Research Article

Toxic Effects of Sodium Bicarbonate ($NaHCO_3$) on Growth and Yield of Rice

Zohaib Ahmad Hassan[1], Ghulam Sarwar[1*], Noor-Us-Sabah[1], Mukkram Ali Tahir[1], Muhammad Aftab[2], Muhammad Zeeshan Manzoor[1], Usman Saleem[3], Ayesha Zafar[1], Imran Shehzad[1], Aneela Riaz[4], Khurshid Ahmad Mufti[5] and Aamer Sattar[2]

[1]Department of Soil and Environmental Sciences, College of Agriculture, University of Sargodha, Sargodha, Pakistan; [2]Institute of Soil Chemistry and Environmental Sciences, Ayub Agricultural Research Institute, Faisalabad, Pakistan; [3]Department of Plant Breeding and Genetics, College of Agriculture, University of Sargodha, Pakistan; [4]Soil Bacteriology Section, Ayub Agriculture Research Institute, Faisalabad, Pakistan; [5]Soil and Water Testing Laboratory, Ayub Agriculture Research Institute, Faisalabad, Pakistan.

Abstract | In Pakistan many soils out of total lands are occupied by sodic soils which in turn is upsetting farmer's income and cause soil quality decline. This trial was led to appraise the toxic consequences of $NaHCO_3$ on growth as well as rice yield parameters. Various levels of $NaHCO_3$ or Sodium Adsorption Ratio (SAR) were developed in the normal soil. This experiment comprised of 7 treatments that were repeated three times according to Completely Randomized Design (CRD). These treatments included; T_1= Control, T_2= 15 SAR, T_3= 20 SAR, T_4= 25 SAR, T_5= 30 SAR, T_6= 35 SAR and T_7= 40 SAR. Subsequently $NaHCO_3$ was added to the soil as per treatment plan and adequate time was allowed to accomplish chosen sodicity levels. Later on, rice nursery was transplanted in all the pots. Various agronomical operations were carried out as per crop requirement. At maturity, rice was harvested from all pots. Various yield contributing components like plant height, fertile tillers, total biomass, straw and paddy yield were noted for all pots of the experiment. Statistical analysis of all collected data was accomplished. It was noted from the results that control (T_1) proved superior with regard to plant height, fertile tillers/pot, total biomass, straw and paddy yield. All these yield contributing components indicated a declining trend in all subsequent treatment. Treatment T_7 (40 SAR) proved inferior to all others in these regards.

Received | December 03, 2020; **Accepted** | January 22, 2021; **Published** | February 15, 2021
***Correspondence** | Ghulam Sarwar, Department of Soil and Environmental Sciences, College of Agriculture, University of Sargodha, Sargodha, Pakistan; **Email:** ghulam.sarwar@uos.edu.pk
Citation | Hassan, Z.A., G. Sarwar, N.U. Sabah, M.A. Tahir, M. Aftab, M.Z. Manzoor, U. Saleem, A. Zafar, I. Shehzad, A. Riaz, K.A. Mufti and A. Sattar. 2021. Toxic effects of sodium bicarbonate (NaHCO3) on growth and yield of rice. *Pakistan Journal of Agricultural Research,* 34(1): 70-76.
DOI | http://dx.doi.org/10.17582/journal.pjar/2021/34.1.70.76
Keywords | Toxicity, $NaHCO_3$, SAR, Yield, Yield parameters and Rice

Introduction

Salt stress is the most common and serious problem of agriculture. According to Ashraf *et al.* (2008) 40,000 ha area of arable land in Pakistan has been lost due to salinity and is increasing quickly each year. 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 occur (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 take capacity of crops that causes decline in growth. If salts pass through in the crops to dangerous extent, ultimately salt concentration will rise to affect senescence and photosynthetic ability of plant abridged to a level that growth of plant cannot endure (Shereen *et al*., 2005). NaCl salts are quickly dissolved in the water and cause ionic effects in rice crop including higher plant (Nishimura *et al*., 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).

