A SEMINAR PAPER ON

# Growth, Ion Accumulation and Yield of Rice as Influenced by Salinity

Course Title: Seminar

Course Code: AGR 598

Term: Summer, 2018

**Submitted to**

## Course Instructors

1. Dr. Md. Mizanur Rahman
Professor

2. Dr. A. K. M. Aminul Islam
Professor

3. Dr. Md. Rafiqul Islam
Professor

4. Dr. Dinesh Chandra Shaha
Assistant Professor

## Major professor

Dr. M. A. Mannan
Professor
Department of Agronomy

**Submitted by**

**Ashrafun Nahar**

MS Student

Reg. No.: 13-05-2919

Department of Agronomy

BANGABANDHU SHEIKH MUJIBUR RAHMAN AGRICULTURAL UNIVERSITY

SALNA, GAZIPUR 1706

**GROWTH, ION ACCUMULATION ANDYIELD OFRICE AS INFLUENCED BY SALINITY**

**ABSTRACT**

**ASHRAFUN NAHAR**

Salinity has been a key abiotic constraint devastating crop production worldwide. Attempts in understanding salt tolerance mechanisms has revealed several key enzymes and altered biochemical pathways inferring resistance to crop plants against salt stress. The past decades have witnessed extensive research in development of salt tolerant cultivars via conventional means, improvised by modern era molecular tools and techniques. Rice (Oryza sativa L) is the staple food crop across several countries worldwide. Being a glycophyte by nature, its growth is severely imparted in presence of excess salt. Rice is susceptible to salinity specifically at the early vegetative and later reproductive stages and the response of the crop to excessive salt toxicity at biochemical and molecular level as well as physiological level is well studied and documented. An understanding of the specific response of rice to ion accumulation at the toxic level can aid in identifying the key factors responsible for retarded growth and limited production of rice with the future scope of mitigating the same. The present review summarizes the differential responses of rice, in particular, to salt toxicity enumerating the detailed morphological, physiological, biochemical and molecular changes occurring in the plant. An attempt to explain salinity tolerance and its future scope and implications in screening for salt tolerance has also been elucidated in the present study.

Keywords: Salt tolerance, Physiological, Proline.

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

# Chapter I

## INTRODUCTION

Rice is the one of the main grain crop all over the world. It is a staple food which feed more than 3 billion people which provide 50-80% daily calorie intake of human (Khush, 2005). Khan and Abdullah (2003) reported that rice crop has been identified as salt-susceptible both in seedling and reproductive stage. Salinity is one of the major abiotic stress for all growth phases of rice due to human-made contributions to global warming, the rate of sea-level rise is expected to increase and possess dramatic effect on rice production especially in coastal areas (Hakim *et al*.,2013).Increasing global warming increases the average temperatures which might cause the 'melting' of polar ice caps, resulting from the rise-up of the sea-water level gains (2.8– 3.1 mm/year), and thus causing salty water intrusion into the coastal areas. Selamat and Ismail (2008) reported that 50 % rice yield is being lost of the salt- sensitive rice genotypes due to salinity problem. In arid and semi-arid regions, limited water and hot dry climates frequently increase salinity levels that limit or prevent crop production (Michael *et al*., 2004). The major inhibitory effect of salinity on plant growth has been attributed to: 1) osmotic effect 2) ion toxicity 3) nutritional imbalance leading to reduction in photosynthetic activities and other physiological disorders (Ali *et al*., 2004).$Na^+$ and $Cl^-$ derived from NaCl are well known as the toxic ions to damage the plant cells in both ionic and osmotic levels. Plant growth and development are directly disturbed, leading to low yield before plant death (Mansour and Salama, 2004; Chinnusamy *et al*., 2005).Salinity causes unfavorable environment and hydrological situation that restrict normal crop production throughout the year. Observations in the recent past indicated that because of increasing degree of salinity of some areas and expansion of salt affected area as a cause of further interruption of salinewater, normal crop production becomes more restricted. In general, soil salinity isbelieved to be mainly responsible for low land use as well as cropping intensity in thearea (Rahman & Ahsan, 2001). Salinity in the country received very little attention in thepast. Increased pressure of growing population demand more food. Thus it has becomeincreasingly important to explore the possibilities of increasing the potential of these(saline) lands for increased production of crops. It necessitates an appraisal of the presentstate of land areas affected by salinity.

**Objectives of the study:**

This study was undertaken considering the following objectives

- To review the effects of salinity on different growth parameters of rice
- To overview the salinity effects on rice yield
- To review the effects of salinity on different ion accumulation in rice
- To assess factors which may reduce the salinity effects in rice plants

# Chapter II

## MATERIALS AND METHODS

This seminar paper is completely a review paper. Therefore, all the information wascollected from secondary sources in order to prepare this paper. Various relevant books and journals, which were available in the library of Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU) were used for the preparation of this paper. For collecting recent information, internet browsing was also practiced. Good suggestions, valuable information and kind consideration from my honorable major professor andother personnel were taken to enrich this paper. After collecting necessary information, it has been compiled and arranged chronologically for better understanding and clarification.

# Chapter III

## REVIEW AND DISCUSSION OF THE FINDINGS

As we know that growth parameter of rice is root length, shoot length, no. of tillers, root-shoot ratio etc. Due to salinity, there is significant change in growth parameters of rice plants. Some of the changes in different parameters are given here.

**Plant height:**

The analysis of variance showed the plant height of different rice genotypes were significantly affectedby the different salinity levels. This result showed the increasein salinity concentration affected the plant height negatively,that caused 21-61% decrease at 12 $dSm^{-1}$even 100% forsome susceptible genotypes (Fig.1.a).In the X axis rice varieties are placed and in Y axis plant height(cm)is placed. Generally, it was observed that salinitycaused the decrease in plant height in all the genotypes thatcould be the cumulative effect of salinity in delayinemergence, the decrease in shoot and root biomass.

