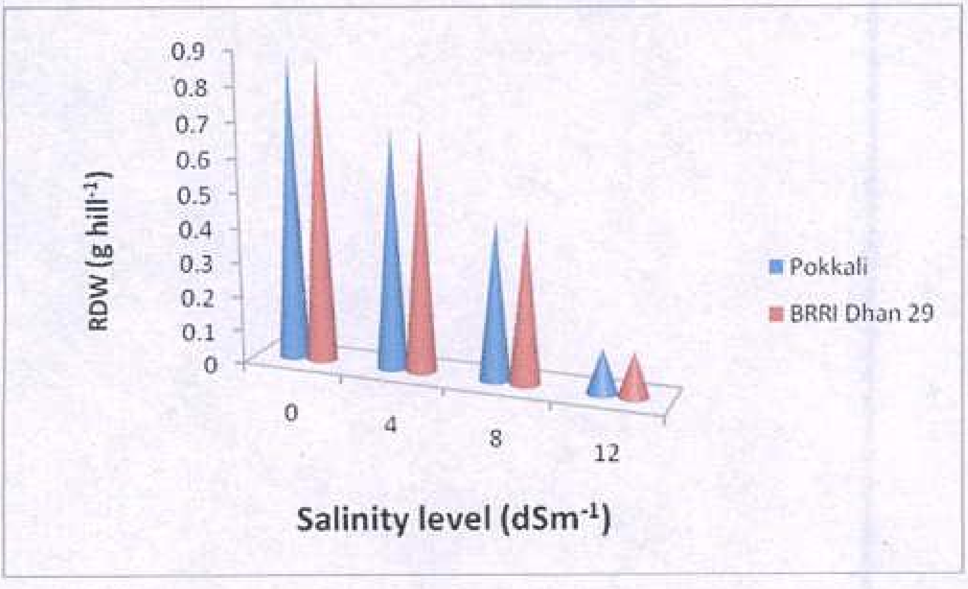


Figure 19. The effect of different salinity levels on root dry weight (RDW) of two selected rice varieties (mean of 4 K levels)

4.4.5 Interaction effect of variety and potassium

The effect of different K levels on root dry weight (RDW) $hill^{-1}$ of two rice varieties varied significantly over all the levels of salinity (Figure 20 & Appendix 8). The absolute RDW $hill^{-1}$ was highest (0.61 g) in 140 kg K_2O ha^{-1} in Pokkali and lowest (0.42 g) in BRRI Dhan 29 in 100 kg K_2O ha^{-1}.

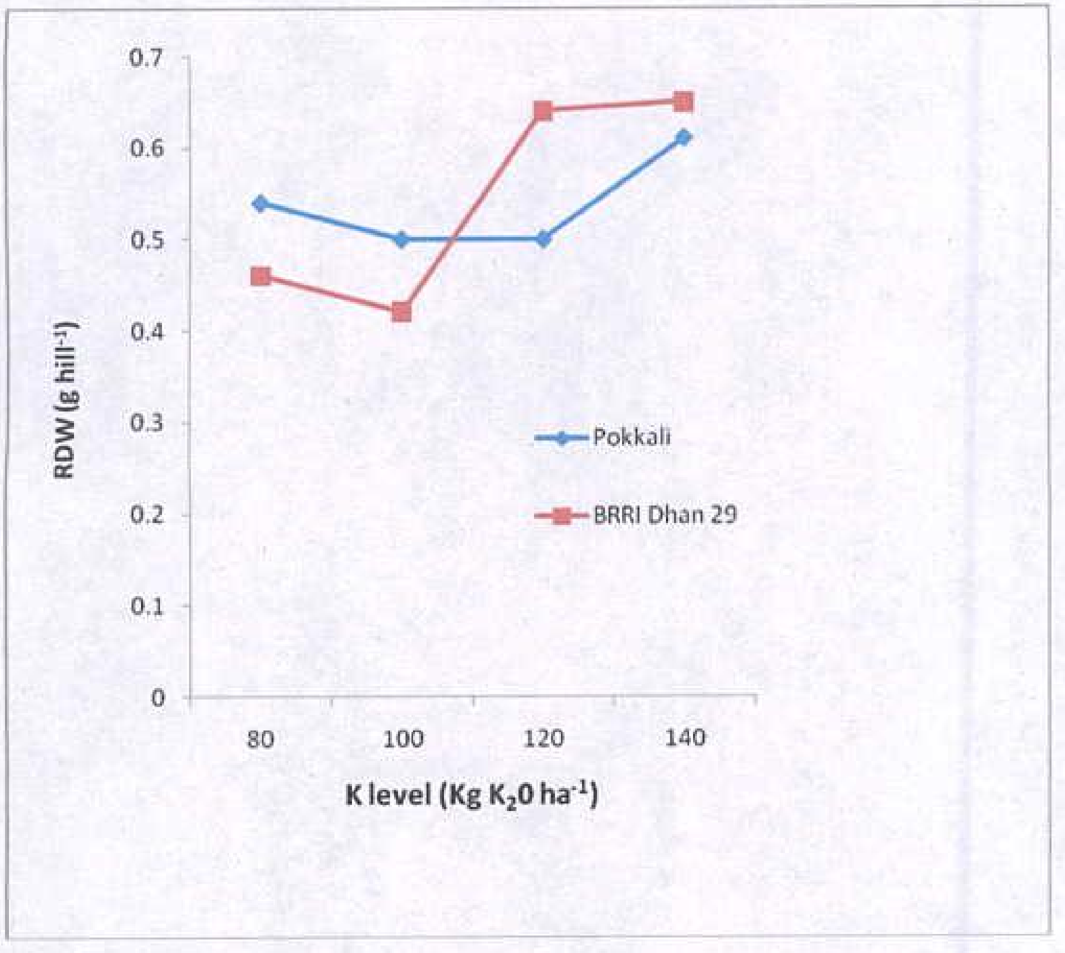


Figure 20. The effect of different K levels root dry weight (RDW) of two selected rice varieties (mean of 4 salinity levels)

4.4.6 Interaction effect of salinity and potassium

The effect of different K levels on root dry weight (RDW) hill^{-1} of rice was significant at different levels of salinity (Appendix-9). The root dry weight increased due to increasing the supplemental K levels at all salinity levels except the highest level of K (140 kg K_2O ha^{-1}) at 8 & 12 dSm^{-1} levels of salinity; where it slightly decreased (Figure 21). The absolute RDW was highest (1.07 g) in 140 kg K_2O ha^{-1} at 0 dSm^{-1} and the lowest (0.11 g) in 140 kg K_2O ha^{-1} at 12 dSm^{-1} (Appendix 9).

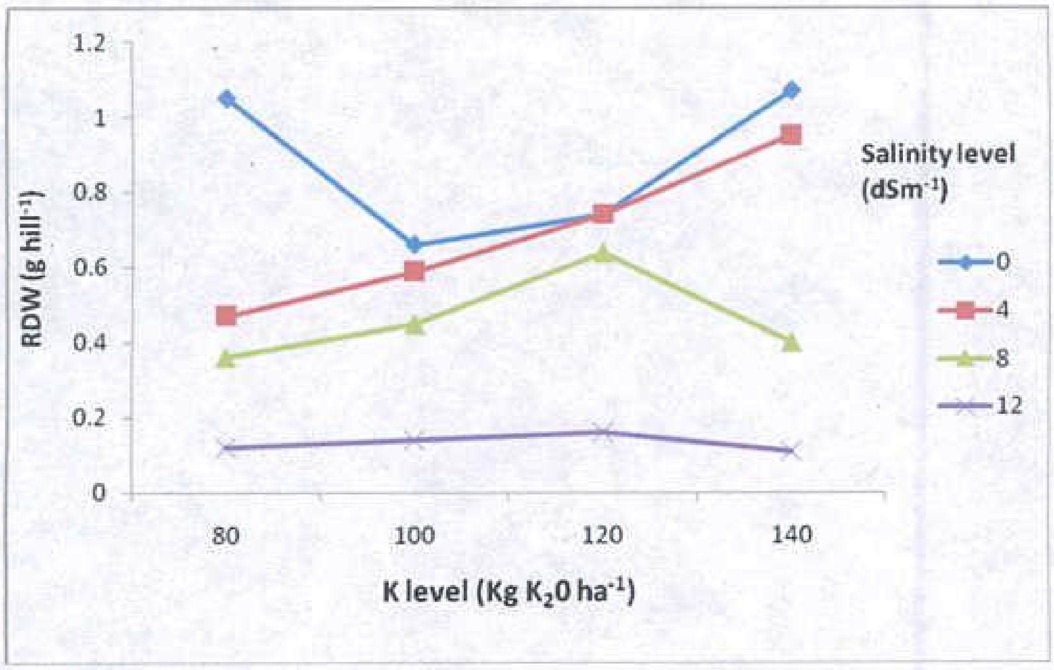


Figure 21. Interaction effect of different salinity and supplemental K levels on root dry weight (RDW) of rice varieties (mean of 2 varieties)

4.4.7 Interaction effect of variety, salinity and potassium

The interaction effect of different salinity and K levels was significant on RDW hill^{-1} of two rice varieties (Table 7). Here, the RDW hill^{-1} of both the rice varieties increased progressively at different salinity levels with increasing the K levels except that at the highest level of K (140 kg K_2O ha^{-1}) and salinity (12 dSm^{-1}) where it slightly decreased. The absolute RDW hill^{-1} was highest (1.07 g) in 140 kg K_2O ha^{-1} at 0 dSm^{-1} in Pokkali and the lowest (0.11 g) in 100 kg K_2O ha^{-1} at 12 dSm^{-1} in BRRI Dhan 29.

Our results corroborate with that of Qadar (1998) who found that application of P or P + K fertilizers at sodic soil significantly increased root and shoot dry weights of rice cultivars.

Table 7. Interaction effect of different salinity and supplemental K levels on root dry weight of two rice varieties

Variety	Salinity level ($dS\ m^{-1}$)	K level (K_2O kg ha^{-1})	Root Dry Weight (g $hill^{-1}$)
Pokkali	0	80	1.053 ab
		100	0.66 a-e
		120	0.74 a-d
		140	1.07 a
	4	80	0.47 c-f
		100	0.59 a-f
		120	0.73 a-d
		140	0.94 abc
	8	80	0.55 c-f
		100	0.57 b-f
		120	0.36 def
		140	0.34 def
	12	80	0.11 f
		100	0.18 ef
		120	0.15 f
		140	0.10 f
BRRI dhan 29	0	80	1.05 ab
		100	0.66 a-e
		120	0.74 a-d
		140	1.07 a
	4	80	0.47 c-f
		100	0.59 a-f
		120	0.73 a-d
		140	0.94 abc
	8	80	0.18 ef
		100	0.33 def
		120	0.92 abc
		140	0.45 c-f
	12	80	0.12f
		100	0.10 f
		120	0.16 f
		140	0.12 f
Significant level			**
$LSD_{0.05}$			0.23
CV (%)			4.12

** 1 % level of Significance

4.5 Total dry matter

4.5.1 Effects of variety

The variation in the content of total dry matter (TDM) hill^{-1} in two rice varieties was statistically significant due to the combined effect of different salinity and K levels (Figure 22 & Appendix 4). The TDM hill^{-1} of the variety Pokkali was highest (12.37 g) and it was found lowest (10.45 g) in BRRI Dhan 29.

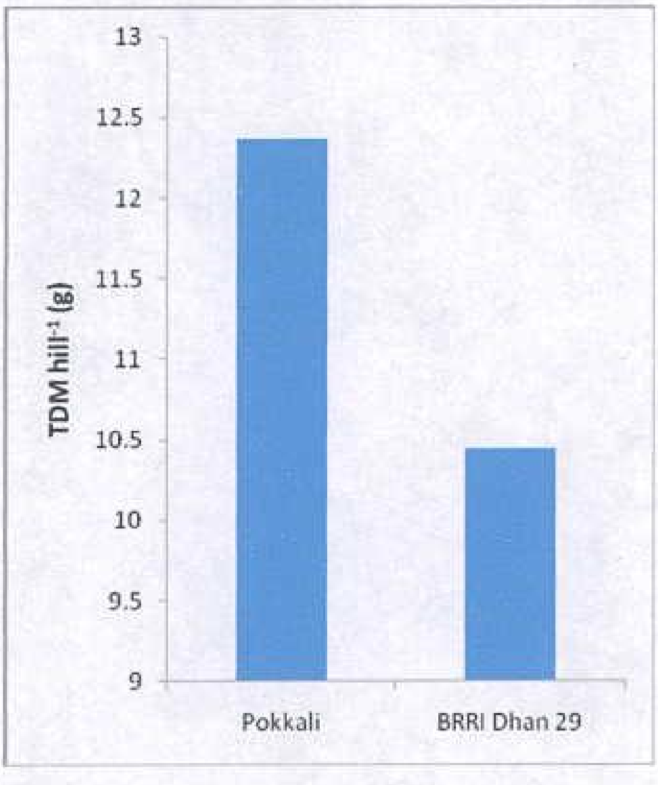


Figure 22. Varietal effect on total dry matter (TDM) of selected rice due to the combined effect of different salinity and K levels

4.5.2 Effects of salinity

The effect of salinity on TDM hill^{-1} of rice varieties differed significantly. It decreased with increasing salinity levels (Figure 23). TDM hill^{-1} was highest (19.94 g) at 0 dSm^{-1} and it was found lowest (1.6 g) at 12 dSm^{-1} (Appendix 5).

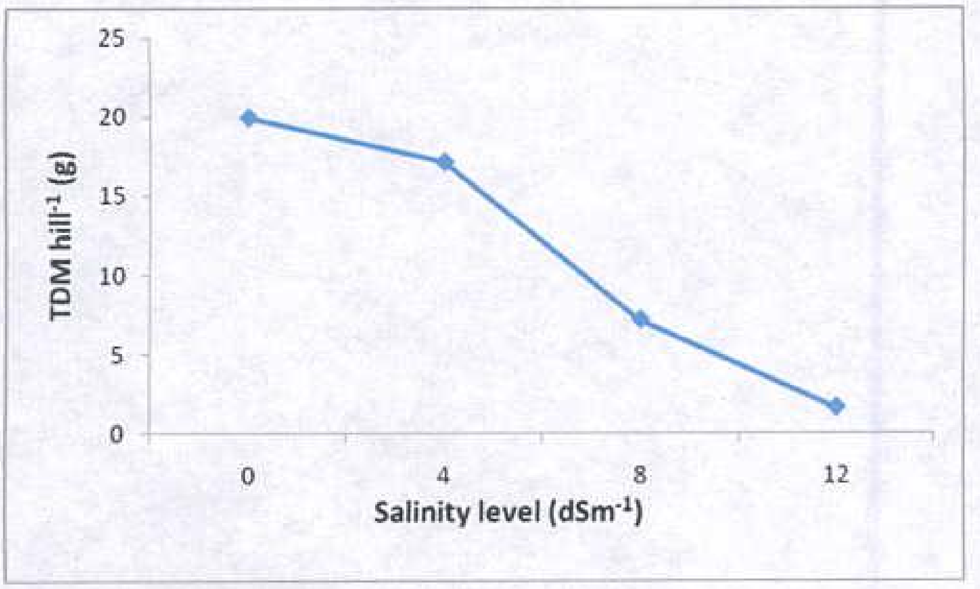


Figure 23. The effect of different salinity levels on total dry matter (TDM) of rice varieties (mean of 2 cultivars and 4 K levels)

4.5.3 Effects of potassium

The effect of supplemental K on TDM hill^{-1} of rice significantly increased due to increasing the K levels upto 120 Kg K_20 ha^{-1} and thereafter slightly decreased (Figure 24). The TDM hill^{-1} was highest (13.47 g) at 120 Kg K_20 ha^{-1} and it was found lowest (9.59 g) at 80 Kg K_20 ha^{-1} (Appendix 6).