Rice is a prime food crop in the whole world. 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 a plant of water but it requires 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. Rice, agronomically and nutritionally, is a significant crop around the globe. It is chief essential 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, rice is one of top five main carbohydrate food crops for the world population. In the world more thickly populated areas, in Asia it is a staple food for 2 million people and 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 Lauchli, 2002). Throughout the world, the major cropping scheme is wheat-rice. In the Indo gigantic plains of South Asia, almost 85 % of the wheat-rice zone is covering Pakistan, India, Bangladesh and Nepal (Cui *et al*.,1995).

When rice genotypes are exposed to salt stress, potassium ion (K^+) in the tissues evidently decreased (Basu *et al*., 2010). The concentration of chloride (Cl^-) and sodium ions (Na^+) were improved with the enhancement in salinity yet K, magnesium (Mg^{2+}) and calcium (Ca^{2+}) concentration of base (root) and shoot diminished with the increase in salinity in all lines of wheat. A pot study was conducted to the check impact of saline water, gypsum and potassium on storage of these supplements in grain protein contents and in wheat (*Triticum aestivum* L.). It was noted that as water saltiness expanded, Na^+ concentration also expanded in grain protein substance roots, leaves and K^+ substance and K^+/Na^+ ratio diminished in roots of plants and leaves. Application of K^+ improved K^+ and K^+ to Na^+ ratio and gypsum application improved calcium (Ca^{2+}) and brought down Na^+/Ca^{2+} in roots and plant leaves. Potassium and salt stress on the whole expanded protein of grain, K^+ and ratio of K^+/Na^+ while K^+ and gypsum together enhanced (Na^+/Ca^{2+}) buildup in plant leaves and diminished Na^+ in plant roots. Protein content of grains expanded in lower K^+ treatment and brought down with expanding K^+ (Bahmaniar and Ranjbar, 2007).

Deleterious impacts of sodicity on plant development are very critical and are related with decline of soil physical properties especially structure (Renasamy and Olsson, 1991). Deteriorated properties of soils lead to meager water use potency, abridged plant development and produce by encouraging crusting and enhancing hindrance to plant roots (Thus and Aylmore, 1993). Penetration of air and water in the soil is lessened to much extent. Crops growing in such environment have air stress. Salts persuade some injurious effects include lessened seedling growth and germination (Zeng and Shannon, 2000; Ashraf, 2010) and repressed leaf expansion which ultimately production of dry matter and photosynthetic area (Mansoor and Salama, 2004). In response to salinity stress, plants also show the high deprivation of chlorophyll symptom yellowing of leaves, as a common physiological and morphological characteristic. Many reports showed that decline in photosynthetic pigments happen due to salinity in several rice species (Chaum *et al*., 2007).

Salt 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 (Zhu, 2001; Darwish *et al*., 2009). Potential of growth of sensitive crops is restricted by soil sodicity and salinity (Eynard *et al*., 2005). The overall objective of this study was to judge the effects of $NaHCO_3$ toxicity on development and production of rice.

Materials and Methods

This experiment was carried out at College of

Agriculture, University of Sargodha (UOS) to evaluate the toxicity of $NaHCO_3$ on growth and yield of rice. For this reason, analysis of soil with regular characteristics (Table 1) was done. After analysis 10 kg of such soil was filled in all pots. Analytical methods of Ghafoor *et al.* (2004) were applied for laboratory analysis. $NaHCO_3$ salt was added to all the 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 with Completely Randomized Design (CRD). At maturity, plant height of rice was measured and number of productive tillers per pot were counted. Afterward, rice plants were harvested and data regarding total biomass, straw and grain yield were noted for each pot of the experiment. Treatments contain;
T_1 = Control (<15 SAR); T_2 = 15 SAR; T_3 = 20 SAR; T_4 = 25 SAR; T_5 = 30 SAR; T_6 = 35 SAR; T_7 = 40 SAR.