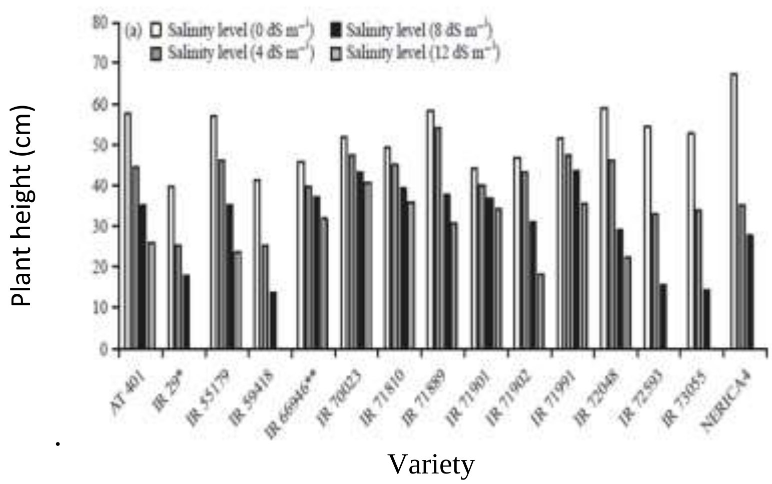



**Figure 1.a**: Plant height of 15 rice genotype in four salinity levels.

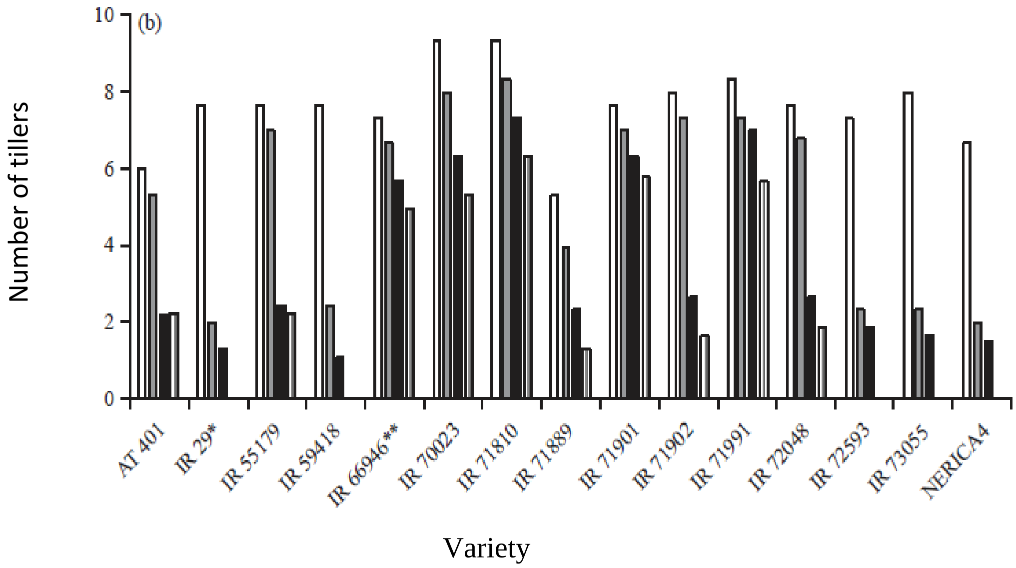
* Susceptible, ** Tolerant

Source:(Girma et al., 2017)

The reduction in plant height in the increased salinity level could be due to lower water potential and reduction in leaf water content which results stomatal closure that limits carbon dioxide assimilation and reduced photosynthetic rate disturbance in mineral supply (excess/deficiency) which induce changes in the concentration of specific ions that affect the growth might be the other reason for reduction of plant height.

**Number of tillers:**

Grain yield of rice is highly dependent on the number of panicle producing tillers. All the genotypes in this experiment were highly affected by the increase in salinity on total and effective number of tillers. In case of genotype IR29 (susceptible check), IR 59418, IR 72593, IR 73055 and NERICA 4 showed 100% loss at 12 dS m-[1] (Fig. 1.b).As the salinity concentration becomes higher and higher the reduction in number of effective tillers per plant was also higher.




* Susceptible, ** Tolerant

**Figure1.b**: Number of tillers of the 15 rice genotype in four salinity levels.

Source:(Girma*et al.*, 2017)

**Root and stem growth**

Based on the variety factor, there were nosignificant ($p > 0.05$) differences in stem length;however, due to NaCI concentration and itsinteraction with the variety, there were highlysignificant ($p \leq 0.01$) differences. In the case of rootlength, the three sources of variation presentedsignificant differences (Table 1).

**Table 1.** Results of analysis of variance (ANOVA) of variety,NaCl concentration and their interaction (Variety x NaCl) for shoot length and root length of rice plants

| Source of variation | DF | Length | |
|---|---|---|---|
| | | Shoot | Root |
| Variety | 1 | ns | ** |
| NaCl concentration | 1 | ** | ** |
| Variety x NaCl | 1 | ** | * |

ns = Non significant; * = Significant at 5% level; ** = Significant at 1 % level.

Source:(Morales *et al.*, 2012)

Application of 100 mMNaCl significantly($p \leq 0.05$) reduced shoot and root length in thevariety Tres Ríos (20 and 15%, respectively , compared to the control) as shown in Figure 2 (A) and Figure 2 (B),while in the variety Cotaxtla there were nosignificant ($p > 0.05$) reductions in shoot and rootlength in the presence of NaCl.

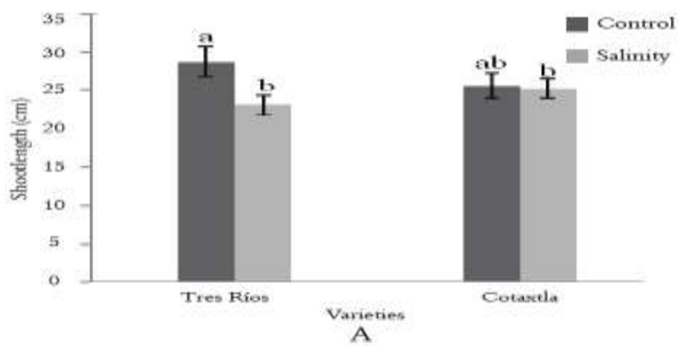



**Figure 2 (A):**Effect of salinity (100 mMNaCl) on the shoot lengthrice plants of Mexican varieties (TresRíos and Cotaxtla), after six days of treatment.