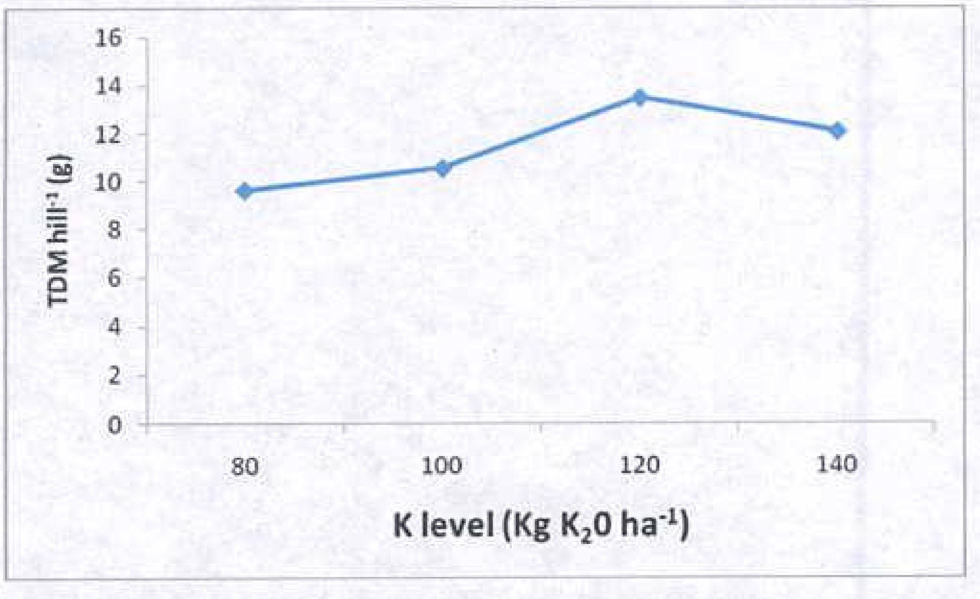


Figure 24. The effect of different K levels on total dry matter (TDM) of rice (mean of 2 cultivars and 4 salinity levels)

4.5.4 Interaction effect of variety and salinity

The effect of different salinity levels on TDM $hill^{-1}$ of the selected rice varieties decreased significantly due to the increase in salinity levels over all the levels of K (Figure 25). The decreasing pattern of TDM was very sharp in BRRI Dhan 29 than Pokkali with increase in salinity levels. The TDM $hill^{-1}$ was highest (19.91 g) at 0 dSm^{-1} in BRRI Dhan 29 and it was found lowest (0.41 g) at 12 dSm^{-1} in BRRI Dhan 29 which was statistically identical with Pokkali at same (0 dSm^{-1}) salinity (Appendix 7).

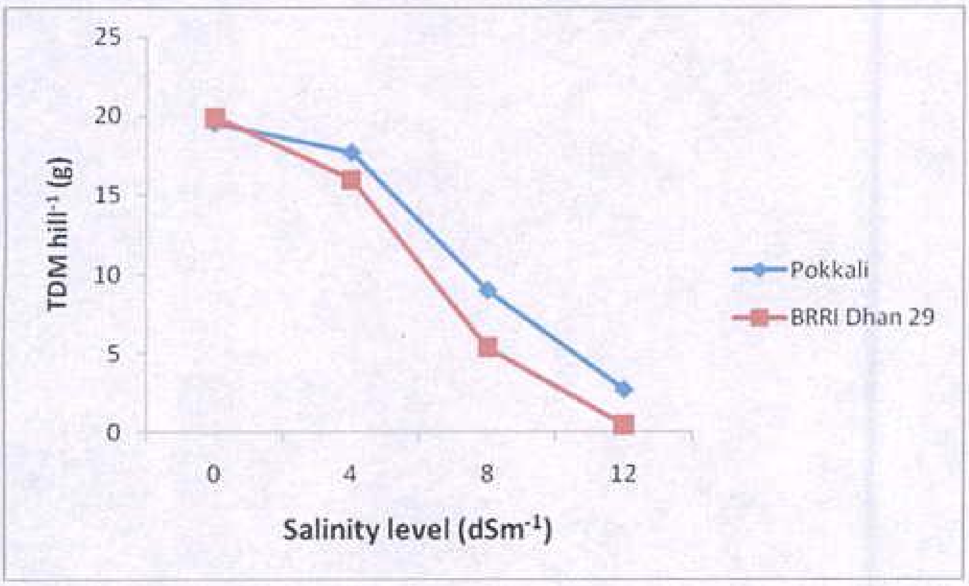


Figure 25. The effect of different salinity levels on total dry matter (TDM) of two selected rice varieties (mean of 4 K levels)

4.5.5 Interaction effect of variety and potassium

The effect of different K levels was significant on TDM $hill^{-1}$ of the rice varieties over all the levels of different salinity (Appendix-8). The TDM $hill^{-1}$ of the selected rice varieties increased as the application of increased levels of supplemental K upto 120 Kg K_20 ha^{-1} and thereafter sharply decreased in BRRI Dhan 29 than Pokkali (Figure 26). TDM $hill^{-1}$ was highest (13.46 g) at 120 Kg K_20 ha^{-1} in Pokkali and it was found lowest (8.37 g) at 80 Kg K_20 ha^{-1} in BRRI Dhan 29.

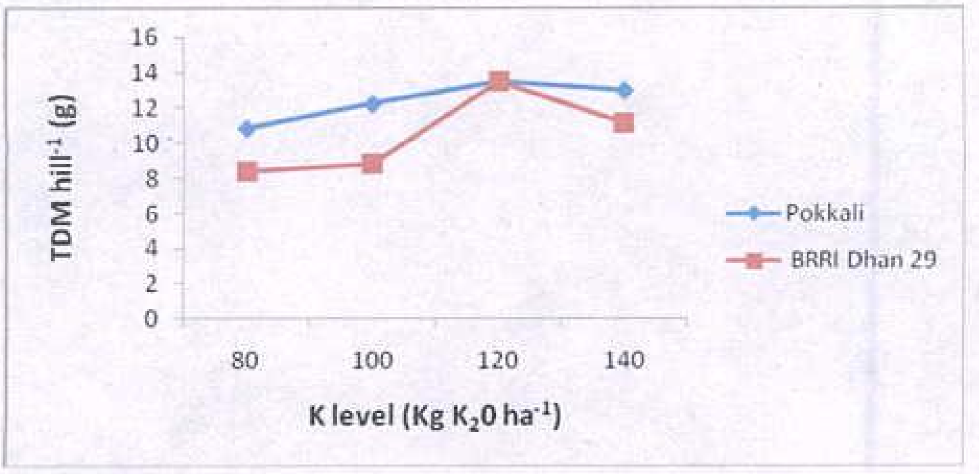


Figure 26. The effect of different K levels on total dry matter (TDM) of two selected rice varieties (mean of 4 salinity levels)

4.5.6 Interaction effect of salinity and potassium

The average TDM $hill^{-1}$ of the rice varieties decreased significantly as the levels of both K and salinity was increased (Figure 27). The TDM $hill^{-1}$ was highest (22.13 g) at 120 Kg K_20 ha^{-1} at 4 dSm^{-1} and it was found lowest (0.66 g) at 80 Kg K_20 ha^{-1} at 12 dSm^{-1} (Appendix 9).

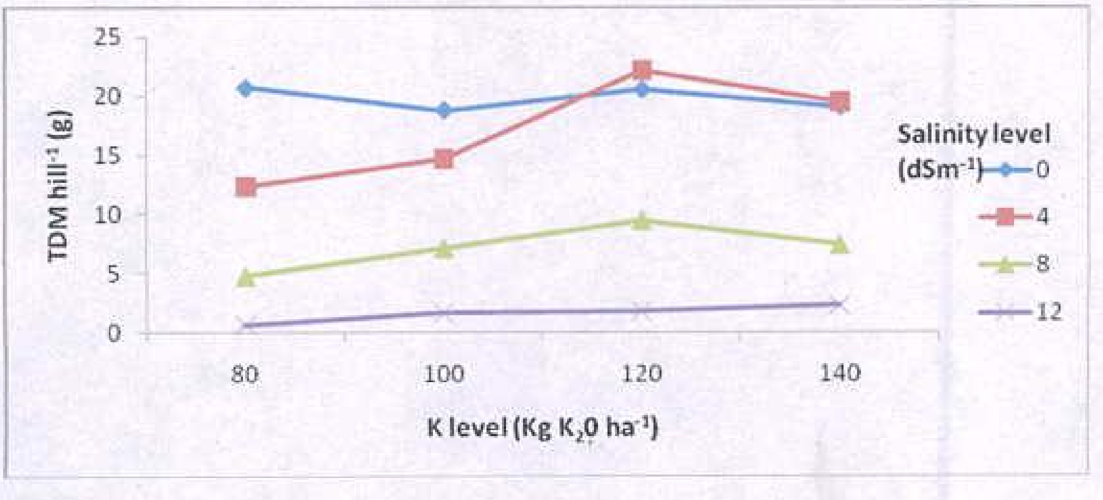


Figure 27. Interaction effect of different salinity and supplemental K levels on total dry matter (TDM) of rice varieties (mean of 2 varieties)

4.5.7 Interaction effect of variety, salinity and potassium

The results presented in Table 8 show that the interaction effect of different salinity and K levels was significantly influenced on TDM $hill^{-1}$ of the two rice varieties. The TDM $hill^{-1}$

increased progressively with increase in K levels except the highest levels of both K (140 kg K_2O ha^{-1}) and salinity (12 dSm^{-1}) where it decreased slightly in BRRI Dhan 29 at 4 and 8 dSm^{-1} salinity with 140 Kg K_20 ha^{-1}. The TDM $hill^{-1}$ was highest (23.06 g) at 120 Kg K_20 ha^{-1} at 4 dSm^{-1} in BRRI Dhan 29 and it was found lowest (0.37 g) at 80 Kg K_20 ha^{-1} at 12 dSm^{-1} BRRI Dhan 29.

Table 8. Interaction effect of different salinity and supplemental K levels on total dry matter (TDM) of two rice varieties

Variety	Salinity level (dS m^{-1})	K level (K_2O kg ha^{-1})	Total dry matter (g $hill^{-1}$)
Pokkali	0	80	21.03 ab
		100	18.58 a-d
		120	21.01 ab
		140	18.33 a-f
	4	80	13.01 b-g
		100	17.58 a-e
		120	21.18 ab
		140	21.33 ab
	8	80	8.30 g-l
		100	9.87 e-j
		120	8.52 f-l
		140	9.28 e-k
	12	80	0.93 jkl
		100	2.84 h-l
		120	3.13 h-l
		140	3.74 h-l
BRRI dhan 29	0	80	20.37 abc
		100	18.76 abc
		120	20.08 abc
		140	21.08 abc
	4	80	11.57 c-h
		100	11.73 c-h
		120	23.06 a
		140	17.57 a-f
	8	80	1.17 i-l
		100	4.35 g-l
		120	10.38 d-i
		140	5.57 g-l
	12	80	0.37 l
		100	0.40 kl
		120	0.53 kl
		140	0.79 kl
Significant level			**
$LSD_{0.05}$			2.67
CV (%)			6.17

** 1 % level of Significance

The above results corroborate with the observations of Mehdi *et al.* (2002), Qadar (1989 and 1998); and Bohra & Doerffling (1993). Sarfraz *et al.* (2002) found that the application of NPK fertilizers + K_2SO_4 to the rice crop significantly enhanced the paddy and straw yields compared to NPK fertilizers + $(NH_4)_2SO_4$.

4.6 Panicle length

4.6.1 Effects of variety

The panicle length significantly differed in two rice cultivars due to the mean effect of salinity and K levels .The panicle length was found highest in Pokkali (21.93 cm) and it was lowest (15.55 g) in BRRI DHAN 29 (Figure 28 & Appendix 10).

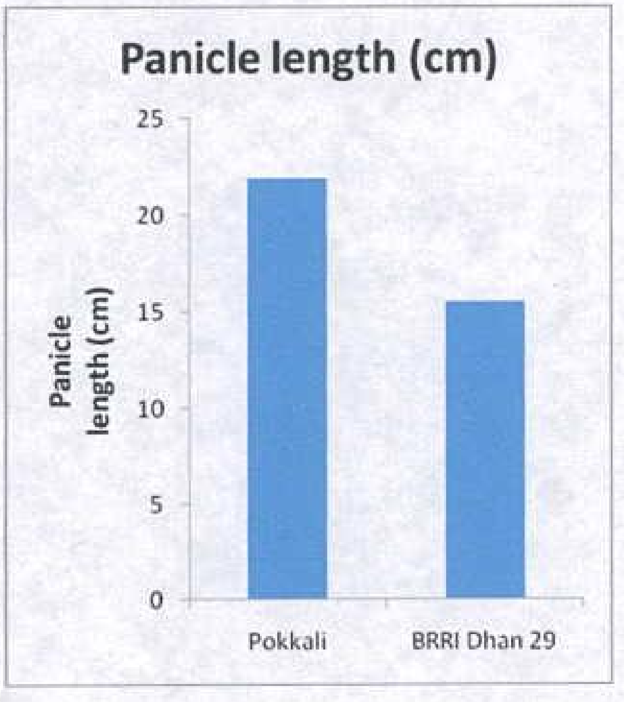


Figure 28. Varietal effect on panicle length (PL) of two rice cultivars due to the combined effect of different salinity and K levels

4.6.2 Effects of salinity

The effect of different salinity levels on panicle length of rice decreased significantly with increasing salinity levels (Figure 29). The panicle length was highest (24.61 cm) in 0 dSm^{-1} and lowest (7.95 cm) in 12 dSm^{-1} (Appendix 11).