Table 1: *Laboratory determinations of basic soil characteristics.*

No.	Characteristic	Unit	Numerical value
1	SP	%	37.5
2	Soil Reaction	-	7.86
3	EC	dS m^{-1}	0.701
4	Carbonates	Milli Equivalents/Litre	3.6
5	Bicarbonates	Milli Equivalents/Litre	6.3
6	Chlorides	Milli Equivalents/Litre	4.1
7	Sulphates	Milli Equivalents/Litre	3.8
8	Calcium+ magnesium	Milli Equivalents/Litre	83
9	Sodium	Milli Equivalents/Litre	4.18
10	Sodium adsorption ratio	-	3.54
11	Sand	%	43
12	Silt	%	50
13	Clay	%	7
14	Textural class	-	Sandy loam soil

Required N, P and K fertilizers were supplied at rate (100-70-70 kg ha^{-1}). Urea, single superphosphate (SSP) and sulfate of potash were added as source of N, P and K. Half of the nitrogen amount was given at time of rice transplanting with all P and K. Remaining nitrogen was given after 30 days of rice transplanting. $ZnSO_4$ was also added 15 days after transplantation at rate of 10 kg per hectare. Crop was grown till maturity and then data concerning yield related parameters was collected and statistical analysis of variance calculation was performed using Statistics 8.1 (Steel and Torrie, 1997). When crop was matured, data related to yield components like height of plants, fertile tillers, total biomass, straw and paddy yield were noted.

Results and Discussion

Plant height

Plant height is very significant characteristic that determines health, vigor and strength of crops. Data showed that extreme rice plant height was achieved undesirably with cumulative dose of $NaHCO_3$ (Figure 1). Extreme plant height was produced with 82.30 cm numerical value was distinguished in T_1 (control) in contradiction of lowest plant height (63.33 cm) obtained from pot soil having 40 SAR (T_7). The T_2 treatment having 15 SAR value displayed 80.75 cm plant height and was next to control. Respective fertile tillers for T_3 and T_4 was noted as 77.79 and 72.50 cm. Alike tendency for plant height was prominent for treatments having SAR values 25 and 30 (T_5 and T_6). Both these treatments viewed fertile tillers of 70.00 and 67.92 cm correspondingly. Soil sodicity seriously exaggerated development as well as capability of plant height in current study. Plant height was seriously lessened with the rise in sodicity levels. These outcomes are in accord with the results of earlier scientists. 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. Mahmood (2007) concluded from a study that plant height of *Acacia ampliceps* was abridged with greater levels of salts.

Fertile tillers

Fertile tillers of any crop are always of much significance as these contribute towards yield. Data exhibited that fertile tillers of rice declined significantly with high contents of $NaHCO_3$ in soil. It indicates that occurrence of $NaHCO_3$ in soil forced injurious effects on fertile tillers. Variances among numerous treatments concerning fertile tillers were distinguished as significant when judged statistically (Figure 2). Extreme fertile tillers were produced with 8.33 numerical value was distinguished in T_1 (control) in contradiction of lowest fertile tillers (2.33) prominent from soil having 40 SAR (T_7). The

T_2 treatment having 15 SAR value displayed 8 fertile tillers and was next to control. Respective fertile tillers for T_3 and T_4 was noted as 7.33 and 6. Alike tendency for fertile tillers was prominent for treatments having SAR values 25 and 30 (T_5 and T_6). Both these treatments viewed fertile tillers of 4.67 and 4.00 correspondingly. Soil sodicity seriously exaggerated development as well as capability of fertile tillers in current study. Tillers were seriously lessened with rise in sodicity levels. These findings were supported by literature such as Zeng and Shannon (2000) and Nazir *et al*. (2001) also reported reduction in tillers number by exposure to higher salt levels. Likewise, El-Hendawy *et al*., 2005 concluded that there is reduction in tillers of wheat when level of sodicity augmented.

