Research Article

Impact of NaCl Toxicity on Yield and Yield Components of Rice (*Oryza sativa*) Grown in Aridisol

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Abstract | Measurement of soluble salt content in soil is termed as soil salinity. Both positive and negatively charged ions are contained in such soils and being free can be absorbed by plants. A pot study was performed to assess the poisonous impact of NaCl salinity on rice growth parameters. Selection of soil with customary characteristics was done. Various levels of salinity; < 4, 4, 6, 8, 10, 12 and 14 dS m^{-1} were established using NaCl salt. Soil was left for appropriate period for accomplishment of salinity. Completely randomized design (CRD) was used for layout of the experiment. Transplantation of seedlings was performed in all pots. Application of mineral fertilizers at recommended rates was done. Crop was grown till maturity and then data gathering concerning yield related parameters was carried out and statistical analysis was performed. It was observed from the results that addition of NaCl proved toxic for growth and yield of rice plants as well as associated parameters such as plant height, number of productive tillers, total biomass, straw and grain yields were negatively influenced by the increasing levels of sodium chloride when compared with control treatment. Injurious impact of NaCl was more pronounced as the concentration of salt increased in the treatments.

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Keywords | Rice, Yield, Yield components, NaCl, Salinity

Introduction

Rice (*Oryza sativa* L.) is member of family Oryzeae. Rice is a prime food crop in whole world. In Asia, over a half of the world's population consume rice as a principal food. It is extremely valued cash crop and earns large amount of foreign exchange. Generally, depending on climate circumstances average life span of rice is 3-7 months. Rice is not an aquatic plant but it involves a large amount of water for growing. With extreme protein contents, rice is core food crops and commonly used in serving commonalities but actual yield per acre of Pakistan is very low. It is a chief staple food and feed above three million people in the world on everyday calorie consumption from 50.0 to 80.0 % (Khush, 2005). Particularly in Asia, from top five main carbohydrate food crops rice is one of them for the world population. In the world, Asia is among most populated areas, where it is a staple food for 2 million people whereas for millions of people in Latin America and Africa (Khush and Virk, 2000). Growth pattern, productivity and growth period of rice crop is seriously impacted by temperature regimes (Darwin *et al*., 2005). It is predictable that salt-affected soils of all irrigated lands are at least 20 % (Pitman and Läuchli, 2002). The major cropping scheme is wheat rice throughout the world. In the Indo gigantic plains of South Asia, almost 85 % of the wheat-rice zone covers Pakistan, India, Bangladesh and Nepal (Timsina and Connor, 2001).

Salt stress is most common and serious problem of agriculture. About 40,000 ha area of cultivable land in Pakistan has been lost and is increasing quickly each year (Ashraf *et al*., 2008). Due to high salinity toxicity, soil water potential is decreased, so plants become incapable to absorb sufficient extent of water from soil, ultimately reduction in plant growth rate (Tester and Davenport, 2003). Wilting occurs by constant salinity stress alike to drought symptoms, with waxed and thickened leaves and with a greenish blue color (Fraga *et al*., 2010). By the osmotic effects salt stress shortens plant growth, shrinks water up takes capacity of crops that causes decline in growth. If salts accumulate in crops to dangerous extent, salt concentration will give rise to affect senescence and photosynthetic leaf zone of plant that subsequently inhibit the growth of plant (Shereen *et al*., 2005).

NaCl can be solubilized in water with ease and cause ionic effects in rice crop including higher plant (Nishimura, 2011). Cell organelles and membrane systems directly damages due to surplus Na+ concentration in plant cells, causing abnormal development and plant growth decrease, before decay of plant (Davenport *et al*., 2005; Quintero *et al*., 2007).