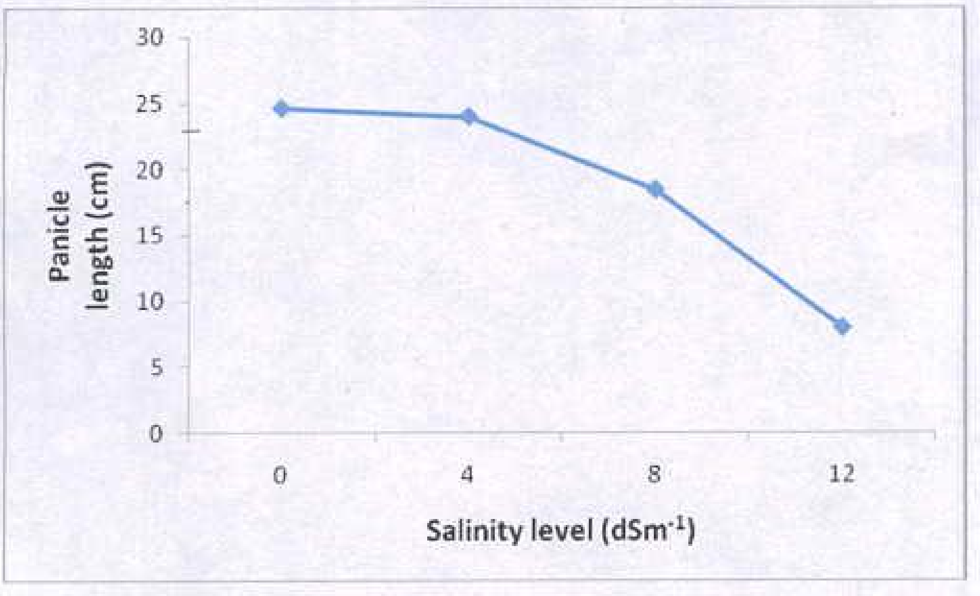


Figure 29. The effect of different salinity levels on panicle length of rice (mean of 2 cultivars and 4 K levels)

4.6.3 Effects of potassium

The panicle length of rice increased significantly upto 120 Kg K_20 ha^{-1} with increasing the supplemental K levels and thereafter it decreased (Figure 30). The absolute panicle length was highest (19.87 cm) in 120 kg K_20 ha^{-1} and lowest (17.7 cm) in 80 kg K_20 ha^{-1} (Appendix-12).

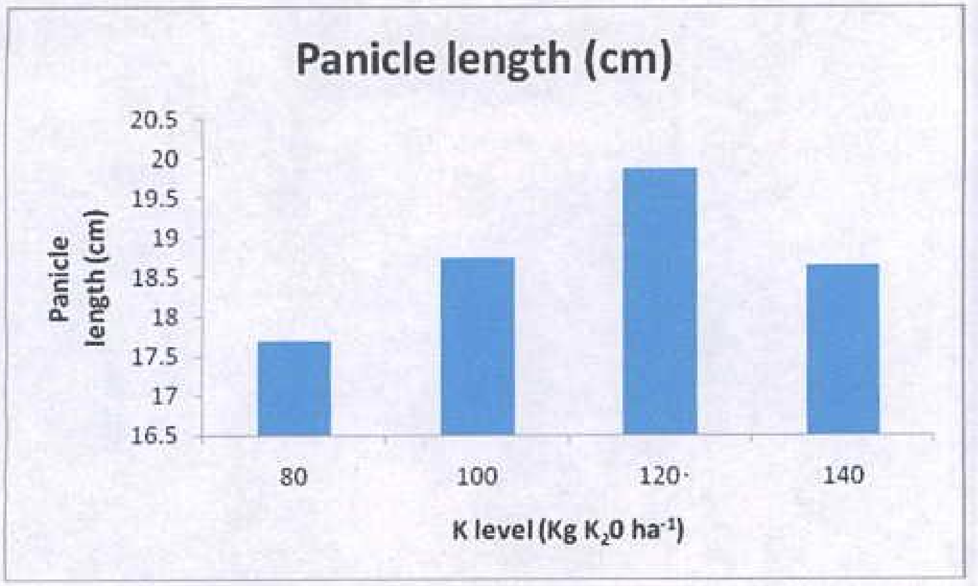


Figure 30. The effect of different K levels on panicle length of rice varieties (mean of 2 cultivars and 4 salinity levels)

4.6.4 Interaction effect of variety and salinity

The result shows that the panicle length of two rice varieties significantly decreased with increasing the salinity levels over all the levels of supplemental K. The variety BRRI Dhan 29 showed very sharp decreasing pattern as compared to Pokkali (Figure 31 and Appendix 13). The panicle length was highest (25.88 cm) in 4 dSm^{-1} in Pokkali and lowest (0.00 or no panicle) in BRRI Dhan 29 at 12 dSm^{-1} (BRRI Dhan 29 did not give any yield at 12 dSm^{-1}).

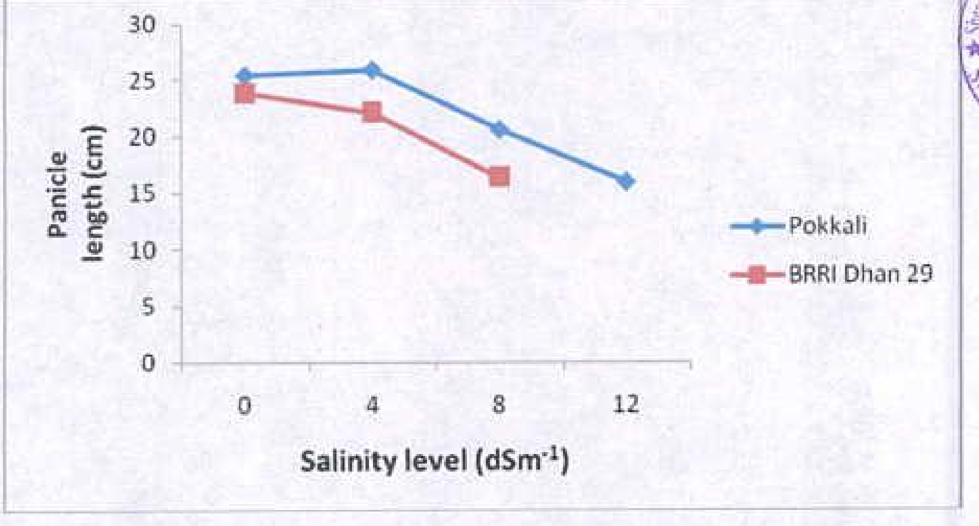


Figure 31. The effect of different salinity levels on panicle length of two rice varieties (mean of 4 K levels)

4.6.5 Interaction effect of variety and potassium

The effect of different supplemental K levels on panicle length of two rice varieties significantly increased over all the levels of salinity (Figure 32). The panicle length was highest (23.47 cm) in 100 kg $K_2 0$ ha^{-1} in Pokkali and the lowest (13.93 cm) in BRRI Dhan 29 at 80 kg $K_2 0$ ha^{-1} (Appendix 14).

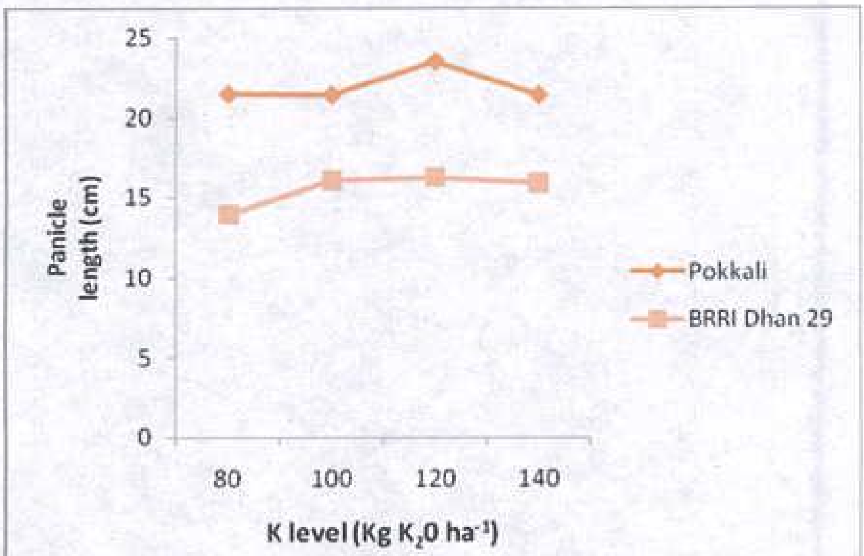


Figure 32. The effect of different K levels on panicle length of two rice varieties (mean of 4 salinity levels)

4.6.6 Interaction effect of salinity and potassium

The effect of different supplemental K levels on panicle length of rice at all the salinity levels was significant. The panicle length increased due to increasing the supplemental K levels at all salinity levels except the highest level of K (140 kg K_2O ha^{-1}) at 12 dSm^{-1} levels of salinity; where it slightly decreased (Figure 33). The panicle length was highest

(25.29 cm) in 120 kg K_20 ha^{-1} at 0 dSm^{-1} and the lowest (4.51 cm) in 80 kg K_20 ha^{-1} at all the levels of salinity (Appendix-15).

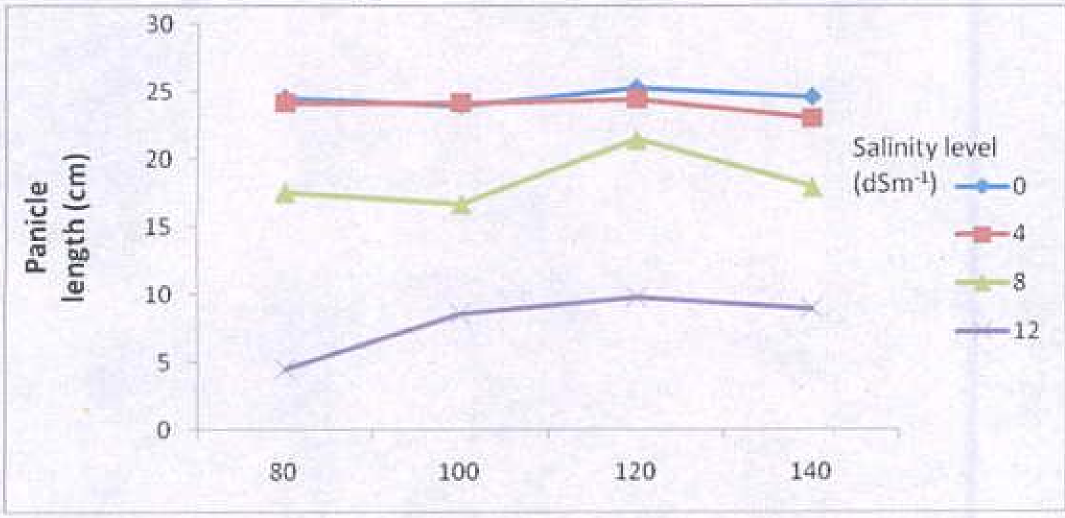


Figure 33. Interaction effect of different salinity and supplemental K levels on panicle length of rice (mean of 2 varieties)

4.6.7 Interaction effect of variety, salinity and potassium

The interaction effect of different salinity and K levels was significant on panicle length of two rice varieties (Table 9). Here, the panicle length of both the rice varieties increased progressively at different salinity levels with increasing the K levels except that at the highest level of K (140 kg K_2O ha^{-1}) at 4 dSm^{-1} salinity level in BRRI Dhan 29 where it slightly decreased. The panicle length was highest (27.18 cm) in 100 kg K_20 ha^{-1} at 0 dSm^{-1} in Pokkali and the lowest (0.00 or no panicle) in all K level at 12 dSm^{-1} in BRRI Dhan 29.

Bohra and Doerffling (1993) found that potassium application significantly increased the percentage of filled spikelets of two varieties (Pokkali and IR28) under salinity.

Table 9. Interaction effect of different salinity and supplemental K levels on panicle length of two rice varieties

Variety	Salinity level (dS m^{-1})	K level (K_2O kg ha^{-1})	Panicle Length
Pokkali	0	80	26.25 ab
		100	24.82 abc
		120	26.22 ab
		140	24.32 abc
	4	80	24.96 abc
		100	27.18 a
		120	25.64 ab
		140	25.77 ab
	8	80	25.66 ab
		100	22.29 a-f
		120	16.70 f
		140	17.54 def
	12	80	9.034 g
		100	19.59 c-f
		120	17.10 ef
		140	17.94 def
BRRI dhan 29	0	80	22.82 a-e
		100	23.18 a-d
		120	24.37 abc
		140	24.92 abc
	4	80	23.41 a-d
		100	21.23 b-f
		120	23.27 a-d
		140	20.37 b-f
	8	80	9.50 g
		100	20.67 b-f
		120	16.68 f
		140	18.39 def
	12	80	0.000 h
		100	0.000 h
		120	0.000 h
		140	0.000 h
Significant level			**
$LSD_{0.05}$			1.57
CV (%)			5.07

** 1 % level of Significance

4.7 Number of filled grain

4.7.1 Effects of variety

The variation in the content of filled grain panicle^{-1} in two rice varieties was statistically significant due to the combined effect of different salinity and K levels ((Figure 34). Considering the performance of variety, the number of filled grain was found highest in BRRI Dhan 29 (27.57) and it was lowest (25.88) in Pokkali (Appendix 10).

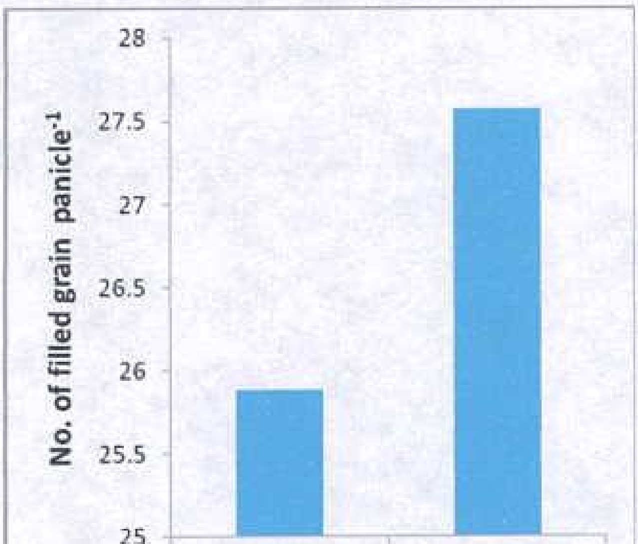


Figure 34. Varietal effect on number of filled grain of two rice cultivars due to the combined effect of different salinity and K levels

4.7.2 Effects of salinity

The effect of salinity on number of filled grain panicle^{-1} of rice varieties decreased significantly with increasing salinity levels (Figure 35). The number of filled grain was highest (62.78) in 0 dSm^{-1} and lowest (0.87) in 12 dSm^{-1} (Appendix 11).

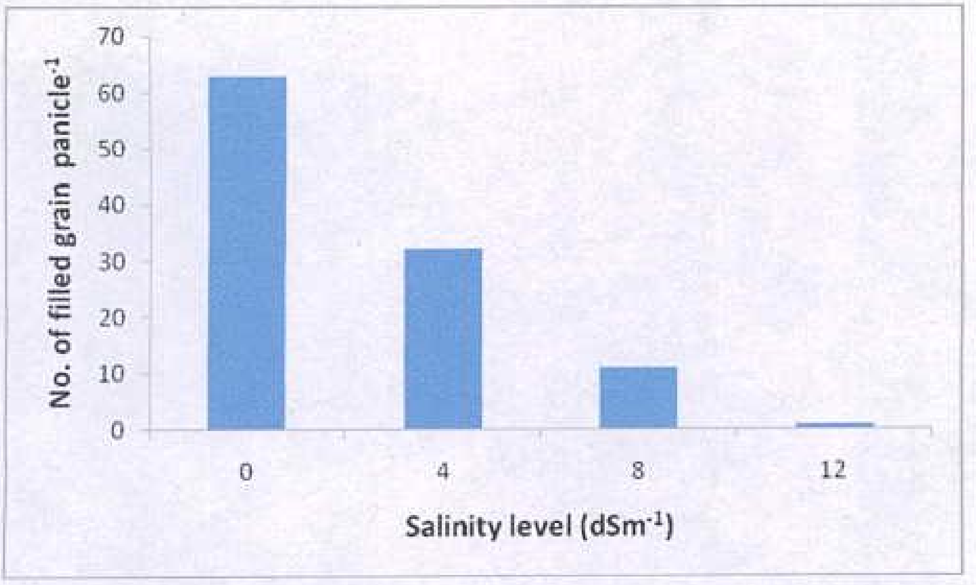


Figure 35. The effect of different salinity levels on number of filled grain of rice (mean of 2 cultivars and 4 K levels)

4.7.3 Effects of potassium

The number of filled grain panicle^{-1} of rice increased significantly with increasing the supplemental K levels (Appendix 12). The number of filled grain was highest (29.21) in 120 kg K_20 ha^{-1} and the lowest (24.17) in 100 kg K_20 ha^{-1} (Figure 36).