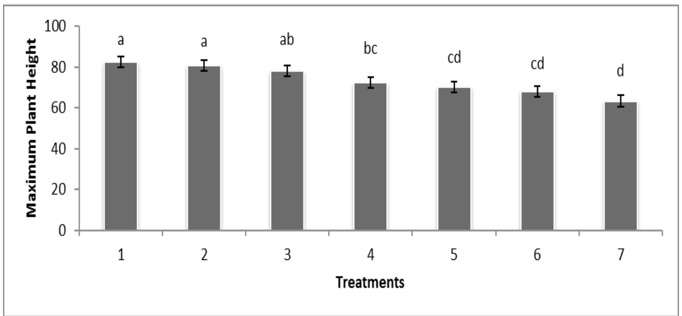

Figure 1: *Effect of various $NaHCO_3$ levels on plant height of rice.*

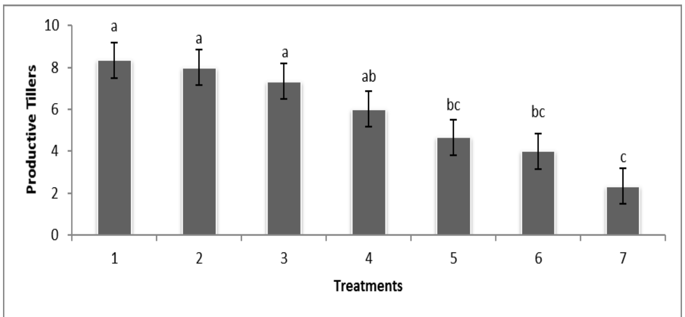

Figure 2: *Effect of various $NaHCO_3$ levels on fertile tillers of rice.*

Total biomass

Total biomass of any crop is imperative property that regulates plants produce. Data showed that total biomass of rice lessened in the regular mode with cumulative addition of $NaHCO_3$ salt in soil. Fallouts presented the lethal actions of $NaHCO_3$ for plant development. Variances between numerous treatments concerning total biomass production persisted significant in relations of statistics (Figure 3). Extreme total biomass production with 138.16 g numerical value was distinguished in T_1 (control) in contradiction of lowest yield (44.83 g) prominent from soil having 40 SAR (T_7). The T_2 treatment having 15 SAR value displayed 125.93 g total biomass and was next to control. Respective total biomass yield for T_3 and T_4 was noted as 93.78 and 73.55 g. Alike tendency for paddy yield was prominent for treatments having SAR values 25 and 30 (T_5 and T_6). Both these treatments viewed paddy yield of 67.14 and 61.60 g correspondingly. Conclusions of preceding experts were too in the equivalent track. Mahmood (2007) found decline in the biomass of *Acacia ampliceps* with cumulative addition of sodium bicarbonate in the soil. Similarly, Aref (2013) noted alike decrease in biomass owing to sodicity. Such a reduction was also noticed by Harnadaz and Al-Matawa (2002) and Islam *et al.* (2007) concluded the deleterious effects of higher salt levels on plant biomass.

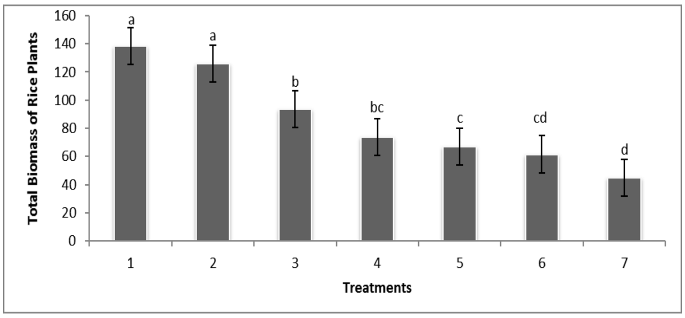

Figure 3: *Effect of various $NaHCO_3$ levels on total biomass of rice.*

Straw yield

Addition of $NaHCO_3$ toxicity in the soil proved harmful for straw yield of rice. Henceforth, straw production is the utmost chief agronomic yield component that is directly linked with paddy. Data showed that straw yield of rice lessened in the regular mode with cumulative contents of $NaHCO_3$ salt in soil (Figure 4). Extreme straw production with 88.73 g numerical value was distinguished in T_1 (control) in contradiction of lowest yield (34.14 g) prominent from soil having 40 SAR (T_7). The T_2 treatment having 15 SAR value displayed 83.96 g yield of straw and was next to control. Respective straw yield for T_3 and T_4 was noted as 63.64 and 50.20 g. Alike tendency for straw yield was prominent for treatments having SAR values 25 and 30 (T_5 and T_6). Both these treatments viewed paddy yield of 47.70 and 45.99 g correspondingly. Conclusions of former researchers proved likewise. Mahmood (2007) observed reduction in yield of *Accacia ampliceps* biomass with cumulative addition of sodicity. Karimi *et al.* (2005) exhibited that by cumulative of sodicity levels, declined rice straw production. 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.