Salinity persuade some injurious effects include lessened seedling growth and germination (Zeng and Shannon, 2000; Ashraf, 2010) and repressed leaf expansion that eventually leads to production of dry matter and photosynthetic area (Mansour and Salama, 2004). In response to salinity stress, plants also show high deprivation of chlorophyll resulted in yellowing of leaves, as a common physiological and morphological characteristic (Chaum *et al*., 2007). Salinity stress together with photo inhibition causes serious injury to several physiological and cellular progressions including, cellular metabolism, photosynthesis, root growth, nutrient uptake and water absorption which all clearly lead to yield deterioration (Zeng and Shannon, 2000; Zhu, 2001; Darwish *et al*., 2009). Potential of growth area of sensitive crops is restricted by soil sodicity and salinity. High salinity might lead to no yield and finally plant death. On yield of crops, the effects of salinity were shown with 5 conductivity levels (0-2, 2-4, 4-8, 8-16, >16 dS m^{-1} individually), a scale of growing yield limitation (Eynard *et al*., 2005). Salinity hinders the plant development and crop produce. The main environmental problem at present that hastens crop yield is salt stress (Majeed *et al*., 2010). Worldwide, salinization is rapidly growing and it affects over 10% of arable land. Average yield is decreasing for numerous major crop plants over 50% (Bray *et al*., 2000). This research was carried out to find out the influence of salt stress on the growth and yield of rice.

Materials and Methods

A pot experiment was carried out at College of Agriculture, UOS, to evaluate the toxicity of NaCl on growth and yield of rice. For this reason, gathering of soil with regular characteristics (Table 1) was done. After analysis 10 kg of such soil was filled in all pots. Analytical methods of Handbook 60 were applied for laboratory analysis (USDA, 1969). NaCl salt was added to respective pots after calculations as per treatment plan and 30 days' time was given to complete chemical reactions on exchange site of the clay. Super basmati nursery of rice was transplanted in all pots. The experiment comprised of seven treatments replicated thrice using completely randomized design (CRD). At maturity, plant height of rice was measured and number of productive tillers per pot was counted. After it, harvesting of rice plants was done and data regarding total biomass, straw and grain yield were noted for each pot of the experiment. Treatments contain; T1= Control (normal soil); T2= EC 4.0 dS m^{-1}; T3= EC 6.0 dS m^{-1}; T4= EC 8.0 dS m^{-1}; T5= EC 10.0 dS m^{-1}; T6= EC 12.0 dS m^{-1} and T7= EC 14.0 dS m^{-1}.

Crop was grown till maturity and then data gathering concerning yield related parameters was carried out and statistical analysis regarding analysis of variance calculation was performed using Statistics 8.1 (Steel *et al*., 1997).

Table 1: *Soil characteristics used for experimentation.*

Sr. No.	Soil characteristic	Unit	Value
1	Soil Reaction (pH)	-	7.92
2	Electrical Conductivity (EC)	dS m^{-1}	1.78
3	Sodium Adsorption Ratio (SAR)	-	10.15
4	Sand	%	45.10
5	Silt	%	26.80
6	Clay	%	28.10
7	Textural Class	-	Sandy Clay Loam

Results and Discussion

Maximum plant height of rice (cm)

The results revealed that on overall average basis plant height was negatively affected by various levels of salinity. Data indicated that plant height significantly decreased with increasing salinity levels (Figure 1). Maximum value of plant height 80.17 cm was noted in control treatment (T_1) having EC less than 4.0 dS m^{-1} and it was followed by T_2 with value of 75.25 cm. Treatment T_7 (EC = 14 dSm^{-1}) resulted in shortest plant height with numerical value of 45.75 cm and this treatment showed significant difference with T_6 (EC 12 dS m^{-1}). The observed values of plant height for T_3, T_4 and T_5 were 68.75, 65.91 and 61.17 cm respectively. However, differences between treatments T_3 and T_4 were non-significant statistically when compared with each other. Similar trend was noticed between T_4 and T_5 (EC 8 and 10 dS m^{-1} respectively). Plant height of rice was significantly influenced by different ranges of salinity depicting the lethal effects of soluble salts on rice growth. Finding of this study were in confirmation with conclusions of Islam *et al.* (2007) and Harnadaz and Al-Matawa (2002). They emphasized that higher salt levels resulted in dwarf plants.