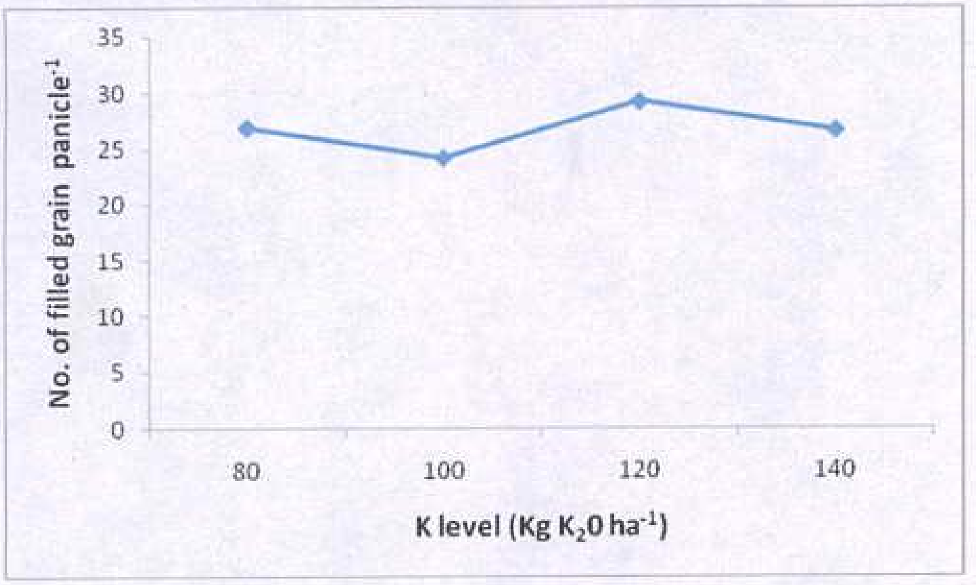


Figure 36. The effect of different K levels on filled grain of rice (mean of 2 cultivars and 4 salinity levels)

4.7.4 Interaction effect of variety and salinity

The effect of different salinity levels on number of filled grain panicle^{-1} of two rice varieties differed significantly over all the levels of K (Appendix 13). The number of filled grain of the two rice varieties under study decreased as the salinity level increased (Figure 37). The number of filled grain was highest (63.26) at 0 dSm^{-1} in BRRI Dhan 29 which was statistically similar to Pokkali at 0 dSm^{-1} salinity level and it was found lowest (0.00 or no grain) at 12 dSm^{-1} in BRRI Dhan 29.

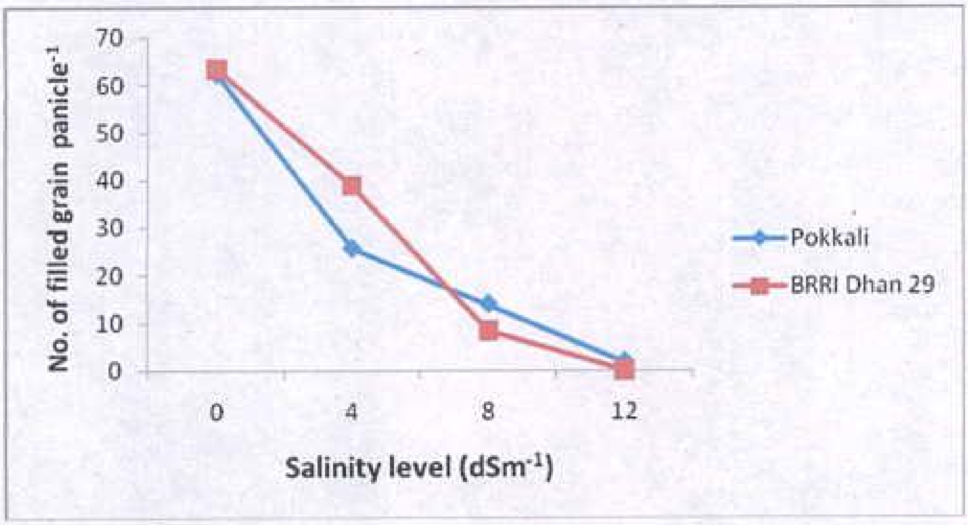


Figure 37. The effect of different salinity levels on number of filled grain of two rice varieties (mean of 4 K levels)

4.7.5 Interaction effect of variety and potassium

The effect of different K levels on number of filled grain panicle^{-1} of two rice varieties significantly increased with increasing of K levels upto 120 Kg K_20 ha^{-1} and thereafter slightly decreased in both the varieties over all the levels of salinity(Figure 38).The number of filled grain panicle^{-1} was highest (29.36 cm) at 120 kg K_20 ha^{-1} in Pokkali and the lowest (23.17) in Pokkali at 100 kg K_20 ha^{-1} (Appendix 14).

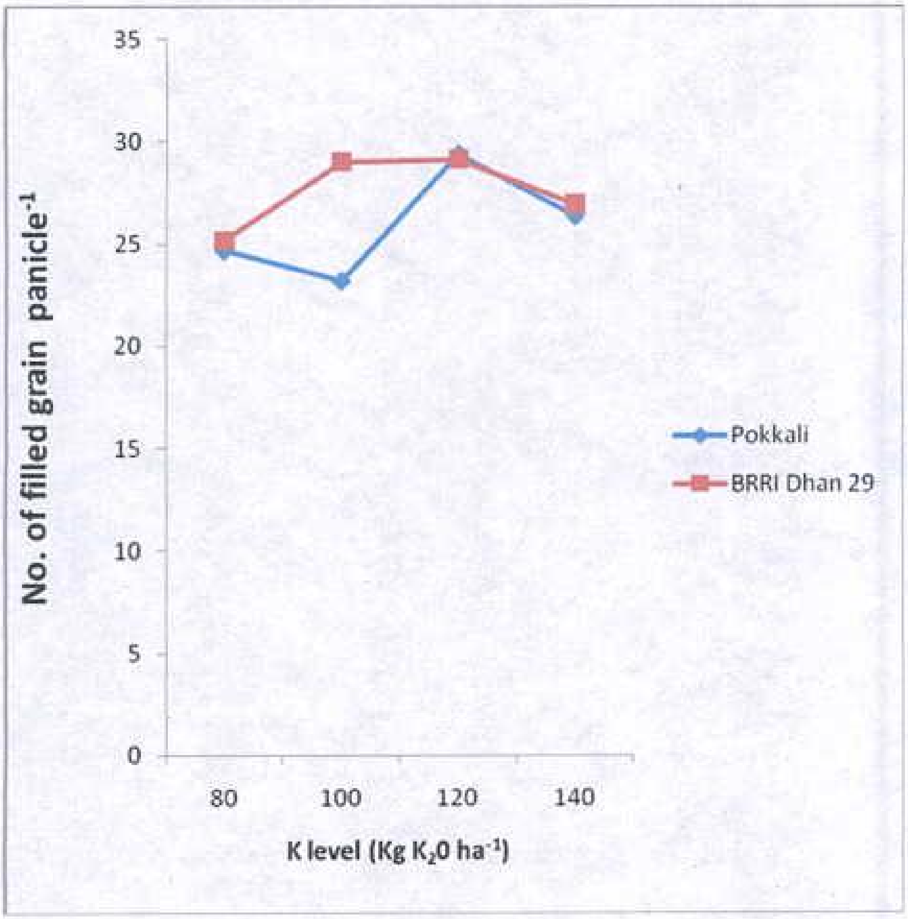


Figure 38. The effect of different K levels on number of filled grain of two rice varieties (mean of 4 salinity levels)

4.7.6 Interaction effect of salinity and potassium

The effect of different K levels on number of filled grain panicle^{-1} of rice cultivars was significant at different levels of salinity (Appendix 15). The absolute number of filled grain was highest (74.26) in 120 kg K ha^{-1} at 0 dSm^{-1} and lowest (0.00 g) in 80 kg K ha^{-1} at 12 dSm^{-1} (Figure 39).

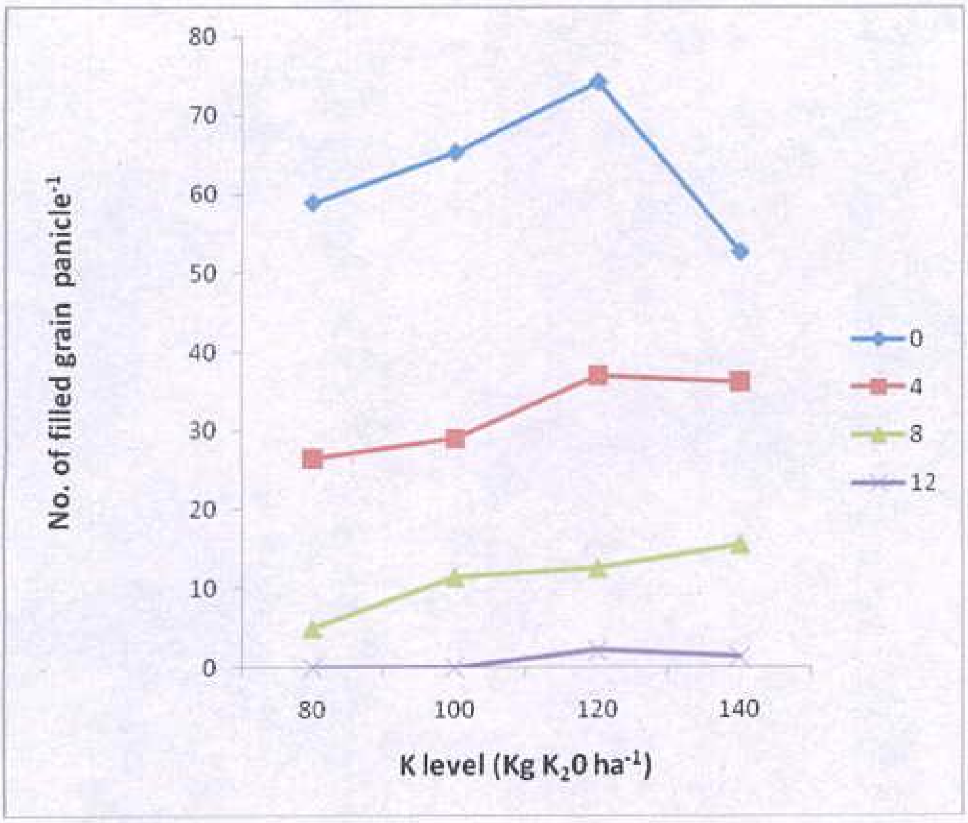


Figure 39. Interaction effect of different salinity and supplemental K levels on number of filled grain of rice varieties (mean of 2 varieties)

4.7.7 Interaction effect of variety, salinity and potassium

The interaction effect of different salinity and K levels was significant on number of filled grain panicle^{-1} of the rice varieties (Table 10). Here, the number of filled grain of both the rice varieties increased progressively at different salinity levels with increasing the K levels except at the highest level of K (140 kg K_2O ha^{-1}) and at salinity 12 dSm^{-1} where it slightly decreased. The number of filled grain panicle^{-1}was highest (81.46) in 120 kg K_2O ha^{-1} at 0 dSm^{-1} in Pokkali and lowest (0.00 or no grain) in all K_2O level at 12 dSm^{-1} in BRRI Dhan 29.

Table 10. Interaction effect of different salinity and supplemental K levels on number of filled grain of two rice varieties

Variety	Salinity level (dS m^{-1})	K level (K_2O kg ha^{-1})	No. of Filled Grain
Pokkali	0	80	49.84 bcd
		100	81.46 a
		120	67.16 ab
		140	50.7 bcd
	4	80	23.70 e-h
		100	21.28 e-i
		120	20.80 e-i
		140	36.61 cde
	8	80	25.11 efg
		100	10.40 f-i
		120	4.750 ghi
		140	15.40 i
	12	80	0.0000 ghi
		100	4.333 i
		120	0.0000 hi
		140	2.667 ab
BRRI dhan 29	0	80	67.92 ab
		100	67.07 ab
		120	63.41 bc
		140	54.66 bc
	4	80	48.66 bcd
		100	36.68 cde
		120	32.08 def
		140	37.32 cde
	8	80	0.0000 i
		100	12.44 f-i
		120	5.167 ghi
		140	15.71 e-i
	12	80	0.0000 i
		100	0.0000 i
		120	0.0000 i
		140	0.0000 i
Significant level			**
$LSD_{0.05}$			1.25
CV (%)			4.3

** 1 % level of Significance

4.8 Thousand grain weight

4.8.1 Effects of variety

While considering the performance of variety, the thousand (1000) grain weight was found highest in Pokkali (35.59 g) and it was lowest (17.82 g) in BRRI DHAN 29 (Figure 40 & Appendix 10).

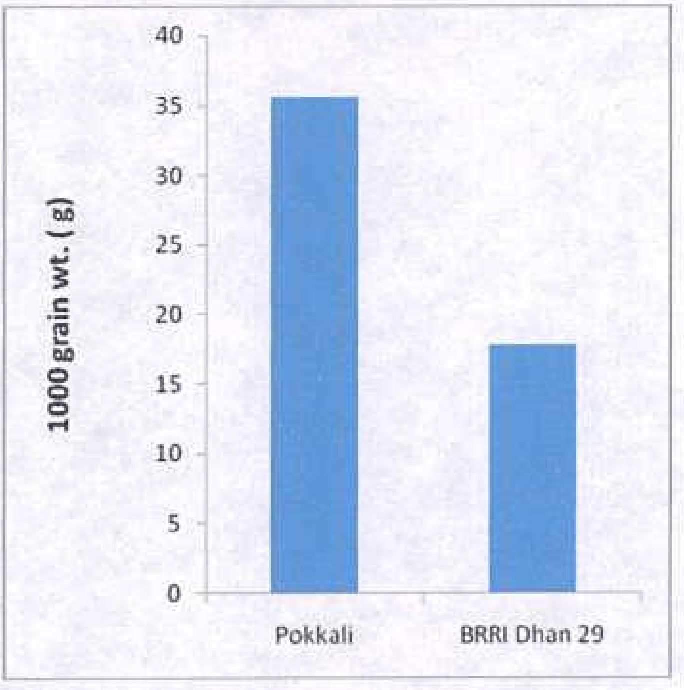


Figure 40. Varietal effect on 1000-grain weight of two selected rice cultivars due to the combined effect of different salinity and K levels

4.8.2 Effects of salinity

The 1000-grain weight of rice significantly decreased due to the increase in the salinity levels (Figure 41). Thousand grain weight was highest (32.46 g) at 0 dSm^{-1} and it was found lowest (18.57 g) at 12 dSm^{-1} (Appendix 11).