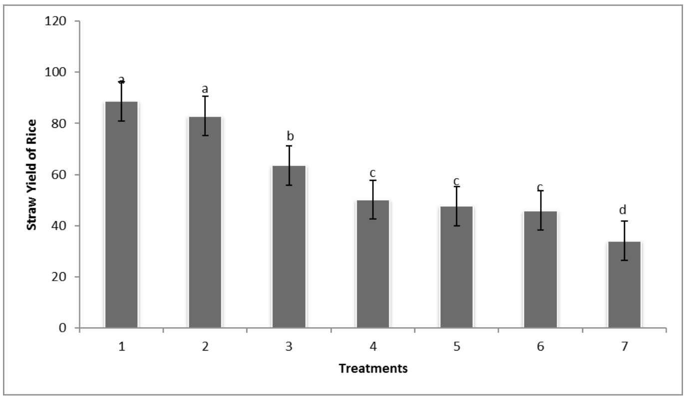

Figure 4: *Effect of various $NaHCO_3$ levels on straw yield of rice.*

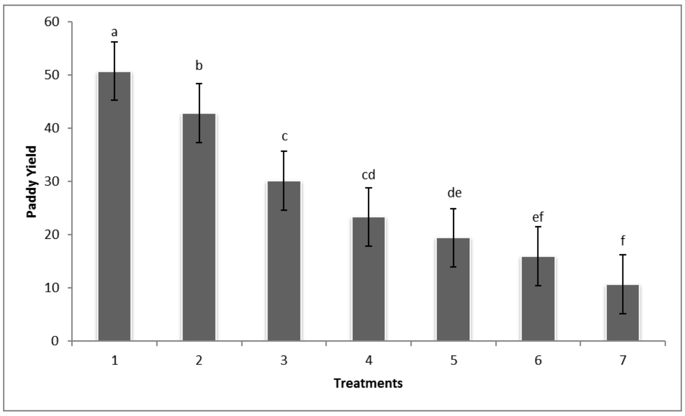

Figure 5: *Effect of various $NaHCO_3$ levels on paddy yield.*

Paddy yield

The imperative goal of all growers in the world is to grow supreme grain yield of any crop. Henceforth, grain production is the utmost chief agronomic yield component. Data showed that paddy yield of rice lessened in the regular mode with cumulative contents of $NaHCO_3$ salt in soil. Fallouts presented the lethal actions of $NaHCO_3$ for plant development. Variances between numerous treatments concerning paddy production persisted significant in relations of statistics (Figure 5). Extreme paddy production with 50.76 g numerical value was distinguished in T_1 (control) in contradiction of lowest yield (10.69 g) prominent from soil having 40 SAR (T_7). The T_2 treatment having 15 SAR value displayed 42.82 g yield of paddy and was next to control. Respective paddy yield for T_3 and T_4 was noted as 30.14 and 23.14 g. Alike tendency for paddy yield was prominent for treatments having SAR values 25 and 30 (T_5 and T_6). Both these treatments viewed paddy yield of 19.43 and 15.94 g correspondingly. Conferring to current trial, paddy production was harmfully exaggerated by toxicity of $NaHCO_3$ on rice growth. These outcomes proved in accord with the conclusions of preceding investigators. Alike effect about the decline in grain yield was noted by Grattan and Oster (2002). Conclusion 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.

Conclusions and Recommendations

Prominent outcomes of this study showed that exposure to higher $NaHCO_3$ salt levels lower down growth, yield and yield related parameters in rice including plant height, number of fertile tillers, total biomass, straw and paddy yield. Control treatment having SAR value less than 15 produced maximum values for all these parameters. While, decline was noticed in all subsequent treatments and trend of decline was strengthened as $NaHCO_3$ salt level amplified in the treatments with the minimum values in T_7 where SAR level of 40 was sustained.

Novelty Statement

Sodium Bicarbonate is toxic for rice growth.