Source: (Morales *et al.*, 2012)

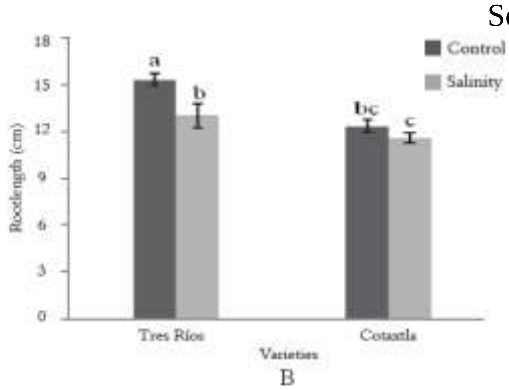



**Figure 2 (B):**Effect of salinity (100 mMNaCl) on the root length of rice plants of Mexican varieties (TresRíos and Cotaxtla), after six days of treatment.

Source: (Morales et al.,2012)

## Yield parameters

Grain yield, thousand kernel weight, harvest index, biomass, root dry weight, shoot dry weight are some of yield parameters.

**Grain yield**

Data of variance analysis in Table 2 showed that effectiveness of different levels of salinity and also different stages of growth on grain yield was significant (P<0.01). Studies indicate that rice yields decrease with 12% for every unit (dS/m), increase in ECe (average root-zone EC of saturated soil extract) above 3.0 dS/m (Maas and Grattan, 1999; Grattan *et al*., 2002).

Crop yield reductions in salt-affected soils result primarily from alteration of various metabolic processes in plants under salt stress (Eynard*et al*., 2005).With regard to the results of grain yield mean comparison (Table 2).

**Table 2.** Mean comparison of salinity levels at different growth stages affected on yield components of rice

| Parameter | Grain yield (g/pot) | 1000-grain weight (g) | Biomass (g/pot) | Harvest index |
|---|---|---|---|---|
| Salinity level ($dSm^{-1}$) | | | | |
| 2 | 18.71 | 21.85 | 50.88 | 37.27 |
| 4 | 17.79 | 22.87 | 49.81 | 36.24 |
| 6 | 14.87 | 24.34 | 42.64 | 34.66 |
| 8 | 12.59 | 21.55 | 41.23 | 27.77 |

Source: (Aref, 2013)

Survey in interaction of different levels of salinity and different growth stages (Figure 3) showed that the most grain yield (23.59 g/pot) belonged to control treatment and the least grain yield (3.84 g/pot) belonged to tillering stage at 8 dS $m^{-1}$ salinity.

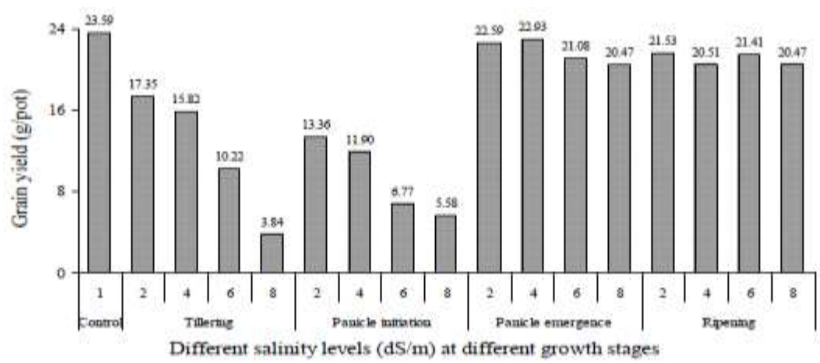



**Figure 3.** Effect of salinity levels at different growing stages on the grain yield.

Source: (Aref., 2013)

**Harvest index**

Zeng and Shannon (2000) stated that harvest index was significantly decreased when salinity was at 3.40 dS $m^{-1}$ and higher. The most harvest index (45.13) was shown in control treatment. Increase in salinity decreased harvest index so that harvest index at treatments of 2, 4, 6 and 8 dS $m^{-1}$ salinity decreased 17.4, 19.7, 23.2 and 38.5%, respectively in comparison with control treatment. The most reduction in harvest index was shown at 8 dS $m^{-1}$. Different growth stages of rice had different reaction to salinity (Table 2). Harvest index in primitive stages of rice growth was less than final stages.

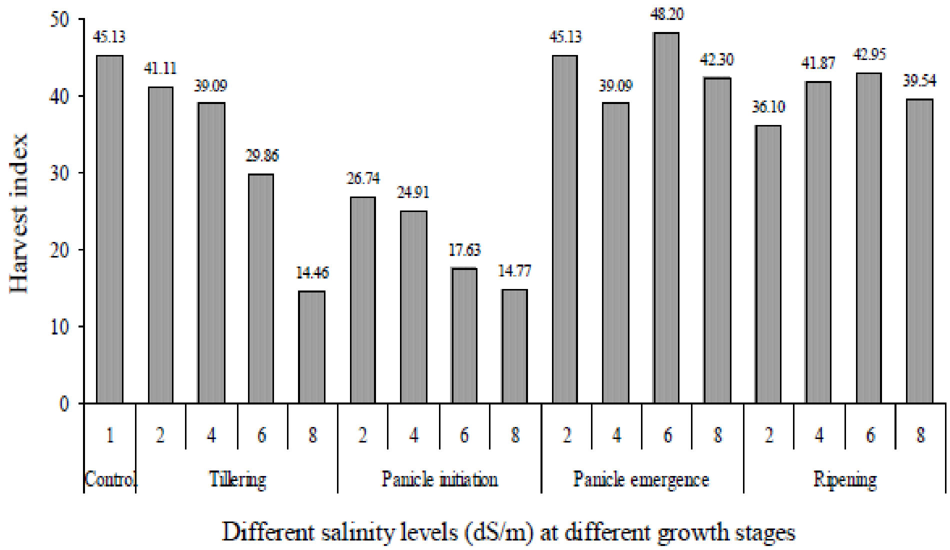



**Figure 4.** Effect of salinity levels at different growing stages on the harvest index.

Source: (Aref., 2013)

A survey on reciprocal effect of different levels of salinity and growth stages (Figure 4), it was shown that the most harvest index (48.20) was obtained in panicle emergence at 6 dS $m^{-1}$ salinity and the least harvest index (14.46) was obtained in tillering stage at 8 dS $m^{-1}$ salinity.