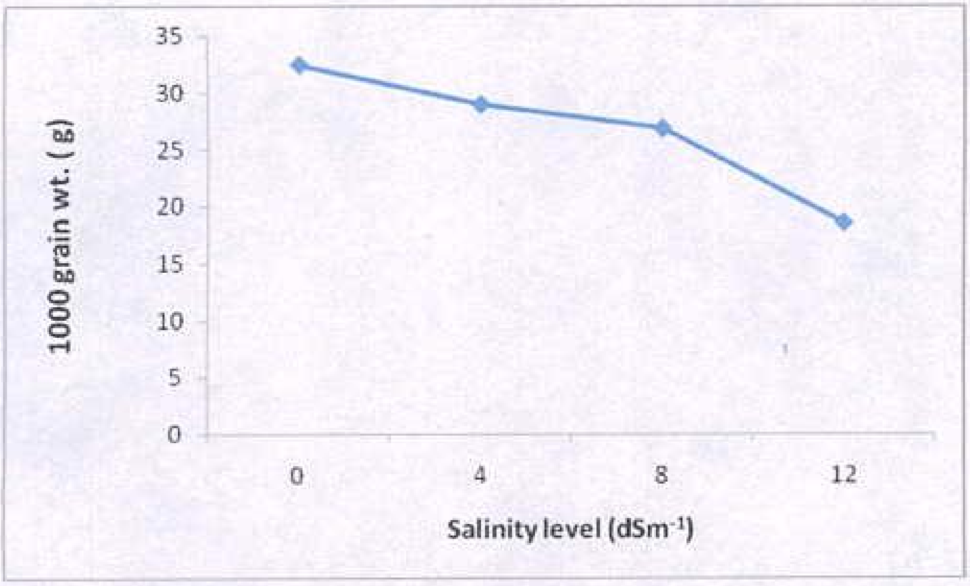


Figure 41. The effect of different salinity levels on 1000-grain weight of two rice (mean of 2 cultivars and 4 K levels)

4.8.3 Effects of potassium

The application of K significantly increased the 1000-grain weight with increasing K levels up to 120 kg K_20 ha^{-1} and then decreased very slightly over all the levels of salinity (Figure 42). Thousand grain weight was highest (27.36 g) at 140 kg K_20 ha^{-1} and it was found lowest (26.01 g) at 80 kg K_20 ha^{-1} (Appendix 12).

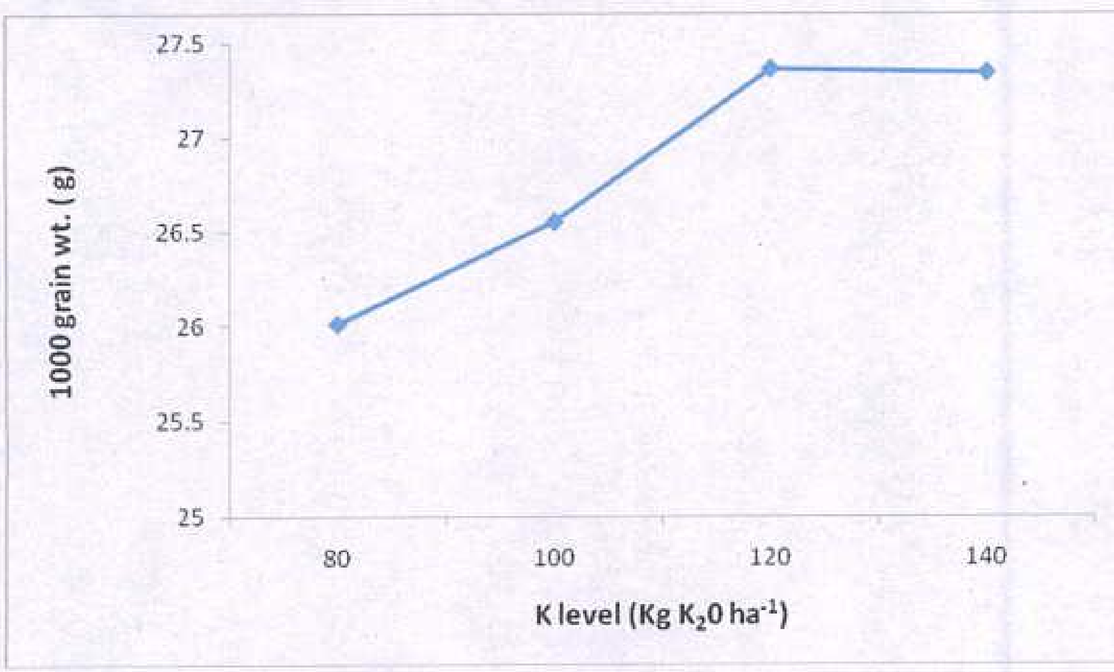


Figure 42. The effect of different K levels on 1000-grain weight of rice varieties(mean of 2 cultivars and 4 salinity levels)

4.8.4 Interaction effect of variety and salinity

The effect of different salinity levels on 1000-grain weight of the two rice varieties differed significantly over all the levels of K (Appendix 13). The 1000-grain weight of the two rice varieties under study decreased as the salinity level increased where BRRI Dhan 29 gave no grain after 8 dSm^{-1} level of salinity (Figure 43). Thousand grain weight was highest (37.67 g) at 0 dSm^{-1} in Pokkali and it was found lowest (0.00 or no yield) at 12 dSm^{-1} in BRRI Dhan 29.

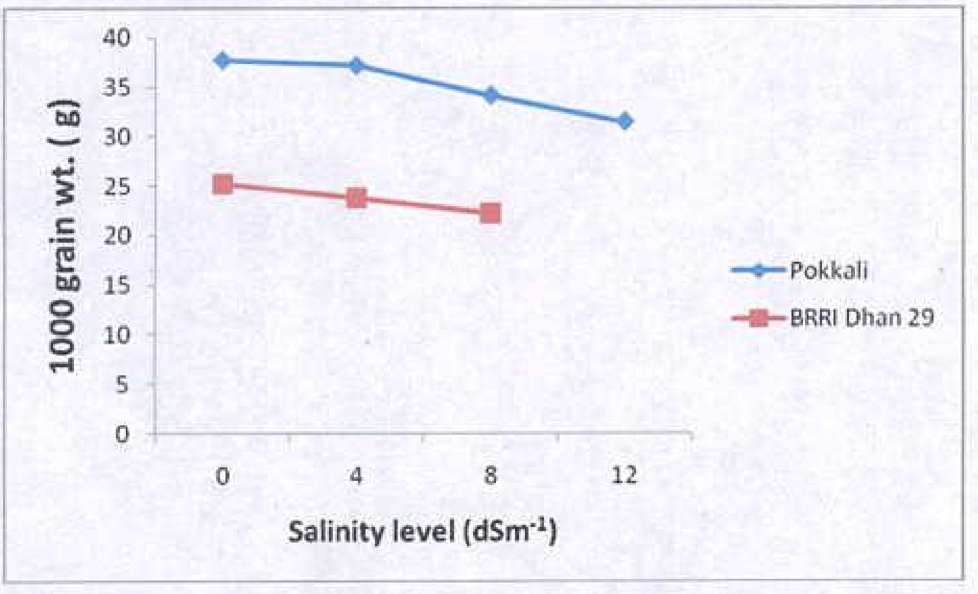


Figure 43. The effect of different salinity levels on 1000-grain weight of two selected rice varieties (mean of 4 K levels)

4.8.5 Interaction effect of variety and potassium

The effect of different supplemental K levels on 1000-grain weight of two rice varieties was significant over all the levels of salinity . The 1000-grain weight of the selected rice varieties increased with increasing K levels(Figure 44). Thousand grain weight was highest (37.03 g) at 120 kg K_20 ha^{-1} in Pokkali and it was found lowest (17.54 g) at 80 kg K_20 ha^{-1} BRRI Dhan 29 (Appendix 14).

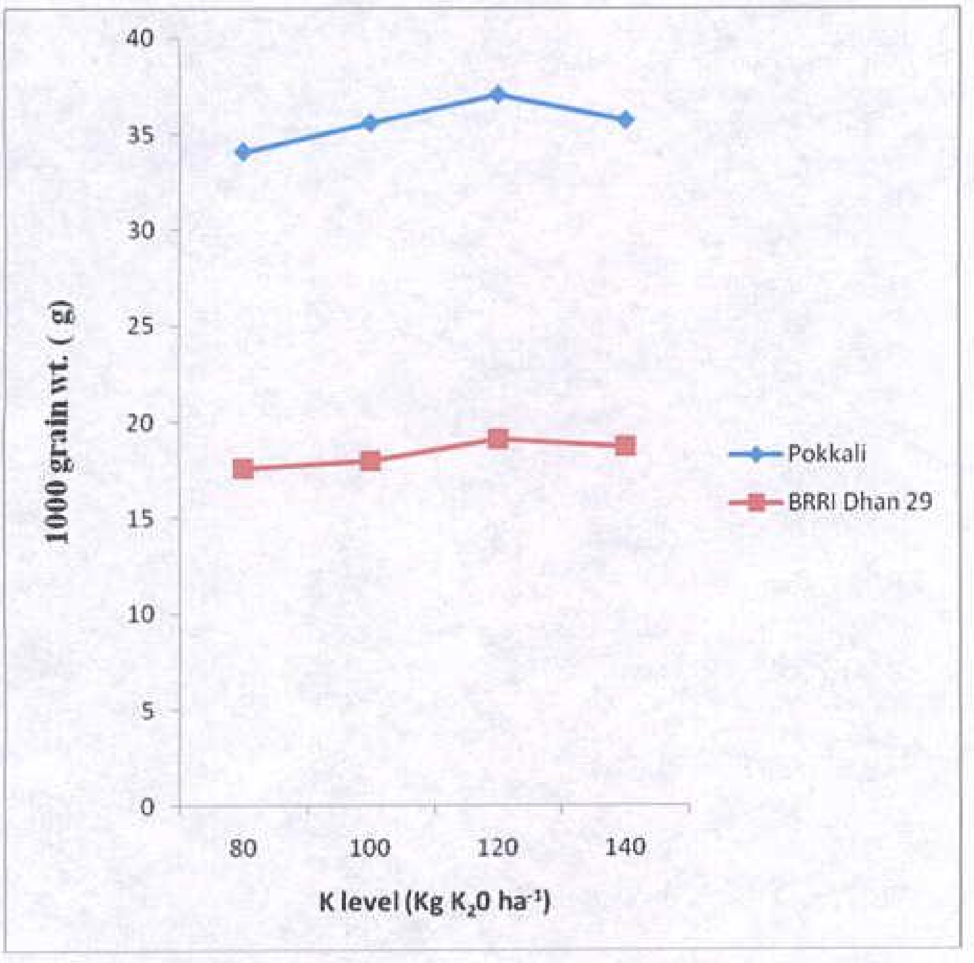


Figure 44. The effect of different K levels on 1000grain weight of two selected rice varieties (mean of 4 salinity levels)

4.8.6 Interaction effect of salinity and potassium

The average 1000-grain weight of selected rice varieties significantly increased as the levels of K increased (Figure 45). Thousand grain weight was highest (33.29 g) at 120 kg K_20 ha^{-1} at 8 dSm^{-1} and it was found lowest (17.55 g) at 80 kg K_20 ha^{-1} at 12 dSm^{-1} (Appendix 15).

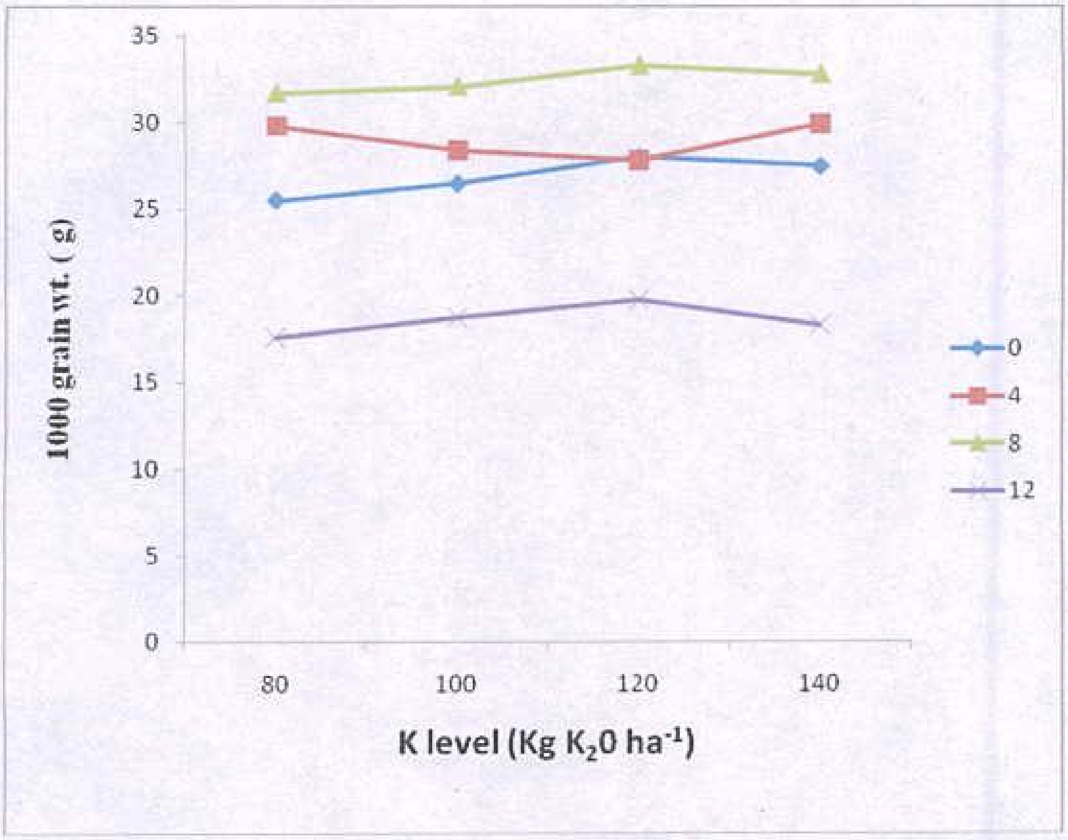


Figure 45. Interaction effect of different salinity and supplemental K levels on 1000-grain weight of rice (mean of 2 varieties)

4.8.7 Interaction effect of variety, salinity and potassium

The results presented in Table 11 show that the interaction effect of different salinity and K levels was significantly influenced on 1000-grain weight of two rice varieties. Thousand grain weight was highest (41.97 g) at 80 kg K ha^{-1} at 8 dSm^{-1} in Pokkali and it was found lowest (0.00 or no yield) at all K level at 12 dSm^{-1} in BRRI Dhan 29.

These results are in agreement with that of Mehdi *et al*., (2002) who stated that the supplementation of K (0, 20, 40, 65 and 80 mg K kg^{-1} soil) in artificially developed salinity (5.6, 8.7 and 11.5 dSm^{-1} levels) in soil of the experiment of rice the tillers, straw and grain yield significantly increased with increasing levels of K but increasing the salinity levels decreased tillers, straw and grain yield of rice. Similar results also found in the findings of Bohra & doerffling (1993) and Sarfraz *et al*. (2002).

