Int.J.Curr.Microbiol.App.Sci (2018) *7*(8): 118-124

International Journal of Current Microbiology and Applied Sciences
ISSN: 2319-7706 **Volume 7 Number 08 (2018)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2018.708.014

Effect of Sodicity on RWC, Proline and Yield of Different Rice (*Oryza sativa* L.) Genotypes

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Keywords

Sodicity, Rice, Biochemical, Protein, Yield

Article Info

Accepted:
04 July 2018
Available Online:
10 August 2018

A B S T R A C T

The present investigation was conducted in the net house of Department of Crop Physiology at Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (U.P.). The experiment was carried out in pot culture in complete randomized block design with three replications and six rice varieties, (Three tolerant verities-CSR 36, CSR 43, Narendra Usar 3) and (Three susceptible-Swarna *Sub* 1, IR 28, IR 29) under sodic soil having pH 8.5-8.6, 9.0-9.1 and 9.5-9.6. Results of the experiments indicated that relative water content in leaves and protein content in leaves showed minimum reduction in all the tolerant varieties at pH 9.5 in comparison to susceptible varieties at flowering stage of observation. Tolerant varieties have less accumulation of Na^+ and maintain better level of potassium at higher sodicity levels while, reverse in case of sensitive varieties. Yield components such as number of panicles $plant^{-1}$ and test weight were higher even at higher pH (9.0, 9.5) in all the tolerant varieties in comparison to susceptible varieties. CSR 36 and CSR 43 had a greater tolerance to sodic soil than IR 64 and IR 29.

Introduction

Rice is a staple food to feed more than 3 billion people and to provide 50-80% daily calorie intake to the world population (Khush, 2005). About 729 million tonnes rice per year is produced globally and 661 million tonnes of that is produced in Asia (FAO, 2012). Khan and Abdullah (2003) reported that rice crop identified as salt-susceptible both in seedling and reproductive stages. The seedling stage of rice, especially the root tissues, is very sensitive to salt stress (Zeng *et al.*, 2001; Yazdani and Mahdieh, 2012). Likewise, studies have demonstrated that fertility, seed set and grain production in rice were inhibited under salinity stress (Abdullah *et al.*, 2001). Salinity is the second major obstacle to reduce rice production after drought condition. Selamat and Ismail (2008) reported that fifty per cent yield is being lost of the salt-sensitive rice genotypes due to salinity. Therefore, production of rice under saline condition is under pressure because salinity may cause plant demise, growth and development (Galvani, 2007; Roychoudhury *et al.*, 2008) and reduced yield up to 50% (Zeng *et al.*, 2002). Salt-affected soils are commonly distributed in arid and semiarid climatic zones and covered 1,307 M ha at global scale (FAO/IIASA/ISRIC/ISS-CAS/JRC, 2008). The largest areas of salt-affected soils are in Australia followed by North and Central Asia, South America and South and West Asia. An estimated area of 6.73 M ha salt-affected soils are in India, of which 2.5 M ha is in the Indo-Gangeticplain (Mandal, *et al.*, 2011; National Remote Sensing Agency, 2008).

Water status is the major reason of growth reduction in plants under salt stress. Increasing salt in root zone reduces the water potential of leaf and subsequently, absorption of water and nutrients by plants are difficult or impossible (Romero-Aranda *et al.,* 2001). Katerji *et al.*, (1997) indicated a decrease in RWC and a loss of turgor resulted in limited water availability for cell extension processes. Based on the results of these researchers it seems there are two issues: (1) In high salt concentration, plants accumulate more Na+ and Cl- in the tissues of the leaves than normal situation. Subsequently, by increasing Na+ and Cl- within the leaf tissues lower osmotic potentials occurs and resulted in more negative water potentials and (2) Root hydraulic conductance reduction decreases the amount of water flow from the roots to the leaves, thus, causing water stress in the leaf tissues.

Accumulation of protein under salt condition may play a major role in terms of plants salt tolerance, where the proteins may serve as a reservoir of energy or may be adjuster of osmotic potential in plants subjected to salinity (Mansour, 2000). It has been concluded that a number of proteins induced by salinity are cytoplasmic which can cause alterations in cytoplasmic viscosity of the cells (Hasegawa *et al.,* 2000). Ashraf and Harris (2004) noted that in salt tolerant cultivars of rice there were a high content of soluble proteins. Several researches showed that soluble protein contents of leaves decreased in response to salinity (Agastian *et al.*, 2000 and Parida *et al.*, 2002). Soluble protein increased at low up to moderate salt stress (Agastian *et al.*, 2000).

Grain yield of rice in salt affected soils is much lower because of its high sensitivity to salt stress (Gao*et al.*, 2007; Ismail *et al.*, 2007). Rice is exceptionally sensitive to salinity and sodicity at early seedling stage (Aslam *et al.*, 1993) and high yield losses have been observed because of high mortality and poor crop establishment.