**Biomass**

With regard to the results of comparing biomass mean in salinity treatments (Table 2), it was showed that applying 4, 6 and 8 dS $m^{-1}$ salinities decreased biomass in comparison with control treatment; in comparison with control treatment, reduction of biomass in these treatments was 1.1, 15.4, and 18.2%, respectively. Most reduction in biomass showed at 4 to 6 dS $m^{-1}$ salinities so that biomass reduction at 6 dS $m^{-1}$ salinity was 14.4% in comparison with salinity of 4 dS m$^{-1}$. Yield components which determinefinal grain yield were also severely affected by salinity effect (Zeng and Shannon, 2000).

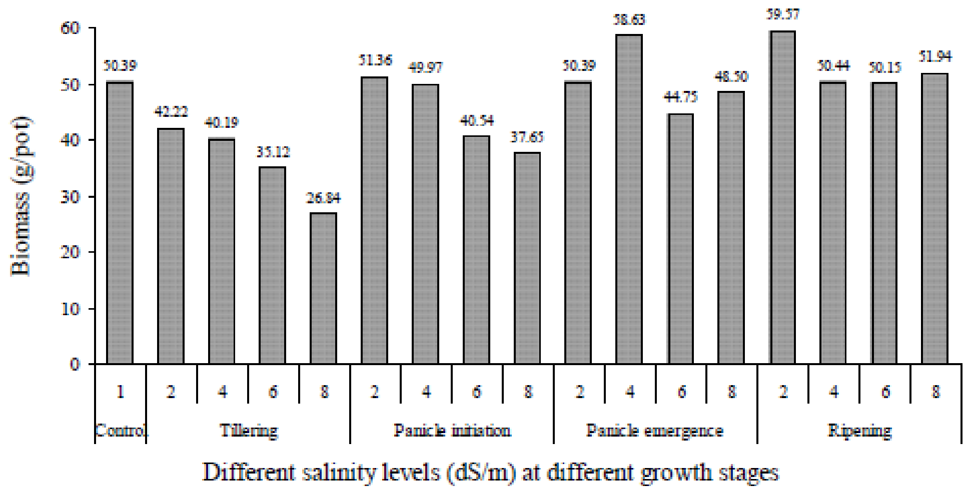



**Figure 5.** Effect of salinity levels at different growing stages on the biomass.

Source: (Aref ., 2013)

In a survey about reciprocal effect of different levels of salinity and growth stages (Figure 5), it was showed that the most biomass (59.57 g/pot) was obtained in ripeness stage at 2 dS m$^{-1}$ salinity and the least biomass (26.84 g/pot) was obtained in tillering stage at 8 dS m$^{-1}$ salinity.

**Effect of salinity on shoot and root dry weight:**

Theresult of salt effect on shoot and root dry weight ispresented in Table 3 Shoot dry weights (SDW) werevaried significantly due to different salt concentrations.At 4 dS m$^{-1}$, Pokkali produced highest shoot dry weight(21.2 g hill$^{-1}$) which was significantly higher than othervarieties followed by MR232 (19.4 g hill$^{-1}$) and MR219(18.1 g hill$^{-1}$). The lowest SDW was observed in BRRI dhan29 (14.6 g hill$^{-1}$). Pokkali also produced highest SDW(15.5 g hill$^{-1}$) followed by MR232 (14.6 g hill$^{-1}$) and theminimum was in IR20 (8.10 g hill$^{-1}$) at 8 dS m$^{-1}$.

**Table 3.** Interaction effect of variety and salinity levels on shoot dry weight, root dry weight and yield of rice varieties

| Rice variety | Salinity levels ($dSm^{-1}$) | Shoot dry weight (g $hill^{-1}$) | Root dry weight (g $hill^{-1}$) |
|---|---|---|---|
| IR20 | 0 | 21.6 | 2.77 |
| | 4 | 16.4 | 1.56 |
| | 8 | 8.1 | 1.19 |
| | 12 | 4.1 | 0.57 |
| Pokkali | 0 | 24.2 | 2.09 |
| | 4 | 21.2 | 1.60 |
| | 8 | 15.5 | 1.06 |
| | 12 | 7.9 | 0.85 |
| MR33 | 0 | 22.8 | 3.28 |
| | 4 | 15.9 | 2.28 |
| | 8 | 11.8 | 1.40 |
| | 12 | 6.2 | 0.87 |
| MR52 | 0 | 21.0 | 2.51 |
| | 4 | 16.9 | 1.90 |
| | 8 | 14.4 | 1.41 |
| | 12 | 6.1 | 0.74 |
| MR211 | 0 | 19.9 | 2.19 |
| | 4 | 17.5 | 1.77 |
| | 8 | 14.3 | 1.12 |
| | 12 | 8.1 | 0.88 |
| MR219 | 0 | 22.5 | 3.19 |
| | 4 | 18.1 | 2.17 |
| | 8 | 11.6 | 1.25 |
| | 12 | 4.9 | 0.66 |
| MR232 | 0 | 21.7 | 3.16 |
| | 4 | 19.4 | 2.63 |
| | 8 | 14.6 | 1.91 |
| | 12 | 8.8 | 1.06 |
| BRRI dhan29 | 0 | 22.9 | 2.87 |
| | 4 | 14.6 | 1.77 |
| | 8 | 8.3 | 0.86 |
| | 12 | 3.9 | 0.52 |

Source: (Hakim *et al*., 2014)

Amongsalinity levels, the highest SDW (21.2 g $hill^{-1}$) wasrecorded in 4 dS $m^{-1}$ followed by 8 dS $m^{-1}$ (15.5 g $hill^{-1}$).The lowest SDW (3.9 g $hill^{-1}$) was recorded in 12 dS $m^{-1}$ salinity.It was observed that SDW gradually decreasedwith increase in salinity level. In case of root dry weight(RDW), the highest value (2.63 g $hill^{-1}$) was found inMR232 at 4 dS $m^{-1}$ followed by MR33 (2.28 g $hill^{-1}$) andthe lowest (1.56 g $hill^{-1}$) was in IR20. At 8 dS $m^{-1}$, genotype MR232 also showed highest (1.19 g $hill^{-1}$) andthe lowest (0.86 h $hill^{-1}$) was in BRRI dhan29. Among thedifferent salinity levels, the highest (2.63 g $hill^{-1}$), RDWwas observed in 4dS $m^{-1}$ and the lowest (0.86) was in12dS m$^{-1}$. It was also observed that RDW decreased with theincrease of salinity.