Table 11. Interaction effect of different salinity and supplemental K levels on thousand (1000) grain weight of two rice varieties

Variety	Salinity level (dS m^{-1})	K level (K_2O kg ha^{-1})	Thousand grain weight (g)
Pokkali	0	80	33.34 f
		100	30.31 gh
		120	28.43 hi
		140	33.67 ef
	4	80	36.32 c-e
		100	33.03 f
		120	32.73 fg
		140	34.31 d-f
	8	80	41.97 a
		100	39.44 ab
		120	37.64 bc
		140	39.61 ab
	12	80	35.10 c-f
		100	39.45 ab
		120	37.46 bc
		140	36.54 cd
BRRI dhan 29	0	80	21.54 m
		100	22.57 m
		120	22.50 m
		140	22.26 m
	4	80	23.23 lm
		100	23.67 lm
		120	22.80 m
		140	25.50 j-l
	8	80	23.58 lm
		100	23.93 k-m
		120	26.53 i-k
		140	26.98 ij
	12	80	0.000 o
		100	0.000 o
		120	0.000 o
		140	0.000 o
Significant level			**
$LSD_{0.05}$			3.2
CV (%)			2.4

** 1 % level of Significance

4.9 Grain yield hill^{-1}

4.9.1 Effects of variety

The variation of grain yield hill^{-1} in two rice varieties was statistically significant due to the combined effect of different salinity and K levels (Appendix 10). The grain yield hill^{-1} of the variety Pokkali was highest (8.78 g) and it was found lowest (6.95 g) in BRRI Dhan 29 (Figure 46).

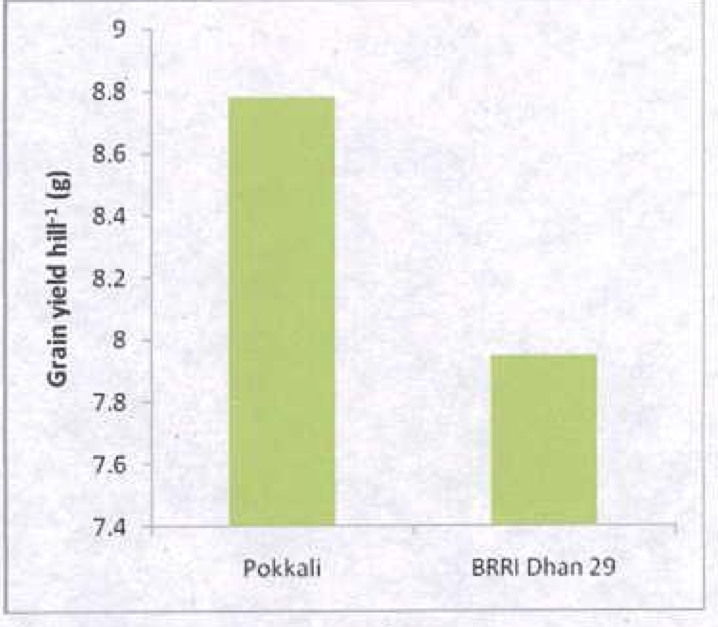


Figure 46. Varietal effect on grain yield hill^{-1} of two rice due to the combined effect of different salinity and K levels

4.9.2 Effects of salinity

The effect of salinity on grain yield hill^{-1} of rice varieties differed significantly (Appendix 11). It decreased with increasing salinity levels (Figure 47). Grain yield hill^{-1} was highest (14.41 g) at 0 dSm^{-1} and it was found lowest (2.07 g) at 12 dSm^{-1}.

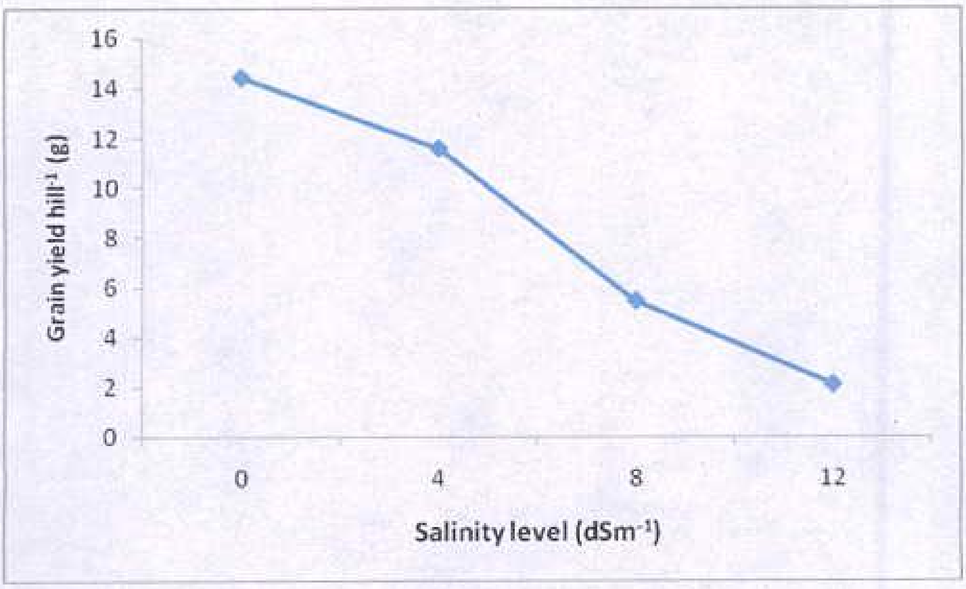


Figure 47. The effect of different salinity levels on grain yield hill^{-1} of rice (mean of 2 cultivars and 4 K levels)

4.9.3 Effects of potassium

The grain yield hill^{-1} of rice significantly increased due to increasing the K levels (Figure 48). Grain yield hill^{-1} was highest (9.01 g) at 120 Kg K_20 ha^{-1} which is statistically identical with 140 Kg K_20 ha^{-1}and it was found lowest (7.08 g) at 80 kg K_20 ha^{-1} (Appendix 12).

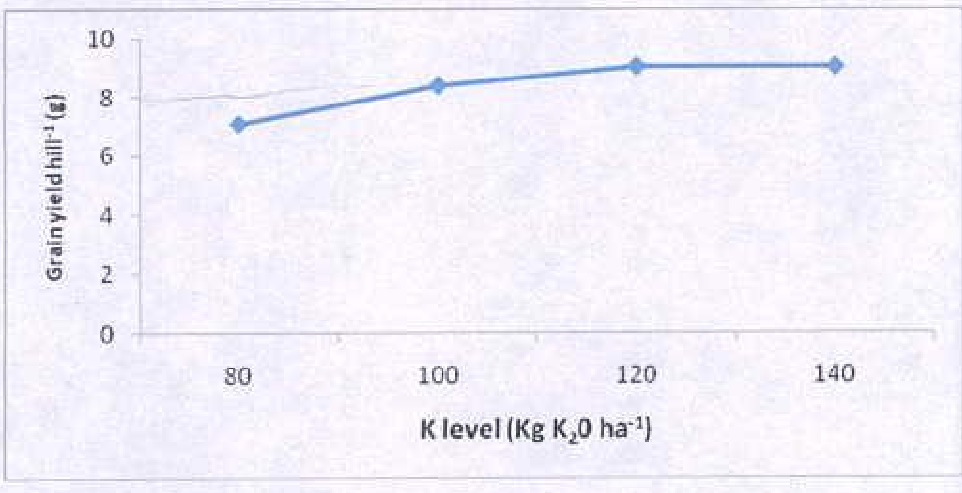


Figure 48. The effect of different K levels on grain yield hill^{-1} of rice(mean of 2 cultivars and 4 salinity levels)

4.9.4 Interaction effect of variety and salinity

The effect of different salinity levels on grain yield hill^{-1} of the two rice varieties decreased significantly due to the increase in salinity levels over all the levels of K (Figure 49) and this decreasing pattern was very sharp in BRRI Dhan 29 than Pokkali. Grain yield hill^{-1}was highest (15.59 g) at 0 dSm^{-1} in BRRI Dhan 29 and it was found lowest (0.00 or no yield) at 12 dSm^{-1} in BRRI Dhan 29 (Appendix 13).

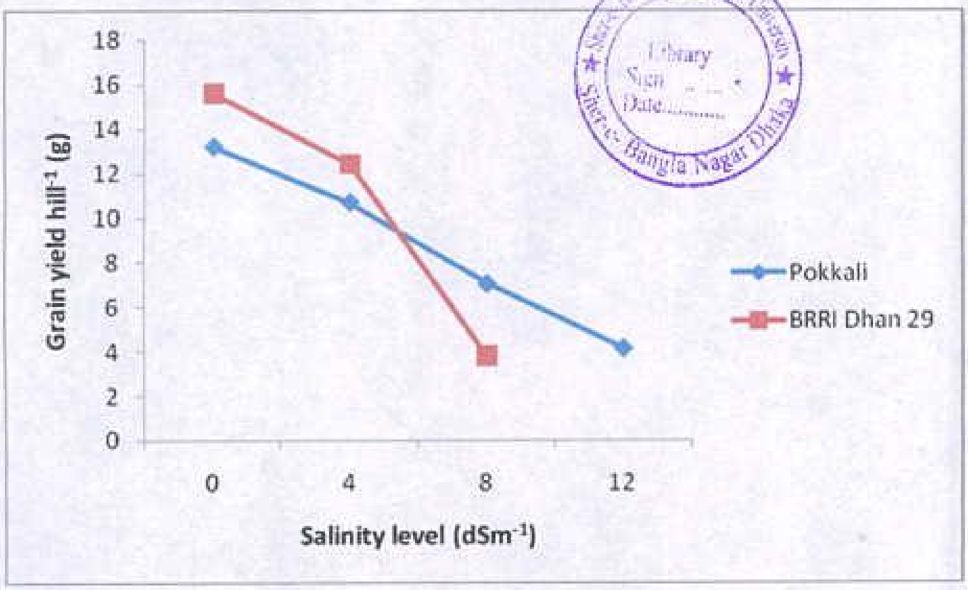


Figure 49. The effect of different salinity levels on grain yield hill^{-1} of two rice varieties (mean of 4 K levels)

4.9.5 Interaction effect of variety and potassium

The effect of different K levels was significant on grain yield hill^{-1} of the rice varieties over all the levels of different salinity (Appendix 14). The grain yield hill^{-1} of the selected rice varieties increased as the application of increased levels of supplemental K (Figure . 50). Grain yield hill^{-1} was highest (10.69 g) at 120 kg K_20 ha^{-1} in Pokkali and it was found lowest (6.67 g) at 80 kg K_20 ha^{-1} in Pokkali.

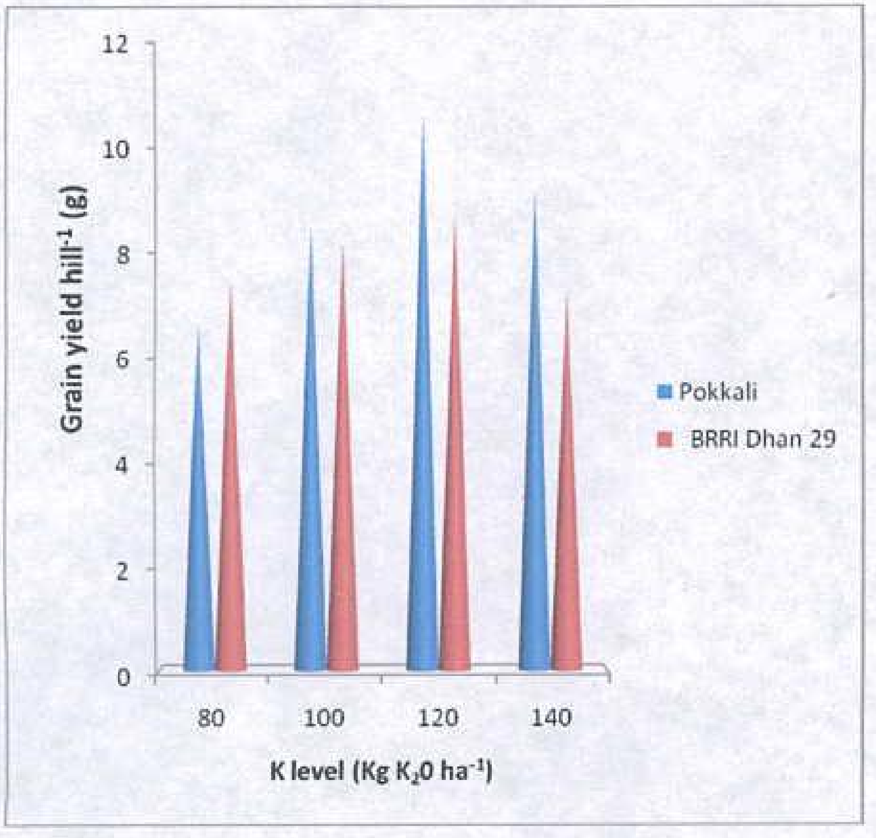


Figure 50. The effect of different K levels on grain yield hill^{-1} of two rice varieties (mean of 4 salinity levels)

4.9.6 Interaction effect of salinity and potassium

The average grain yield hill^{-1} of the two selected rice varieties increased as the levels of both K and salinity was increased except 0 and 4 dSm^{-1} salinity levels with 120 kg K_2O ha^{-1} (Figure 51). Grain yield hill^{-1} was highest (15.59 g) at 120 kg K_2O ha^{-1} at 0 dSm^{-1} and it was found lowest (1.23 g) at 80 kg K_2O ha^{-1} at 12 dSm^{-1} (Appendix-15).

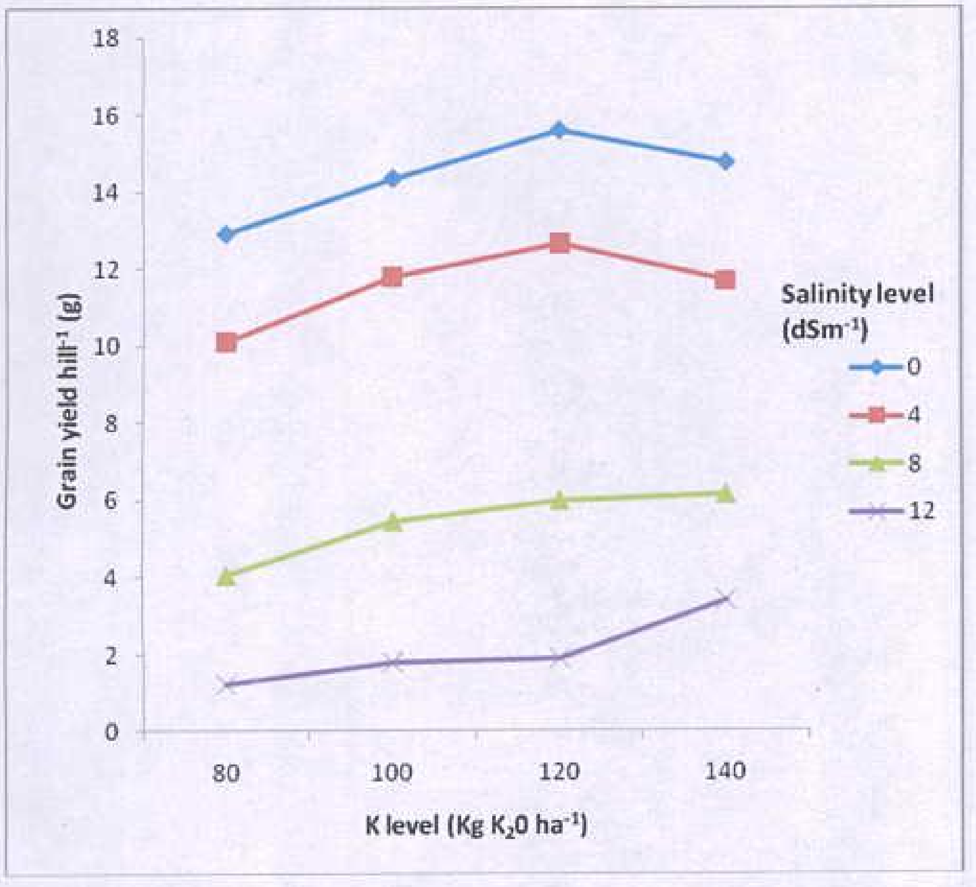


Figure 51. Interaction effect of different salinity and supplemental K levels on grain yield hill^{-1} of rice (mean of 2 varieties)

4.9.7 Interaction effect of variety, salinity and potassium

The results presented in Table 12 show that the interaction effect of different salinity and K levels was significantly influenced on grain yield hill^{-1} of two selected rice varieties. Where grain yield hill^{-1} increased progressively with increase in K levels except the highest levels of both K (140 kg K_2O ha^{-1}) at 4 and 8 dSm^{-1} levels of salinity in BRRI Dhan 29 where it decreased slightly. Grain yield hill^{-1} was highest (16.95 g) at 120 kg K ha^{-1} at 0 dSm^{-1} in BRRI Dhan 29 and it was found lowest (0.00 or no yield) at all K level at 12 dSm^{-1} BRRI Dhan 29 .