Modern high yielding varieties require considerable investment to ameliorate these soils to ensure reasonable yields, but this investment is beyond the capabilities of the resource-limited small holder farmers living off these salt affected areas.

Materials and Methods

The present investigation was carried out in the net house of Department of Crop Physiology, Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad (U.P.) under pot culture during *Kharif* (wet season) 2015 and 2016 under sodic soil, with six varieties of rice *viz*., CSR 36, CSR 43, Narendra Usar Dhan 3 (salt tolerant), IR 28, IR 29 and Swarna *Sub*1 (salt susceptible).The experiment was conducted in earthen pots at 3 pH levels (8.5-8.6, 9.0-9.1, 9.5-9.6) with six varieties CSR 36, CSR 43, Narendra Usar Dhan 3 (salt tolerant), IR 28, IR 29 and Swarna *Sub*1 (salt susceptible), thus the experiment consisted a total of 18 treatment combinations. The whole experiment was planned under complete randomized block design with three replications. Soil pH of various plots of Main Experiment Station (MES) of Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad (U.P.) were tested and soil having pH 8.5, 9.0 as well as 9.5 were collected upto 15 cm depth (surface soil) and brought to net house of the Department of Crop Physiology. Soils were mashed and sieved to get it well pulverized before filling the pots. Uniform earthen pots of 12 cm diameter and 20 cm depth were used for this study. A small piece of stone along with cotton was put at the hole of the pot in the base for retaining of water in sufficient amount. After that each pot was filled with 8 kg of well pulverized dry soil. Before transplanting of seedling, soil pH of each pot was tested to confirm the pH of the soil.

Thirty five days old seedlings of all the 6 rice varieties were transplanted in earthen pots at 10 places. Ten days after transplanting five plants were maintained in each pot, two seedlings were used for transplanting. Six pots constituted a set for each variety at each pH value. In this way, each replication having 108 pots and treatments were replicated three times. Each pot was irrigated with 1 liter of water at an interval of one day to maintain the proper soil moisture for good growth. The relative water content (RWC) was determined by the method described by Turner (1981). Protein content in leaves was estimated by the method of Lowery *et al.*, (1951). Number of panicles plant^{-1} was counted on three tagged plants per replication and their average was taken to express number of panicles plant^{-1}. 1000 grains were counted from the samples of each treatment. These counted grains were weighed and recorded as test weight at 15% moisture level.

Results and Discussion

It is evident from the data that the relative water content of plants reduced with the increase of pH levels at all the growth stages of observation (Table 1). However, the reduction was less in tolerant varieties (CSR 36, CSR 43, Narendra Usar Dhan 3) as compared to susceptible varieties (IR 28, IR 29, Swarna *Sub* 1) at all the growth stages. Maximum RWC was recorded in CSR 36 followed by CSR 43 and Narendra Usar Dhan 3 while minimum was found in IR 29 at all the growth stages. The effect of 9.5 pH was more severe as compared to lower pH levels (8.5 and 9.0 pH).The mean effect of variety and treatments was found significant, while the interaction effect was found non-significant at all the stages of observations. This result are in accordance with the findings of Chutipaijit *et al.*, 2009 and Amirjani, 2010 also reported that tolerant varieties maintained higher relative water content under salinity stress with respect to sensitive varieties. The increase in relative water content might be due to increase in osmotic pressure of cytoplasm which is accompanied by the synthesis of osmolytes which ultimately enhanced water flow into two plant organs.

The data pertaining in Table 2 show that protein content decreases with the increase of pH level of all the varieties but maximum decrease was observed at higher pH (9.5 pH) as compared to that in lower pH levels (8.5 and 9.0 pH) at all the stages in all the varieties. At all the stages of observation maximum protein content in leaves was observed in CSR 36 followed by CSR 43, while IR 29 showed minimum protein content followed by IR 28 at all pH levels. The mean effect of variety and treatment was significant at all the stages of observation, whereas, interaction effect was found non-significant at all the stages of observations. Exposure to salinity can result in denovo protein synthesis or an up-regulation of the process to increase the concentration of certain proteins already present in the plant (Singh *et al.*, 1987). Proteins accumulating in plants grown under saline conditions act as a storage form of nitrogen which is re-utilized in absence of stress (Jha and Singh 1997, Akbar *et al.*, 1972 and Akbar and Yabuno, 1975).