**Thousand kernel weight**

The IR 73055, IR 72593, IR 59418and NERICA 4 had the lowest thousand kernel weight rangingfrom 7.17-10.10 g (Table 4). These genotypes could not resistthe salinity concentration and did not produce any grain at12 dS m$^{-1}$ but IR 71901, IR 70023, IR 71810, AT 401 andIR 71991 were tolerant with 22-37% reduction over the control.

**Table 4.**Thousand kernel weight of rice genotypes with different salinity levels

| | Salinity level (dS m$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | Thousand Kernel Weight (TKW) | | | | |
| Genotype | 0 | 4 | 8 | 12 | Mean |
| AT 401 | 23.67 | 21.35 | 18.33 | 16.00 | 19.84 |
| IR 29* | 21.80 | 14.13 | 11.93 | 0.00 | 11.97 |
| IR 55179 | 24.00 | 18.37 | 11.43 | 10.23 | 14.75 |
| IR 59418 | 18.90 | 11.43 | 9.67 | 0.00 | 10.00 |
| IR 66946* | 24.32 | 18.60 | 17.70 | 17.00 | 18.26 |
| IR 70023 | 24.77 | 22.67 | 20.20 | 19.00 | 21.66 |
| IR 71810 | 23.67 | 21.67 | 19.43 | 16.80 | 20.39 |
| IR 71889 | 22.67 | 20.47 | 11.40 | 10.30 | 16.21 |
| IR 71901 | 21.00 | 19.33 | 18.40 | 16.33 | 18.77 |
| IR 71902 | 21.93 | 20.73 | 11.50 | 9.10 | 15.82 |
| IR 71991 | 24.97 | 21.33 | 19.63 | 15.67 | 20.40 |
| IR 72048 | 21.63 | 20.00 | 10.47 | 9.00 | 15.28 |
| IR 72593 | 22.57 | 13.13 | 9.00 | 0.00 | 11.18 |
| IR 73055 | 22.33 | 13.30 | 7.17 | 0.00 | 10.70 |
| NERICA4 | 24.67 | 13.73 | 10.10 | 0.00 | 12.13 |
| Mean | 22.22 | 18.02 | 13.76 | 9.30 | 15.82 |

*Susceptible check, **TolerantSource: (Girma*et al.*, 2017)

The highest amount of reduction at 12 dS $m^{-1}$wasregistered in IR 59418, IR 72593, IR 73055 and NERICA 4 wheretheir reduction in thousand kernel weight at 8 dS $m^{-1}$wasmore than 50%. At 8 and 12 dS $m^{-1}$the lowest reduction wasregistered in IR 70023, IR 71810 and IR 71901 with therange of 12-18 and 22-29%, respectively (Table 4). Generally,in every addition of 1 U (dS $m^{-1}$) salinity between0-12 dS $m^{-1}$decreased the grain weight by 0.74 g. Theinfluence of salinity on thousand grain weight was high in thisexperiment.

**Total number of empty grains per panicles**

According to Aref*et al*. (2012),conclusions of mean comparison of total number ofempty grains per panicles (Table 5) showed that controltreatment (1 $dSm^{-1}$) had the least total number of emptygrains per panicles (229.00). Treatments of 2, 4, 6 and 8$dSm^{-1}$ had total number of empty grains per paniclerespectively as follow: 313.58, 270.75, 296.75, and274.08 which all placed in the same statistical class.These salinity level increased total number of emptygrains per panicles in compare with control treatment (37, 18, 29 and 20% increase, respectively). Increasing emptygrain decreases rice yield. Therefore increased salinityresulted in increased total number of empty grains perpanicles and finally it decreases yield.

**Percentage of ratio of number of unfilled panicles to tillers**

With regard to the conclusions of mean comparison of percentage of ratio of number of unfilled panicles to tillers (Table 5), control treatment (1 $dSm^{-1}$) had the least percentage of ratio of number of unfilled panicles to tillers (5.40). Increased salinity increased percentage of ratio ofnumber of unfilled panicles to tillers so that it increased from 2 to 8 $dSm^{-1}$ and the most amount of it (19.95) observed at 8 $dSm^{-1}$. Percentage of ratio of number of unfilled panicles to tillers is one of the determining factors of yield so that whatever this ratio increases, yield decreases too.In different growth stages of rice, percentage of ratio of number of unfilled panicles to tillers was different.

**Table 5**. Changes in growth parameters on different level of salinity

| | Total number of empty grains per panicles | Percentage of ratio of number of unfilled panicles to tillers |
|---|---|---|
| Salinity levels ($dSm^{-1}$) | | |
| 2 | 313.58 | 12.35 |
| 4 | 270.75 | 16.33 |
| 6 | 296.75 | 16.70 |
| 8 | 274.08 | 19.95 |

Source: (Aref*et al*.,2012)

## Ion accumulation

Saliniy has significant effects on different ion accumulation of different rice varieties. According to (Hakim *et al*., 2014) different ion was accumulated in different amounts.

**N ion concentrations:**

In shoot, nitrogen ionconcentration ranged from 1.93 to 2.20%, having thehighest (2.20) in the control followed by 12dS $m^{-1}$ (2.11)and the minimum (1.93) was in 8dS $m^{-1}$(Table 6). In thecase of root, N ion concentration was also significantly varied. Thehighest N ion (1.24) was found in the control which wassignificantly highest and followed by 4 dS $m^{-1}$ (1.11). Thelowest N ion (0.93) was in 12 dS $m^{-1.}$ It was observedthat N ion deceased in the root with the increase insalinity levels.

**Phosphorous concentration:**

In shoot, the highestphosphorous concentration (0.47) was found in the control (non-saline condition) followed by 4 dS $m^{-1}$ (0.37)and the lowest (0.22) was in 12 dS $m^{-1}$. In higher salinitylevel (12 dS $m^{-1)}$ showed maximum phosphorousaccumulation (0.27) in the root which was significantlyhigher than the other salinity levels and the minimumaccumulation (0.10) was in the control (Table 6). It wasobserved that phosphorous ion accumulation decreased inthe shoot with the increase in salinity but reverse was truein case of root.