These results are in agreement with that of Mehdi *et al.*, (2002) who stated that the supplementation of K (0, 20, 40, 65 and 80 mg K kg^{-1} soil) in artificially developed salinity (5.6, 8.7 and 11.5 dSm^{-1} levels) in soil of the experiment of rice the tillers, straw and grain yield significantly increased with increasing levels of K but increasing the salinity levels decreased tillers, straw and grain yield of rice. Similar results also found in the findings of Bohra & doerffling (1993) and Sarfraz *et al.* (2002).

Table 12. Interaction effect of different salinity and supplemental K levels on grain yield $hill^{-1}$ of two rice varieties

Variety	**Salinity level ($dS\ m^{-1}$)**	**K level (K_2O kg ha^{-1})**	GDW
Pokkali	0	80	11.24 c-h
		100	13.17 b-e
		120	14.24 a-d
		140	14.23 a-d
	4	80	8.230 g-j
		100	10.51 e-h
		120	11.57 c-g
		140	12.57 b-f
	8	80	4.776 j-n
		100	6.540 i-m
		120	7.710 h-k
		140	9.180 f-i
	12	80	2.470 no
		100	3.790 lmn
		120	3.567 l-o
		140	6.803 i-l
BRRI dhan 29	0	80	14.61 abc
		100	15.53 ab
		120	16.95 a
		140	15.30 ab
	4	80	11.99 b-f
		100	13.09 b-e
		120	13.74 a-e
		140	10.80 d-h
	8	80	3.373 l-o
		100	4.413 k-n
		120	4.307 k-n
		140	3.140 mno
	12	80	0.000 o
		100	0.000 o
		120	0.000 o
		140	0.000 o
Significant level			**
$LSD_{0.05}$			3.2
CV (%)			2.4

** 1 % level of Significance

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted at the net house of the department of Genetics and Plant Breeding, Sher-e-Bangla Agricultural University, Dhaka-1207 under pot-culture during the Boro season (December-June) of the year 2008-09 to study the reclamation of salinity by potassium supplementation on growth and yield of rice. The experiment was completed using two varieties (one salt tolerant cultivar Pokkali as standard check and BRRI dhan 29 developed by Bangladesh Rice Research Institute) and 4 salinity levels (0, 4, 8 and 12 dS m^{-1}) and 4 supplemental K levels (80, 100, 120, 140 kg K_2O ha^{-1}). Data were taken on plant height, root dry weight, shoot dry weight, total dry matter, effective number of tiller $hill^{-1}$, panicle length, number of filled grain, thousand grain weight and grain yield $hill^{-1}$. Significant varietal differences were found in plant height, shoot dry weight, total dry matter, effective number of tiller $hill^{-1}$, panicle length, number of filled grain, thousand grain weight and grain yield $hill^{-1}$ except in case of root dry weightwhere Pokkali is better than BRRI Dhan 29.

Plant height, root dry weight, shoot dry weight, total dry matter, effective number of tiller $hill^{-1}$, panicle length, number of filled grain, thousand grain weight and grain yield $hill^{-1}$ decreased with increasing salinity. With increasing potassium level plant height, root dry weight, shoot dry weight, total dry matter, effective number of tiller $hill^{-1}$, panicle length, number of filled grain, thousand grain weight and grain yield $hill^{-1}$increased up to 120 kg K_2O ha^{-1} then decreased.

Due to interaction effect of variety and salinity the plant height at different days after transplanting (DAT) were decreased with increasing level of salinity in both the varieties. The highest plant height was observed in Pokkali at 0 dS m^{-1} and lowest in BRRI dhan 29 at 12 dS m^{-1} . Other growth parameters also followed same pattern. The interaction effect of variety and potassium also significantly varied on growth and yield parameters where all the parameters in creased with increase in K levels upto 120 kg K_2O ha^{-1} in both the cultivars.

The highest number of effective tiller hill^{-1} was found at 0 dS m^{-1} with 120 kg K_2O ha^{-1}. In each salinity level the number of effective tiller hill^{-1} increased with the increase of potassium level upto 120 kg K_2O ha^{-1} in both variety.

Number of effective tiller hill^{-1}, panicle length and number of grain panicle^{-1} and grain yield hill^{-1} decreased with increasing salinity. The highest number of effective tiller hill^{-1}, panicle length and grain yield hill^{-1} was found with 0 dS m^{-1} and the lowest was found with 12 dS m^{-1}. Pokkali gave the highest panicle length at 0 dS m^{-1}, then decreased with increasing salinity. On the other hand, panicle length in BRRI dhan 29 decreased with increasing salinity and at 12 dSm^{-1} it did not give any effective tiller as well as panicle.

The interaction effect of variety salinity and potassium significantly differed. The plant height, root dry weight, shoot dry weight, total dry matter, effective tiller hill^{-1} , panicle length, grain panicle^{-1} and grain yield hill^{-1} increased of the two rice cultivars with increasing K levels at all salinity levels except 140 kg K_2O ha^{-1} at 12 dSm^{-1} salinity.

CHAPTER VI

REFERENCES

Abdel-Rahman, A.M.M., Zayed, B.A. & Shehata, S.M. (2004). Response of two rice cultivars to potassium fertilizer under saline soil. *Egypt .J. Agric., Res.* **82(1)**, 209-217.

Akram, M., Ashraf, M. Y., Ahmad, R., Rafiq, M., Ahmad, I. and Iqbal, J. (2010). Allometry and yield components of rice (*Oryza sativa* L.) hybrids to various potassium levels under saline conditions. *Arch. Biol. Sci.* ,62 (4): 1053-1061.

Alam, S. M., Ansari , R., Mujtaba , S. M. and Shereen, A. 2001. Salinization of millions of hectares of land continues to reduce crop productivity severely worldwide. NIA, Tandojam, Pakistan.

Ashraf, M. and Harris. P. J. C. 2004. Potential biochemical indicators of salinity tolerance in plants. *Plant Sci.,* 166: 3-16.

Ashraf, M. Y. 1998. Photosynthetic efficiency of wheat under water stress conditions. *Pakistan J. of Scientific and Industrial Resear.,* **41**:156-163.

Ashraf, M. Y., and Sarwar, G. 2002. Salt tolerance potential in some members of *BrassiKceae*. Physiological studies on water relations and mineral contents. In *Prospects for saline Agriculture*.

Ashraf, M., Rahmatullah, A. R., Bhatti, A. S., Afzal, M., Sarwar, A., Maqsood, M. A. and Kanwal, S. 2010. Amelioration of salt stress in rice (*Oryza sativa* L.) by supplying potassium and silicon in hydroponics. *Pedosphere*. **20**(2): 153–162

Baba, T and Fujiyama, H. 2003. Differences in short-term responses of rice and tomato to sodium salinization and supplemental potassium and Calcium. *Soil Sci. Plant Nutr.*, 49(5): 669-675.

Bhumbla, D.R. and Abrol, I.P. 1978. Soils and Rice. IRRI, Los Banos, Philippines. pp 719-734.

Bohra, J. S. and Doerffling , K. 1993. Potassium nutrition of rice (*Oryza sativa* L.) varieties under NaCl salinity. *Plant and soil*. 152(2): 299-303.

Cha-um, S., Vejchasarn, P. and Kirdmanee, C. 2005. An Effective Defensive Response in Thai Aromatic Rice Varieties (*Oryza sativa* L. spp. *indiK*) to Salinity. *J. Crop Sci. Biotech.*,10 (4): 257 – 264.

Din, C., Mehdi, S. M., Sarfraz, M., Hassan, G. and Sadiq, M. 2001. Comparative Efficiency of Foliar and Soil Application of K on Salt Tolerance in Rice. *Pakistan J. of Biological Sci.,* 4(7): 815 – 817.

Du-Pont, F.M. 1992. Salt induced changes in ion transport: regulation of primary pumps and secondary transporters. ***In*:** Cooke, D.T. and D.T. Clarkson (eds.), Transport and Receptor Proteins of Plant Membranes, Molecular Structure and Function. Plenum Press, New York. pp. 91-100.

Fageria, N. K. 2003. Salt tolerance of rice cultivars. *Plant and Soil*., 88(2): 237-243.

Finck, A. 1977. Soil salinity and plant nutritional status. ***In:*** Managing Saline Water. Proceedings of the International Conference. Texas Tech. Univ., Lubbock, Texas. pp. 199-210.

Flowers, T. J., and Flowers, S. A. 2005. Why does salinity pose such a difficult problem for plant breeders? *Agriculture water management,* **78**, 15-24.

Hadi, A., Nohoi, G., Arifin, I. K. 1999. Status and availability of potassium to rice plant in tidal swampy soil in the tropics. *Japanese J. of Tropical Agric*., 43(2): 84-90.

IAEA(*International Atomic Energy Agency*) Report, 1995. Management strategies to utilize salt affected soils. IAEA-TECDOC-814, Soil fertility, Irrigation and crop production section, Joint FAO/IAEA Division of nuclear techniques in food and agriculture, Vienna, Australia.

Jackson, M.L. 1973. Soil chemical analysis. Prentice-Hall of India, Pvt. Ltd.,pp. 326-338.

Jacoby, B. 1999. Mechanisms involved in salt tolerance of plants. ***In:*** Pessarakli, M. (ed.), Handbook of Plant and Crop Stress (2nd ed.). Marcel Dekker, New York, pp. 97-123.

Javecl, M.and Muhammad, S. 2009. Effect of foliar applied potassium on the growth and chemical composition of rice under saline conditions. *Pakistan J. Soil Sci.* 7(1): 1-2.

Kandil, A. A, Sultan, M. S. , Badawi, M. A. El-Rahman, A. A. A. and Zayed, B. A. 2010. Performance of rice cultivars as affected by irrigation and potassium fertilizer under saline soil conditions. 1-Physiological and chemical characteristics. *Crop Environ.,* 1: 35-38.

Koyama, M. L., Levesley, A., Koebner, R. M. D., Flowers, T. J. and Yeo, A. R. 2001. Quantitative Trait Loci for Component PhysiologiKl Traits Determining Salt Tolerance in Rice. *Plant Physiology,* 125: 406-422.

Marschner, H. 1971. Why sodium replace potassium in plants? *In:* "Potassium in Biochemistry and Physiology". pp. 50-63. International Potash Institute, Basel, Switzerland.

Maloo, S.R. 1993. Breeding and screening techniques for salt tolerance in crop plants. ***In:*** Somani, L.L. and K.L. Totawat (eds.), Management of Salt-Affected Soils and Waters. Agrotech Publishing AKdemy, Udaipur-313001, India. pp. 321-357.

Mehdi, S.M., Sarfraz, M. and Hafeez, M. 2007. Response of rice advance line PB-95 to potassium appliKtion in saline-sodic soil. *Pakistan Journal of Biological Science,* 10: 2935-2939.

Munns, R. 1993. Physiological processes limiting growth in saline soils: some dogmas and hypotheses. *Plant and Cell Environment,* **16**, 15-24.

Noaman, M. N. 2004. Effect of potassium and nitrogen fertilizers on growth and biomass of some halophytes grown under high level of salinity. *Journal of Agronomy,***3**; 25-30.

Qadar, A. 1995. Requirement of rice crop for phosphorus and potassium at varying sodicity levels. *J. of Plant Nutri*tion, 18(**11**): 2291-2303.

Qadar, A. 1998. Alleviation of sodicity stress on rice cultivars by phosphorus and potassium fertilization .Plant and Soil, **203(2):** 269-277.

Rajarathinam, S., Koodalingam K. and Raja, V.D.G. 1988. Effect of potassium and sodium in rice for tolerance of soil salinity. *Journal of Potassium Research,* **4**: 174-178.

Russel, D.F. 1986. MSTAT-C Package Programme. Dept. of Crop and Soil Science, Michigan State University, USA.

Sheng M, Tang M; Chan, H; Yang B, Zhang F, Huang Y. 2008. Influence of arbuscular mycorrhizae on photosynthesis and water status of maize plants under salt stress. Mycorrhiza, 18: 287–296.

Shukla, U.C. and Mukhi, A.K.. 1979. Sodium, potassium and zinc relationship in corn. *Agron. J.,* **71**: 235-237.

Song, J.Q. and Fujiyama, H. 1996. Ameliorative effect of potassium on rice and tomato subjected to sodium salinization. *Soil Sci. Plant Nutrition* **42**: 493-501.

Thomas, R.L., Sheard, R.W. and Moyer, J.R. 1967. Comparison of conventional and automated procedures for nitrogen, phosphorus and potassium analysis of plant material using a single digestion. *Agron. J.,* 59: 240-243.

Thomas, S. and Nambisan, P. 1999. Effect of salt stress on uptake and partitioning of sodium, potassium and Calcium in rice seedlings. *Oryza*., 36(1): 42-45.

Velu, G., Srivastava, G.C., 2000. Status of sodium-potassium as a basis of salinity tolerance in rice. *Indian J. Plant Physiology* 5: 300-302.

Yang, X. E., Liu, J. X., Wang, W. M., Ye, Z. Q., and Luo A. C. 2004. Potassium internal use efficiency relative to growth vigour potassium distribution and Krbohydrates alloKtion in rice cultivars. *Journal of Plant Nutrition,* **27**: 837-852.

Yeo, A.R. and Flowers, T.J. 1982. Accumulation and loKlisation of sodium ions within the shoots of rice (*Oryza sativa* L.) varieties differing in salinity resistance. *Plant Physiology,* 56: 343-348.

Yoshida, S. 1981. Salinity. ***In***: Fundamentals of Rice Production. IRRI, Philippines. pp.175-76.