Author's Contribution

Zohaib Ahmad Hassan: Conception and design of the work and conduction of experiment.
Ghulam Sarwar: Academic supervisor.
Noor-Us-Sabah: Drafting and technical assistance.
Mukkram Ali Tahir: Co-supervision and technical assistance at every step.
Muhammad Aftab and Aamer Sattar: Interpretation of data and excel work for graphs making.
Usman Saleem and Khurshid Ahmad Mufti: 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.

References

Ali, A., T.C. Tucker, T.L. Thompson and M. Salim. 2001. Effects of salinity and mixed ammonium and nitrate nutrition on the growth and nitrogen utilization of barley. J. Agron. Crop Sci., 186: 223-228. https://doi.org/10.1046/j.1439-037x.2001.00471.x

Aref, F., 2013. Effect of saline irrigation water on yield and yield components of rice (*Oryza sativa* L.). Afr. J. Biotech., 12: 3503-3513.

Ashraf, M., 2010. Inducing drought tolerance in plants: Some recent advances. Biotechnol. Adv., 28: 169-183. https://doi.org/10.1016/j.biotechadv.2009.11.005

Ashraf, M., H.R. Athar, P.J.C. Harris and T.R. Kwon. 2008. Some prospective strategies for improving crop salt tolerance Adv. Agron., 97: 45-110. https://doi.org/10.1016/S0065-2113(07)00002-8

Bahmaniar, M.A. and G.A. Ranjbar. 2007. Response of rice cultivars to rates of nitrogen and potassium application in field and pot conditions. Pak. J. Biol. Sci., 10(9): 1430-1437. https://doi.org/10.3923/pjbs.2007.1430.1437

Basu, S., A. Roychoudhury, P. Saha and D.N. Sengupta. 2010. Differential antioxidative responses of indica rice cultivars to drought stress. Plant Growth Regulat., 60(1): 51-59. https://doi.org/10.1007/s10725-009-9418-4

Chaum, S., K. Supaibulwatana and C. Kirdmanee. 2007. Glycine betaine accumulation, physiological characterizations and growth efficiency in salt tolerant and salt sensitive lines of indica rice (*Oryza sativa L.* ssp. Indica) in response to salt stress. J. Agron. Crop Sci., 193: 157-166. https://doi.org/10.1111/j.1439-037X.2007.00251.x

Cui, H., Y. Takeoka and T. Wada. 1995. Effect of sodium chloride on the panicle and spikelet morphogenesis in rice: I. External shoot morphology during young panicle formation. Japanese J. Crop Sci., 64(3): 593-600. https://doi.org/10.1626/jcs.64.587

Darwin, R., M. Tsigas, J. Lewandrowski and A. Raneses. 2005. World agriculture and climate change: Economic adaption. USDA Agric. Econ. Rep. No. 703.86.

Darwish, E., C. Testerink, M. Khalil, O. El-Shihy and T. Munnik. 2009. Phospholipids signaling responses in salt stressed rice leaves. Plant Cell Physiol., 50(5): 986-997. https://doi.org/10.1093/pcp/pcp051

Davenport, R., R.A. James, A. Zakrisson-Plogander, M. Tester and R. Munns. 2005. Effect of potassium application on wheat (*Triticum aestivum L.*) cultivars grown under salinity stress. World Appl. Sci. J., 26: 840-850.

El-Hendawy, S.E., Y. Hu, G.M. Yakout, A.M. Awad, S.E. Hafiz and U. Schmidhalter. 2005. Evaluating salt tolerance of wheat genotypes using multiple parameters. Eur. J. Agron., 22: 243-253. https://doi.org/10.1016/j.eja.2004.03.002

Eynard, A., R. Lal and K. Wiebe. 2005. Crop response in salt affected soils. J. Sustain. Agric., 27: 5-50. https://doi.org/10.1300/J064v27n01_03

Fraga, T.I., F.C. Carmona, I. Anghinoni, S.A. Junior and E. Marcolin. 2010. Flooded rice yield as affected by levels of water salinity in different stages of its cycle. R. Bras. Ci. Solo., 34: 175-182. https://doi.org/10.1590/S0100-06832010000100018

Ghafoor, A., M. Qadir and G. Murtaza. 2004. Salt-affected soils: Principles of management. Allied Book Centre, 34-Urdu Bazar, Lahore, Pakistan.