**$Na^+$ ion accumulation:**

Highest sodium accumulation inroot and shoot was found at 12dS $m^{-1}$ followed by 8 dS$m^{-1}$(3.65 % in root and 2.48% in shoot). The lowest (0.54and 0.76% for shoot and root, respectively) absorptionwas in the control. It was found that Na accumulation inthe shoot and root increased with the increase in salinityin the growth media (Table 6).

**Potassium and Calcium ions accumulation:**

Potassiumand calcium ions accumulation were significantlyinfluenced by salinity in the root and shoot of rice. In shoot, thehighest potassium and calcium ion accumulations werefound (2.76 %K and 0.78%Ca) in the control followed by4dS $m^{-1}$ (2.33% K and 0.67% Ca) and the lowest wasnoted in 12 dS $m^{-1}$ (1.28% K and 0.31% Ca) (Table 6).Similar trended was also followed by the root in the caseof K and Ca accumulation. It was observed that $K^+$ and$Ca^{++}$ions accumulation decreased with the increase of salinity levels. It was also found the $K^+$ and $Ca^{++}$ ionsaccumulation was higher is the shoots than the roots.

**Magnesium ion accumulation:**

Magnesium ionaccumulation was also followed by the same trend like potassium and calcium. The control showed the highestaccumulation (0.63 and 0.43% for shoot and root,respectively) and the minimum (0.34 and 0.15 for shootand root, respectively) was in 12 dS $m^{-1}$(Table 6).

**Table 6**. The main effect of salinity on mineral nutrients and yields of eight rice varieties

| T reatments | Nitr ogen | | Pho sphorus | | Sodi um | | Pota ssium | | Calc ium | | mag nesium | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S alinity levels (dSm$^{-1}$) | **hoot** | **oot** | **hoot** | **oot** | **hoot** | **oot** | **hoot** | **oot** | **hoot** | **oot** | **hoot** | **oot** |
| 0 | .20 | .24 | .47 | .10 | .54 | .76 | .76 | .77 | .78 | .61 | .63 | .43 |
| 4 | .02 | .11 | .37 | .13 | .45 | .27 | .33 | .54 | .67 | .55 | .52 | .32 |
| 8 | .93 | .05 | .28 | .18 | .48 | .65 | .89 | .36 | .57 | .45 | .44 | .22 |
| 1 2 | .11 | .93 | .22 | .27 | .67 | .37 | .28 | .31 | .41 | .32 | .34 | .15 |
| F -test | * | * | * | * | * | * | * | * | * | * | * | * |
| V ariety | | | | | | | | | | | | |
| I R20 | .30 | .22 | .28 | .19 | .25 | .43 | .63 | .42 | .58 | .39 | .48 | .24 |
| P okkali | .08 | .91 | .32 | .13 | .60 | .67 | .83 | .34 | .61 | .48 | .48 | .29 |
| M R33 | .82 | .19 | .29 | .24 | .10 | .97 | .11 | .57 | .55 | .43 | .47 | .29 |
| M R52 | .80 | .10 | .34 | .16 | .02 | .37 | .91 | .43 | .63 | .55 | .50 | .28 |
| M R211 | .86 | .93 | .41 | .11 | .80 | .84 | .73 | .51 | .58 | .56 | .51 | .28 |
| M R219 | .13 | .10 | .30 | .17 | .27 | .46 | .68 | .64 | .56 | .49 | .48 | .28 |
| M R232 | .63 | .07 | .35 | .11 | .90 | .41 | .02 | .56 | .69 | .54 | .80 | .27 |
| B RRI dhan29 | .88 | .13 | .35 | .28 | .34 | .93 | .63 | .54 | .62 | .44 | .45 | .33 |
| C V (%) | .93 | .23 | .68 | 0.75 | 1.25 | 4.38 | .71 | .72 | .08 | 4.03 | 1.85 | .50 |

**Source: (**Hakim *et al*., 2014)

**Total chlorophyll content**

Chl a, Chl band total carotenoid content in salt stressed plants weresignificantly decreased depending on NaCl concentration.When grown without salt stress, the sand culture riceplants significantly showed higher amount ofmajor pigments compared to plants under salinity stress. After salt stress, the pigment concentrations of the riceplants were several folds lower than plants grown withoutsalt-stress . Results indicated that salt stressaffected Chl a more than Chl b (Fig. 6). The affect wasmore severe on the Chla of Basmati-385 as compared toNIAB-IR 9 and Shaheen Basmati.