Zafar, S., Ashraf, M. Y., Sarwar, G., Mahmood, S.,Kausar, A. and Ali, I. 2004. Variation in growth and ion uptake in salt tolerant and sensitive rice cultivars under NaCl salinity. *Asian J. of Plant Sci.,* 3(**2**): 156-158.

Zayed, B. A., Elkhoby, W. M., Shehata, S. M. and A.mmar, M. H. 2007. Role of potassium application on the productivity of some inbred and hybrid rice varieties under newly reclaimed saline soils. African Crop Science Conference Proceedings. **8**: 53-60.

Zayed, B. A., Elkhoby, W. M., Shehata, S.M. and A.mmar, M. H. 2007. Role of potassium application on the productivity of some inbred and hybrid rice varieties under newly reclaimed saline soils. *African Crop Sci. Society*. Internet Publications.

Zeng, L. and Shannon, M.C.. 2000. Salinity effects on seedling growth and yield components of rice. *Crop Sci.,* 40(4): 996-1003.

CHAPTER VII

APPENDICES

Appendix 1. Effects of variety on plant height of rice at different days after transplantation (DAT) due to the combined effect of different salinity and K levels

Variety	Plant height (cm) at different DAT			
	30	45	At flowering	At Harvest
Pokkali	92.385 a	107.688 a	117.904 a	120.80 a
BRRI dhan 29	47.164 a	51.794 b	57.729 b	58.054 b
Significant level	**	**	**	**
$LSD_{0.05}$	4.05	3.57	2.98	4.14
CV (%)	7.37	5.07	4.12	5.50

Appendix 2. Effects of Salinity level on plant height of rice at different days after transplantation(mean of 2 cultivars and 4 K levels)

Salinity level (dSm^{-1})	Plant height (cm) at different DAT			
	30	45	At flowering	At Harvest
0	82.91 a	101.7 a	117.0 a	118.9 a
4	78.34 a	94.29 b	111.2 b	108.6 b
8	69.60 ab	78.88 c	94.46 c	92.89 c
12	48.25 c	44.08 d	35.07 d	30.90 d
Significant level	**	**	**	**
$LSD_{0.05}$	4.05	3.57	2.98	4.14
CV (%)	7.37	5.07	4.12	5.50

Appendix 3. Effects of Potassium level on plant height of rice at different days after transplantation (DAT) of rice (mean of 2 cultivars and 4 salinity levels)

K level (K_2O kg ha^{-1})	Plant height (cm) at different DAT			
	30	45	At flowering	At Harvest
80	63.80 c	74.11 c	74.89 d	80.49 c
100	70.69 b	81.38 a	90.81 b	86.71 c
120	72.54 a	80.30 b	96.47 a	98.32 a
140	72.07 a	83.17 a	89.95 b	91.35 b
Significant level	**	**	**	**
$LSD_{0.05}$	2.05	2.57	2.98	4.14
CV (%)	7.37	5.07	4.12	5.50

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 4: Varietal effect on different growth parameters of selected rice due to the combined effect of different salinity and K levels

Variety	Shoot dry wt. (g $hill^{-1}$)	Root dry wt. (g $hill^{-1}$)	Total dry matter (g $hill^{-1}$)
Pokkali	11.84 a	0.54	12.37 a
BR29	9.90 b	0.54	10.45 b
Significant level	*	NS	*
$LSD_{0.05}$	2.001	-	2.012
CV (%)	12.54	3.42	12.02

Appendix 5: The effect of different salinity levels on different growth parameters of two rice varieties (mean of 2 cultivars and 4 K levels)

Salinity (dSm^{-1})	Shoot Dry Weight	Root Dry Weight	Total dry matter (g $hill^{-1}$)
0	18.867 a	0.8833 a	19.94 a
4	16.447 b	0.6898 b	17.12 b
8	6.708 c	0.4684 c	7.17 c
12	1.467 d	0.1358 d	1.60 d
Significant level	**	**	**
$LSD_{0.05}$	2.57	0.21	2.75
CV (%)	5.07	4.12	5.34

Appendix 6: The effect of different K levels on different growth parameters of rice (mean of 2 cultivars and 4 salinity levels)

K level (K_2O kg ha^{-1})	Shoot Dry Weight	Root Dry Weight	Total dry matter (g $hill^{-1}$)
80	9.096 c	0.5035 b	9.59 c
100	10.058 b	0.4667 c	10.51 b
120	12.922 a	0.5735 a	13.47 a
140	11.412 a	0.6336 a	12.04 a
Significant level	**	**	
$LSD_{0.05}$	2.27	0.12	2.44
CV (%)	5.07	4.12	5.23

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

** —> Significant at 0.01 level of probability; *—> Significant at 0.05 level of probability

NS —> Non-significant

Appendix 7: The effect of different salinity levels on different growth parameters of two rice varieties (mean of 4 K levels)

Variety	Salinity level (dSm^{-1})	Shoot dry wt. ($g\ hill^{-1}$)	Root dry wt. ($g\ hill^{-1}$)	Total dry matter($g\ hill^{-1}$)
Pokkali	0	18.698 a	0.88 a	19.57 a
	4	17.592 b	0.69 b	17.69 b
	8	8.516 c	0.46 c	8.97 c
	12	2.530 e	0.13 e	2.66 e
BR29	0	19.035 a	0.88 a	19.91 a
	4	15.302 b	0.69 b	15.99 b
	8	4.899 d	0.47 d	5.36 d
	12	0.403 f	0.13 f	0.41 f
Significant level		**	**	**
$LSD_{0.05}$		1.829	1.829	0.0258
CV (%)		12.54	12.02	3.42

Appendix 8: The effect of different K levels on different growth parameters of two selected rice varieties (mean of 4 salinity levels)

Variety	K level (K_2O kg ha^{-1})	Shoot dry wt. ($g\ hill^{-1}$)	Root dry wt. ($g\ hill^{-1}$)	Total dry matter ($g\ hill^{-1}$)	Grain dry wt.($g\ hill^{-1}$)
Pokkali	80	10.273 cd	0.54 b	10.81 cd	8.50 d
	100	11.722 a-c	0.50 a	12.22 a-c	10.36 c
	120	12.968 ab	0.50 a	13.46 a	11.55 ab
	140	12.373 a	0.61 a	12.98 a	12.21 a
BR29	80	7.918 e	0.46 d	8.37 e	9.87 c
	100	8.393 de	0.42 c	8.81 de	10.78 bc
	120	12.877 a	0.64 c	13.51 bc	11.77 a
	140	10.451 cd	0.65 c	11.11 ab	12.26 a
Significant level		**	**	*	*
$LSD_{0.05}$		1.829	1.829	0.0258	0.942
CV (%)		12.54	12.02	3.42	9.08

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

** —> Significant at 0.01 level of probability; *—> Significant at 0.05 level of probability

NS —> Non-significant

Appendix 9: Interaction effect of different salinity and supplemental K levels on different growth parameters of rice varieties (mean of 2 varieties)

Salinity level (dSm^{-1})	K level (K_2O kg ha^{-1})	Shoot dry wt. (g $hill^{-1}$)	Root dry wt. (g $hill^{-1}$)	Total dry matter (g $hill^{-1}$)
0	80	19.65 ab	1.05 b	20.70 ab
	100	18.01 ab	0.66 ab	18.77 bc
	120	19.80 ab	0.74 a	20.54 ab
	140	17.99 ab	1.07 a	19.06 b
4	80	11.82 e	0.47 d	12.3 de
	100	14.06 cd	0.59 cd	14.65 cd
	120	21.39 a	0.74 c	22.13 a
	140	18.50 ab	0.95 c	19.45 bc
8	80	4.37 g	0.36 f	4.73 g
	100	6.66 fg	0.45 e	7.11 fg
	120	8.81 f	0.64 e	9.45 f
	140	6.98f	0.40 e	7.38 fg
12	80	0.54 h	0.12 gh	0.66 h
	100	1.48 h	0.14 gh	1.62 h
	120	1.68 h	0.16 g	1.74 h
	140	2.16 h	0.11 h	2.27 h
Significant level		*	*	*
$LSD_{0.05}$		2.586	2.587	2.037
CV (%)		12.54	12.02	3.42

Appendix 10: Varietal effect on different yield parameters of selected rice due to the combined effect of different salinity and K levels

Variety	No. of effective tiller $hill^{-1}$	Panicle length (cm)	No. of filled grain $panicle^{-1}$	Grain yield (g $hill^{-1}$)	1000 grain wt. (g)
Pokkali	4.24 b	21.93 a	25.88 b	8.78 a	35.59 a
BR29	6.91 a	15.55 b	27.57 a	6.95 b	17.82 b
Sig. level	**	**	*	*	*
$LSD_{0.05}$	1.139	0.095	2.001	1.012	8.31
CV (%)	1.76	3.42	12.54	12.02	6.18

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

** —> Significant at 0.01 level of probability; *—> Significant at 0.05 level of probability

NS —> Non-significant

Appendix 11: The effect of different salinity levels on different growth parameters of two rice varieties (mean of 2 cultivars and 4 K levels)

Salinity (dSm^{-1})	No. of effective tiller $hill^{-1}$	Panicle length (cm)	No. of filled grain $panicle^{-1}$	Grain yield ($g\ hill^{-1}$)	1000 grain wt. (g)
0	8.95 a	24.61 a	62.78 a	14.41 a	32.46 a
4	8.41 a	23.97 a	32.14 b	11.56 b	28.95 b
8	3.16 b	18.42 b	11.12 c	5.43 c	26.83 c
12	0.37 c	7.95 c	0.87 d	2.07 d	18.57 d
Significant level	**	**	**	**	**
$LSD_{0.05}$	2.05	3.57	9.67	2.29	0.95
CV (%)	7.37	5.67	12.54	12.02	6.18

Appendix 12: The effect of different K levels on different growth parameters of two rice varieties (mean of 2 cultivars and 4 salinity levels)

K level (K_2O kg ha^{-1})	No. of effective tiller $hill^{-1}$	Panicle length (cm)	No. of filled grain $panicle^{-1}$	Grain yield ($g\ hill^{-1}$)	1000 grain wt. (g)
80	4.50 b	17.7 c	26.90 b	7.08 c	26.01 b
100	4.58 b	18.74 b	24.17 c	8.38 b	26.55 ab
120	5.87 a	19.87 a	29.21 a	9.01 a	27.34 ab
140	5.95 a	18.65 b	26.63 b	9.00 a	27.36 a
Significant level	**	**	**	**	**
$LSD_{0.05}$	1.25	1.24	2.13	1.11	0.95
CV (%)	7.37	4.65	12.54	12.02	6.18

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

** —> Significant at 0.01 level of probability; *—> Significant at 0.05 level of probability

NS —> Non-significant

Appendix 13: The effect of different salinity levels on different yield parameters of two selected rice varieties (mean of 4 K levels)

Variety	Salinity level (dSm^{-1})	No. of effective tiller $hill^{-1}$	Panicle length (cm)	No. of filled grain $panicle^{-1}$	Grain yield (g $hill^{-1}$)	1000 grain wt. (g)
Pokkali	0	7.00 ab	25.40 a	62.29 a	13.22 ab	37.67 a
	4	7.33 ab	25.88 a	25.59 bc	10.71 bc	37.14 b
	8	3.08 bc	20.54 a-c	13.91 bc	7.05 c-d	34.10 c
	12	0.75 c	15.91 c	1.75 c	4.15 d-e	31.44 d
BR29	0	10.91 a	23.82 ab	63.26 a	15.59 a	25.25 e
	4	9.50 a	22.07 a-c	38.68 ab	12.40 ab	23.80 f
	8	3.25 bc	16.31 bc	8.33 c	3.80 d-e	22.22 g
	12	0.00 c	0.00 d	0.00 c	0.00 e	-
Significant level		**	**	**	**	*
$LSD_{0.05}$		1.440	0.0258	28.26	4.625	1.34
CV (%)		1.76	3.42	6.27	1.028	6.18

Appendix 14: The effect of different K levels on different yield parameters of two selected rice varieties (mean of 4 salinity levels)

Variety	K level (K_2O kg ha^{-1})	No. of effective tiller $hill^{-1}$	Panicle length (cm)	No. of filled grain $panicle^{-1}$	Grain yield (g $hill^{-1}$)	1000 grain wt. (g)
Pokkali	80	3.91 c	21.47 b	24.66 bc	6.67 c	34.06 b
	100	4.50 bc	23.47 a	23.17 c	8.50 b	35.56 a
	120	4.66 bc	21.41 b	29.36 a	10.69 a	37.03 a
	140	5.08 b	21.39 b	26.34 b	9.27 ab	35.69 a
BR29	80	5.08 b	13.93 e	29.14 a	7.49	17.54 cd
	100	4.66 bc	16.26 c	29.04 a	8.25 b	17.96 c
	120	7.08 a	16.07 d	25.16 bc	8.74 b	19.09 c
	140	6.83 ab	15.92 d	26.92 b	7.31 bc	18.68 c
Significant level		**	*	**	**	*
$LSD_{0.05}$		1.440	0.0258	1.829	1.29	1.34
CV (%)		1.76	3.42	12.54	4.62	6.18

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

** —> Significant at 0.01 level of probability; *—> Significant at 0.05 level of probability

NS —> Non-significant

Appendix 15: Interaction effect of different salinity and supplemental K levels on different yield parameters of rice varieties (mean of 2 varieties)

Salinity level (dSm^{-1})	K level (K_2O kg ha^{-1})	No. of effective tiller $hill^{-1}$	Panicle length (cm)	No. of filled grain $panicle^{-1}$	Grain yield (g $hill^{-1}$)	1000 grain wt. (g)
0	80	8.83 ab	24.53 ab	58.88 ab	12.92 a-c	27.45 ef
	100	8.66 ab	24.00 ab	65.287 ab	14.35 ab	26.44 fg
	120	9.50 ab	25.29 a	74.26 a	15.59 a	25.47 g
	140	8.83 ab	24.62 ab	52.67 bc	14.76 ab	27.97 d-f
4	80	7.66 a-c	24.18 ab	36.17 cd	10.11 c	29.77 cd
	100	6.33 b-d	24.20 ab	28.97 de	11.79 bc	28.35 c-e
	120	10.50 a	24.45 ab	26.43 d-f	12.65 a-c	27.76 ef
	140	9.16 ab	23.07 bc	36.96 cd	11.68 bc	29.90 bc
8	80	1.33 e	17.57 d-f	12.55e-g	4.07 de	32.78 a
	100	3.00 de	21.47 cd	11.42 e-g	5.47 d	31.68 ab
	120	3.16 de	16.69 e-f	4.95 fg	6.00 d	33.29 a
	140	5.16 cd	17.96 d-f	15.55 d-g	6.16 d	32.08 a
12	80	0.16 e	4.51 h	0.00 g	1.23 e	17.55 i
	100	0.333 e	9.79 fg	2.16 g	1.89 e	19.73 h
	120	0.333 e	8.55 f-h	0.00 g	1.78 e	18.73 hi
	140	0.66 e	8.97 f-h	1.33 g	3.40 e	18.27 hi
Significant level		*	*	*	*	*
$LSD_{0.05}$		2.036	0.037	20.08	3.28	1.90
CV (%)		1.76	3.42	12.54	12.02	6.18

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

** —> Significant at 0.01 level of probability; *—> Significant at 0.05 level of probability

NS —> Non-significant