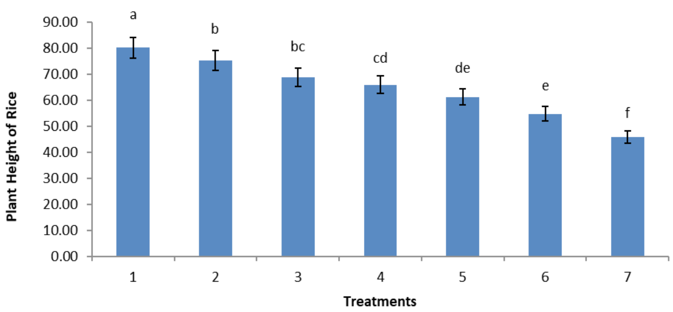

Figure 1: *Effect of NaCl toxicity on height of rice plants.*

Number of fertile tillers

Results indicated that numbers of fertile tillers of rice were significantly affected by increasing levels of salinity. The differences among various treatments regarding number of fertile tillers were significant in terms of statistics (Figure 2). Highest number of fertile tillers (24) was observed in control treatment (T_1). These two treatments T_1 (control) and T_2 (EC 4 dS m^{-1}) remained non-significant when compared with each other. The lowest number of fertile tillers 6 was observed for treatment T_7 (EC 14 dS m^{-1}) and this treatment showed non-significant difference with T_6 (EC 12 dS m^{-1}). The noted number of fertile tillers per pot for T_3 (EC 6 dSm^{-1}) T_4 (EC 8 dS m^{-1}) and T_5 (EC 10 dS m^{-1}) were 17.33, 16 and 12.67 respectively. However, treatments T_3 and T_4 were non-significant when compared with each other. Similar difference was noticed between T_4 and T_5 (EC level of 8 and 10 dSm^{-1}).

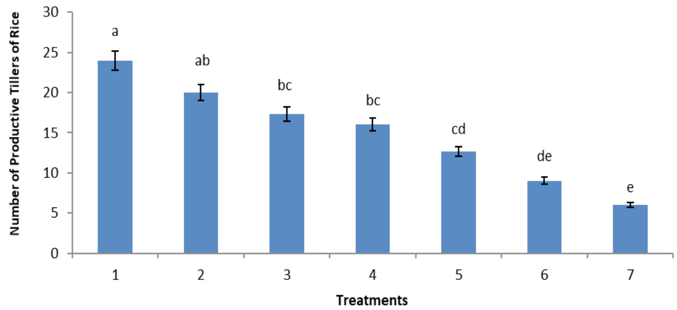

Figure 2: *Effect of NaCl toxicity on number of productive tillers of rice plants.*

Effect of salinity on fertile tillers production was apparent. Indirect relation was observed regarding number of such tillers and salinity levels. There were no fertile tillers at higher salinity level. These findings were supported by literature such as Zeng and Shannon (2000), Ling (2000) and Young (2003) also reported reduction in tillers number by exposure to higher salt levels.

Total plant biomass of rice

The results revealed that on overall average basis total plant biomass of rice was significantly affected by various levels of salinity. Reduction in total biomass was apparent upon exposure to higher salt levels (Figure 3). Maximum value of total plant biomass per pot (53.49 g) was noted in control treatment T_1 (EC < 4 dS m^{-1}) and it was followed by T_2 with value of 47.87 g. However, these two treatments (T_1 and T_2) remained at par when adjudged statistically. Treatment T7 resulted in minimum total biomass (14.31g) and this treatment showed non-significant difference with T_6 (EC 12 dS m^{-1}). Such a reduction

Links Researchers

in plant biomass was also noticed by Harnadaz and Al-Matawa (2002) and Islam *et al*. (2007) concluding the deleterious effects of higher salt levels on plant biomass.

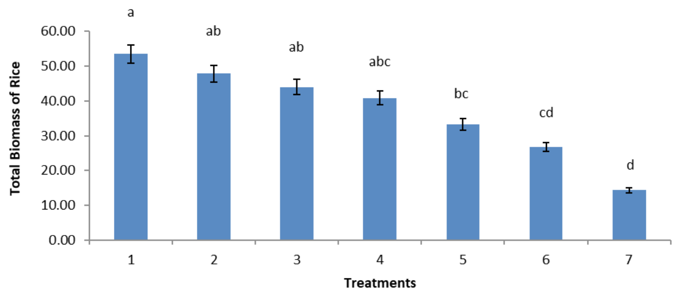

Figure 3: *Effect of NaCl toxicity on total biomass of rice plants.*

Straw yield of rice

Deleterious effect of higher salt levels on straw yield of rice was plotted in Figure 4. The highest value of straw yield 38.75 g pot^{-1} was noted in treatment T_1 (control) having EC level less than 4.0 dS m^{-1} and it was followed by T_2 having value of 34.96 g pot^{-1} straw yield. These two treatments T_1 (control) and T_2 (EC = 4dSm^{-1}) remained non-significant when compared each other. The lowest value of straw yield 10.55 g pot^{-1} was noted for treatment T_7 (EC 14 dS m^{-1}) and this treatment showed significant difference when compared with T_6 (EC 12 dS m^{-1}). The observed values of straw yield for $T_{3,}$ T_4 and T_5 were 32.10, 31.46 and 24.77 g pot^{-1} respectively. The value of straw yield of different levels of salinity was decreased at the end of experiment as a result of deleterious effects of NaCl salt. Ali *et al*. (2001), Harnadaz and Al-Matawa (2002) and Islam *et al*. (2007) also reported similar trend of reduction in rice straw yield as a consequence of salts toxicity.