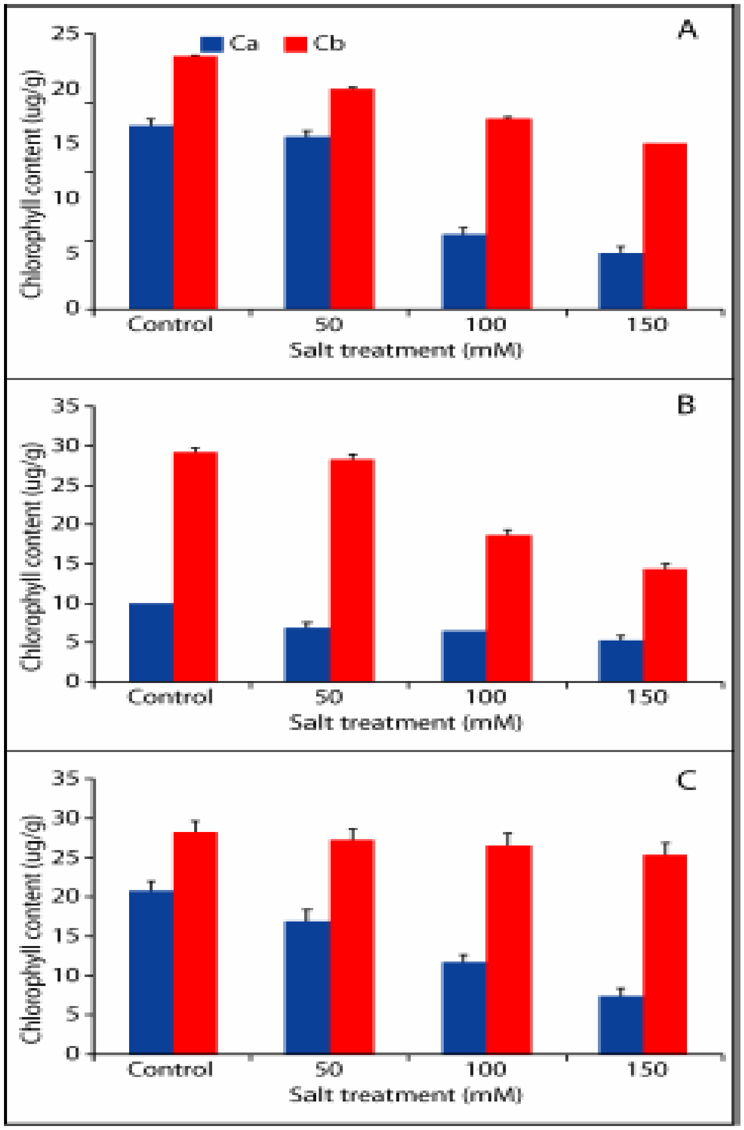



**Figure 6**. Effect of different concentration of salt on chlorophyll content ofBasmati-385 (A), NIAB-IR 9 (B) and S.B (Shaheen Basmati) (C).

Source: (Jamil et al., 2012)

**Proline content**

The proline content in all the salt-tolerant genotypes was increased with increasing salinity (Fig. 7).However, proline content in the salt-sensitive genotype decreased significantly at 60 mmol/L NaCl. At 60 mmol/L NaCl, the highest proline content was obtained in BINA dhan10 whereas the lowest content was found in salt-sensitive rice (BRRI dhan28). BINA dhan10 accumulated about 2.2-fold higher proline where BRRI dhan47 and BINA dhan8 accumulated 1.7- and 1.4-fold higher proline compared to the control, respectively. Increased accumulation of proline in plants is correlated with improved salinity tolerance (Ashraf and Foolad, 2007; Hasanuzzaman*et al*., 2014). Proline content significantly increased in all the genotypes with increasing salt concentration (Fig. 7). Among the salt-tolerant rice genotypes, BINA dhan10 accumulated 2.2-fold higher proline while the other genotypes BINA dhan8 and BRRI dhan47 accumulated 1.5- and 1.7-fold higher proline at 60 mmol/L NaCl compared to the control, respectively.The proline accumulation was also higher at 20 and 40 mmol/L NaCl in BRRI dhan28, however, the accumulation decreased at a higher level of salinity (60 mmol/L NaCl) (Fig. 7). The decrease in proline accumulation in the salt-sensitive rice genotype was observed probably due to low synthesis of proline or higher degradation of proline under high salinity stress. In different studies, a positive relation between the accumulation of proline and stress tolerance in plants is observed(Lutts*et al*, 1996; Kumar *et al*, 2003). Higher proline content in BINA dhan10 might be one reason for the observed higher salt tolerance when compared to the other genotypes. Demiral and Turkan (2005) also reported that enhanced salt tolerance of rice has a relation with increased capacity of antioxidant system. Proline has been suggested to function as an antioxidant in protecting cells against various abiotic stress, since proline scavenges free radicals and suppresses ROS accumulation.

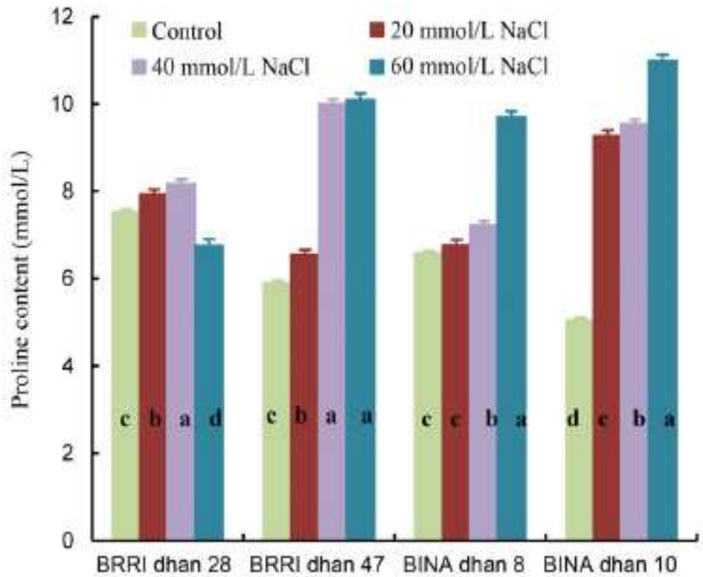



**Figure 7.**Effects of salinity on proline content in different varieties of rice.

Source: (Kibriaet al., 2017)

When plants are grown under salineconditions, as soon as the new cell starts itselongation process, the excess of salts modifiesthe metabolic activities of the cell wall causingthe deposition of various materials which limitthe cell wall elasticity. Secondary cell wallsooner, cell walls become rigid andconsequently the turgor pressure efficiency incell enlargement is decreased. The other causes for the reduction in yield perplant, leaf area and yield components in ricemight be occurred due to shrinkage of the cell contents,reduced development and, unbalanced nutrition, damage ofmembrane, differentiation oftissues and disturbed avoidingmechanism. The reduction inyieldand yield components under salinitywere also due to reduced growth which is result ofdecreased water uptake, toxicity of sodium andchloride in the shoot cell as well as reducedphotosynthesis.

All the experiments in which salt tolerant varieties are used, all of them are giving an overall idea that salt tolerant varieties are very useful in the increasing rate of salinity. They have the capacity to accumulate more proline which ultimately increase the stress tolerance. Salt tolerant varieties perform better than the sensitive varieties. It may be considered as a factor which can reduce the effect of salinity.

# Chapter IV

## CONCLUSIONS

- Salinity decreased the growth rate very drastically except the salt tolerant varieties.Growth parameters like plant height, number of tillers, root and shoot growth decreased with increasing salinity. So salinity has a negative effect on growth of rice plant.