Table.1 Effect of sodicity on relative water content (%) in leaves of different varieties of rice at flowering stage

Variety / pH	8.5	9.0	9.5	Mean
Narendra Usar Dhan 3	84.82	83.85	82.14	83.60
CSR 36	88.16	87.38	85.91	87.15
CSR 43	86.30	85.41	83.83	85.18
Swarna *Sub* 1	79.74	79.35	76.74	78.61
IR 28	78.78	77.16	74.37	76.77
IR 29	74.90	72.57	69.59	72.35
Mean	82.11	80.95	78.77	-
SEm±	V=0.39, T=0.27, V×T =0.67			
CD at 5%	V=1.11, T=0.79, V×T =NS			

Table.2 Effect of sodicity on protein content (mg g^{-1} fresh weight) in leaves of different varieties of rice at flowering stage

Variety / pH	8.5	9.0	9.5	Mean
Narendra Usar Dhan 3	8.63	8.19	7.38	8.07
CSR 36	9.79	9.45	8.78	9.34
CSR 43	9.27	9.67	8.95	9.30
Swarna *Sub* 1	7.71	7.13	6.21	7.02
IR 28	6.84	6.14	5.08	6.02
IR 29	6.23	5.38	4.12	5.24
Mean	8.08	7.66	6.75	-
SEm±	V=0.23, T=0.16, V×T =0.40			
CD at 5%	V=0.66, T=0.47, V×T =NS			

Table.3 Effect of sodicity on number of panicles $plant^{-1}$ in different varieties of rice

Variety / pH	8.5	9.0	9.5	Mean
Narendra Usar Dhan 3	8.01	7.68	7.21	7.63
CSR 36	9.79	9.67	9.41	9.62
CSR 43	8.14	7.98	7.59	7.91
Swarna *Sub* 1	6.80	6.39	5.68	6.29
IR 28	6.61	6.11	5.25	5.99
IR 29	5.21	4.52	3.47	4.40
Mean	7.43	7.06	6.44	-
SEm±	V=0.13, T=0.09 VxT =0.22			
CD at 5%	V=0.37, T=0.26 VxT= NS			

Table.4 Effect of sodicity on number of test weight (g) in different varieties of rice

pH / Variety	8.5	9.0	9.5	Mean
Narendra Usar Dhan 3	22.46	21.85	20.77	21.69
CSR 36	23.25	22.76	21.78	22.60
CSR 43	24.21	23.84	23.05	23.70
Swarna *Sub* 1	19.82	18.61	16.80	18.41
IR 28	20.85	20.10	18.84	19.93
IR 29	20.27	19.25	17.64	19.05
Mean	21.81	21.07	19.81	-
SEm±	V=0.16, T= 0.11 VxT =0.28			
CD at 5%	V=0.46, T= 0.32 VxT=NS			

Protein synthesis is also destined to play an active role in osmotic adjustment. A significant increase in protein content and positive correlation has been ensured in tolerant rice seedlings compared to the sensitive ones.

The perusal of the data of number of panicles plant^{-1} presented in Table 3 clearly indicate that no. of panicles plant^{-1} decreased with the increase in pH level. The effect of higher pH levels (9.0 and 9.5 pH) severely reduces the number of panicles plant^{-1} in all the varieties as compared to lower pH level (8.5 pH).

The tremendous decline in number of panicles plant^{-1} were observed due to high sodicity as a result mean effect of treatment showed 6.44, 7.06 number of panicles plant^{-1} at 9.5 and 9.0 pH respectively against 7.43 panicles plant^{-1} at 8.5 pH.

Among all the cultivars grown under different pH levels maximum number of panicles plant^{-1} was noted in CSR 36 followed by CSR 43 and Narendra Usar Dhan 3 at all pH levels whereas, the minimum number of panicles plant^{-1} was recorded in IR 29 and Swarna *Sub* 1. The mean effect of variety and treatments was found significant whereas the interaction was found non-significant.

The data showed reduction in test weight in all the varieties with increased pH level however the effect of higher pH level (9.5 pH) was found more detrimental as compared to lower pH levels (8.5, 9.0 pH) (Table 4). Among all the cultivars grown under different pH levels minimum reduction in test weight with increased pH levels was observed in CSR 43 followed by CSR 36 and Narendra Usar Dhan 3 while Swarna *Sub* 1 showed maximum reduction in test weight followed by IR 29 and IR 28 however among all the cultivars maximum test weight was noticed in CSR 43 at all pH levels whereas, the minimum test weight was recorded in Swarna *Sub* 1. The mean effect of variety and treatments was found significant however interaction was found non-significant. The negative effect of sodicity on the number of panicles plant^{-1} and test weight was not severe in tolerant varieties while the effect on susceptible varieties was more detrimental. The results of the study are in conformity with the findings of Zeng and Shannon, 2000.

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How to cite this article:

Nikita Nehal, A.H. Khan, Nitish Sharma, K.K. Mishra, Mayanker Singh and Sanjay Kumar Tripathi. 2018. Effect of Sodicity on RWC, Proline and Yield of Different Rice (*Oryza sativa* L.) Genotypes. *Int.J.Curr.Microbiol.App.Sci.* 7(08): 118-124.
doi: https://doi.org/10.20546/ijcmas.2018.708.014