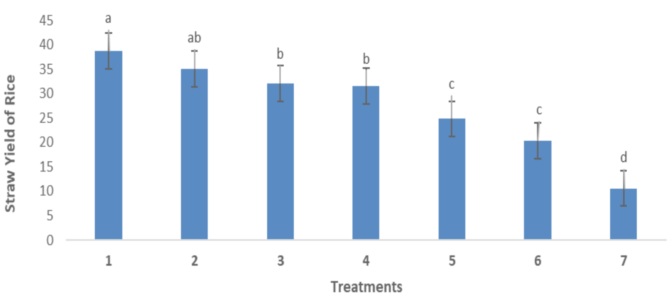

Figure 4: *Effect of NaCl toxicity on straw yield of rice.*

Paddy yield

Results indicated that paddy yield was significantly reduced by increasing levels of salinity (Figure 5). Highest paddy yield (14.77 g pot^{-1}) was noted in control treatment (T_1) and it was followed by treatment (T_2) having value 12.78 g pot^{-1}. These two treatments T_1 (control) and T_2 (EC 4 dS m^{-1}) remained non-significant when compared with each other. The lowest value (3.70 g pot^{-1}) was observed for treatment T_7 having EC 14 dS m^{-1} and this treatment showed significant difference with T_6 (EC 12 dS m^{-1}) and all other treatments. The observed values of paddy yield per pot for T_3 (EC 6 dS m^{-1}) T_4 (EC 8 dS m^{-1}) and T_5 (EC 10 dS m^{-1}) were 11.75, 9.65 and 8.53 g pot^{-1} in that order. Findings of this study was supported by Ali *et al*. (2001) and Islam *et al*. (2007). They also claimed reduction in paddy yield as a result of higher salt levels.

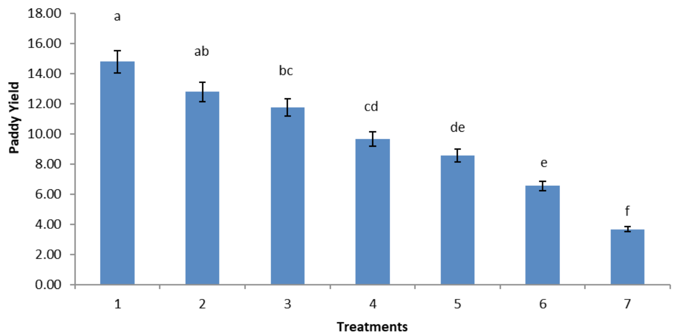

Figure 5: *Effect of NaCl toxicity on paddy yield.*

Conclusions and Recommendations

It can be concluded that exposure to higher salt levels lower down growth, yield and yield related parameters in rice including plant height, highest number of productive tillers, maximum total biomass and straw yield. Control treatment having EC value less than 4.0 dS m^{-1} produced highest values for all these parameters. However, decline was noticed in all subsequent treatments and trend of decline was strengthened as NaCl salt level increased in the treatments with the lowest values in T7 where EC level of 14 dS m^{-1} was maintained.

Novelty Statement

NaCl toxicity proved injurious for rice growth.

Author's Contributions

Hafiz Muhammad Waseem: Basic researcher who conducted research.
Ghulam Sarwar: University supervisor.
Noor-us-Sabah: Drafting and technical assistance.
Mukkram Ali Tahir: Co-Supervisor.
Muhammad Aftab and Aamer Sattar: Interpretation of data and excel work for graphs making.

Usman Saleem and Sher Muhammad: Statistical analysis.

Muhammad Zeeshan Manzoor and Ayesha Zafar: Helped in Lab. work and write up.

Imran Shehzad and Aneela Riaz: Proof reading and final editing.

Conflict of interest

The authors have declared no conflict of interest.

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