- Salinity also reduced the yield of rice. It reduced the grain yield, thousand grain yield, and root and shoot dry weight, total biomass, harvest index etc. in rice. Here also the susceptible varieties perform worse than tolerant varieties.

- Salinity creates the ion imbalance in rice plant. It reduces the Nitrogen ion, Phosphorus ion, Calcium ion, Magnesium ion, Potassium ion and the concentration of sodium ion is increased. As ion imbalance occurred, so the growth and yield of rice yield is reduced.

- There is a scope to grow of salt tolerant verities in the saline areas. Few salt tolerant verities perform better in saline condition due to high proline accumulation which increases stress tolerance than the susceptible verities. These tolerant genotypes can be used in salinity affected areas thus it creates a scope for increasing the yield of rice.

# References

Ali, Y., Aslam, Z., Ashraf, M. Y., & Tahir, G. R. (2004). Effect of salinity on chlorophyll concentration, leaf area, yield and yield components of rice genotypes grown under saline environment. International Journal of Environmental Science & Technology, 1(3), 221-225.

Aref, F. (2013). Effect of saline irrigation water on yield and yield components of rice (*Oryza sativa* L.). African Journal of Biotechnology, 12(22), 3503-3513.

Aref, F., & Rad, H. E. (2012). Physiological characterization of rice under salinity stress during vegetative and reproductive stages. Indian Journal of Science and Technology, 5(4), 2578-2586.

Ashraf, M., &Foolad, M. (2007). Roles of glycine betaine and proline in improving plant abiotic stress resistance. Environmental and experimental botany, 59(2), 206-216.

Chinnusamy, V., Jagendorf, A., & Zhu, J. K. (2005). Understanding and improving salt tolerance in plants. Crop Science, 45(2), 437-448.

Demiral, T., &Türkan, I. (2005). Comparative lipid peroxidation, antioxidant defense systems and proline content in roots of two rice cultivars differing in salt tolerance. Environmental and experimental botany, 53(3), 247-257.

Eynard, A., Lal, R., &Wiebe, K. (2005). Crop response in salt-affected soils. Journal of sustainable agriculture, 27(1), 5-50.

García Morales, S., Trejo-Téllez, L. I., Gómez Merino, F. C., Caldana, C., Espinosa-Victoria, D., & Herrera Cabrera, B. E. (2012). Growth, photosynthetic activity, and potassium and sodium concentration in rice plants under salt stress. ActaScientiarum. Agronomy, 34(3), 317-324.

Girma B. T., Ali H. M., &Gebeyaneh A. A. (2017).Effect of Salinity on Final Growth Stage of Different Rice(*Oryza sativa* L.) Genotypes. Asian Journal of Agricultural Research, 11(1), 1-9.

Grattan, S., Zeng, L., Shannon, M., & Roberts, S. (2002). Rice is more sensitive to salinity than previously thought. California agriculture, 56(6), 189-198.

Hakim, M. A., Juraimi, A. S., Hanafi, M. M., Ismail, M. R., Rafii, M. Y., Islam, M. M., &Selamat, A. (2014). The effect of salinity on growth, ion accumulation and yield of rice varieties. J. Anim. Plant Science, 24(3), 874-885.

Hakim, M. A., Juraimi, A. S., Ismail, M. R., Hanafi, M. M., &Selamat, A. (2013). A survey on weed diversity in coastal rice fields of Sebarang Perak in peninsular Malaysia. J Anim Plant Science, 23, 534-542.

Hasanuzzaman, M., Alam, M., Rahman, A., Hasanuzzaman, M., Nahar, K., & Fujita, M. (2014). Exogenous proline and glycine betaine mediated upregulation of antioxidant defense and glyoxalase systems provides better protection against salt-induced oxidative stress in two rice (*Oryza sativa* L.) varieties. BioMed Research International.

Jamil, M., Bashir, S., Anwar, S., Bibi, S., Bangash, A., Ullah, F., &Rha, E. S. (2012). Effect of salinity on physiological and biochemical characteristics of different varieties of rice. Pak. J. Botany, 44(2012), 7-13.

Khan, M. A., & Abdullah, Z. (2003). Salinity–sodicity induced changes in reproductive physiology of rice (*Oryza sativa* L.) under dense soil conditions. Environmental and Experimental Botany, 49(2), 145-157.

Khush, G. S. (2005). What it will take to feed 5.0 billion rice consumers in 2030. Plant molecular biology, 59(1), 1-6.

Kibria, M. G., Hossain, M., Murata, Y., &Hoque, M. A. (2017). Antioxidant defense mechanisms of salinity tolerance in rice genotypes. Rice Science, 24(3), 155-162.

Kumar, S. G., Reddy, A. M., &Sudhakar, C. (2003). NaCl effects on proline metabolism in two high yielding genotypes of mulberry (*Morus alba* L.) with contrasting salt tolerance. Plant Science, 165(6), 1245-1251.

Lutts, S., Kinet, J. M., &Bouharmont, J. (1996). Effects of salt stress on growth, mineral nutrition and proline accumulation in relation to osmotic adjustment in rice (*Oryza sativa* L.) cultivars differing in salinity resistance. Plant Growth Regulation, 19(3), 207-218.

Maas, E. V., & Grattan, S. R. (1999). Crop yields as affected by salinity. Agronomy, 38, 55-110.

Mansour, M. M. F., &Salama, K. H. (2004). Cellular basis of salinity tolerance in plants. Environmental and Experimental Botany, 52(2), 113-122.

Michael, D., Peel, B., Waldron, L., & Kevin, B. (2004). Screening for salinity tolerance in Alfalfa. Crop Science, 44, 2049-2053.

Rahman, M. M., & Ahsan, M. (2001). Salinity constraints and agricultural productivity in coastal saline area of Bangladesh. Soil resources in Bangladesh: Assessment and utilization, 1, 1-14.

Selamat, A., & Ismail, M. R. (2009). Deterministic model approaches in identifying and quantifying technological challenges in rice production and research and in predicting population, rice production and consumption in Malaysia. Pertanika Journal of Tropical Agricultural Science, 32(2), 267-291.

Zeng, L., & Shannon, M. C. (2000). Salinity effects on seedling growth and yield components of rice, 8(5), 996-1003