Grattan, S.R. and J.D. Oster. 2002. Drainage water reuse. I.D. Sys., 16: 297-310. https://doi.org/10.1023/A:1024859729505

Harnadaz, M.C. and Al-Matawa. 2002. Salinity effects on seedling growth and yield components of rice. Crop Sci., 40: 996-1003. https://doi.org/10.2135/cropsci2000.404996x

Islam, M.Z., M.A.B. Mia, M.R. Islam and A. Akhter. 2007. Effect of different saline levels on growth and yield attributes of mutant rice. J. Soil. Nat., 1: 18-22.

Karimi, G., M. Ghorbanli, H. Heidari, R.K. Nejad and A.H. Assareh. 2005. The effects of NaCl on growth, water relations, osmolytes and ion content in Kochia prostrata. Biol. Plant, 49: 301-304. https://doi.org/10.1007/s10535-005-1304-y

Khush, G.S. and P.S. Virk. 2000. Rice breeding: Achievement and future strategies. Crop Improve, 27: 115-144.

Khush, G.S., 2005. What it will take to feed 5 billion rice consumers in 2030. Plant Mol. Biol., 59(1): 1-6. https://doi.org/10.1007/s11103-005-2159-5

Mahmood, K., 2007. Salinity, sodicity tolerance of *Acacia Amplíceps* and identification of techniques useful to avoid early-stage salt stress, Kassel University Press GmbH. (Vol. 29).

Mansoor, M.M.F. and K.H.A. Salama. 2004. Cellular basis of salinity tolerance in plants. Environ. Exp. Bot., 52: 113-122. https://doi.org/10.1016/j.envexpbot.2004.01.009

Nazir, N., M. Ashraf and E. Rasul. 2001. Genomic relationships in oil seed Brassica with respect to salt tolerance photosynthetic capacity and ion relations. Pak. J. Bot., 33(SI): 483-501.

Nishimura, T., S. Chaum, M. Takagaki and K. Ohyama. 2011. Survival percentage, photosynthetic abilities and growth characters of two indica rice *(Oryza sativa L.* spp. Indica) cultivars in response to isosmotic stress. Span. J. Agric. Res., 9: 262-270. https://doi.org/10.5424/sjar/20110901-162-10

Pitman, M.G. and A. Lauchli. 2002. Global impact of salinity and agriculture ecosystem. In: salinity environment plants- Molecules, Lauchli A. and luttge U. (Eds,). Kluwer Academic Publishers, Dordresht, 3-20. https://doi.org/10.1007/0-306-48155-3_1

Quintero, J.M., J.M. Fournier and M. Benlloch. 2007. Sodium accumulation in shoot is related to water transport in potassium starved sunflower plants but not in plants with a normal potassium status. J. Plant Physiol., 164: 60-67. https://doi.org/10.1016/j.jplph.2005.10.010

Renasamy, P. and K.A. Olsson. 1991. Sodicity and soil structure. Aust. J. Soil Res., 29: 935-952. https://doi.org/10.1071/SR9910935

Shereen, A., S. Mumtaz, S. Raza, M.A. Khan and S. Solangi. 2005. Salinity effects on seedling growth and yield components of different inbred rice line. Pak. J. Bot., 37:131-139.

Steel, R. and G.D. Torrie. 1997. Principles and procedures of statistics: A biometrical approach. 3rd edition., Mc Grow Hill, New York.

Tester, M. and R. Davenport. 2003. Sodium tolerance sodium transport in higher plants. Ann. Bot., 91: 503-527. https://doi.org/10.1093/aob/mcg058

Thus, R. S. and L.A.G. Aylmore. 1993. Retention and release of diquat and paraquat herbicides in soils. Soil Res., 31: 97-109. https://doi.org/10.1071/SR9930097

Zeng, L. and M.C. Shannon. 2000. Salinity effects on seedling growth and yield components of rice. Crop Sci., 40: 996-1003. https://doi.org/10.2135/cropsci2000.404996x

Zhu, J.K., 2001. Plants salt tolerance. Trends Plant Sci., 6(2): 66-71. https://doi.org/10.1016/S1360-1385(00)01838-0