ISSN 1023-1072

Pak. J. Agri., Agril. Engg., Vet. Sci., 2014, 30 (1): 19-23

TOLERANCE OF BARLEY (*HORDIUM VULGARE* L.) TO CHLORIDES OF SODIUM, CALCIUM AND MAGNESIUM

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ABSTRACT

The effect of five chloride salt compositions on the growth and yield of *Hordium vulgare* L. (cv. local) was compared in a pot experiment designed with three replications. Five chloride salt compositions included in the study were: T_1: Control (without salt); T_2: NaCl; T_3: $MgCl_2$; T_4: $CaCl_2$ and T_5: Equal concentration (40+40+40 *mM*) of NaCl: $MgCl_2$: $CaCl_2$. The concentration of each salt composition was 120 *mM*. The results obtained from the study indicated that the influence of 120 *mM* NaCl was more lethal to barley plants. Compared to other salt compositions, plants stressed with NaCl had higher concentration of Na^+ and lower concentration of K^+ both in straw and grains, which exhibited lower K^+/Na^+ ratio.

Keywords: Barlery, calcium, chlorides, sodium, magnesium.

INTRODUCTION

Soil salinity decreases plant growth by imposing hyper-osmotic and hyper-ionic effects (Jaleel *et al.*, 2007). Among the specific toxic ions, Cl^- has been found as one of the most dominant toxic anions present in the saline soils of Sindh (Sial, 1985; Rajpar and Sial, 1997). Chloride particularly disturbs the physiology of plants especially by reducing the uptake of nutrient anions such as nitrates, phosphates, etc. (Munns and Tester, 2008). Availability of excessive chloride concentration in root medium induces diverse effects on crops yield, net photosynthesis rate (Boyer, 1965; Rajasekaran *et al*., 1997), chlorophyll content, respiration, transpiration, pre-dawn leaf water potential, stomatal density and conductance, leaf area (Katerji *et al*., 2000; Romero-Aranda *et al.,* 2001), CO_2 fixation, protein synthesis (Ramagopal, 1987; Levine *et al.,* 1990) and other essential biochemical and metabolic processes of the plant.

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Presence of various forms of chlorides such as NaCl, $CaCl_2$, $MgCl_2$, etc. may differ in their nature to affect growth and development of plants. Chlorides of Na^+ may become more toxic and injurious to plants than the Cl^- of Ca^{2+} and Mg^{2+}. At an equal concentration, the mixture of chlorides of Na^+, Ca^{2+} and Mg^{2+} can be less toxic and injurious to plants than the Cl^- of Na^+ alone. There are several reports which indicate that the plants differ in their tolerance to salinity (Kumar *et al*., 2002) suggesting that plants probably differ in tolerance to chloride toxicity. Some crop species and varieties can be found much more tolerant or sensitive to chlorides than the others. Also the higher sensitivity of cereals to salinity has been better explained on the basis of Cl^- accumulation rather than Na^+ (Qadir, 1990). It is therefore essential to identify important commercial crops including cereals tolerant to chloride stress rather than Na^+. Among the cereals, barley is considered as one of the important grains of Pakistan used for forage, grain and industrial purpose, including distilled beverages. Although, considerable research on salt-tolerance of barley has already been done (Naseer *et al*., 2001; Ahmed *et al*., 2003; Bagci *et al*., 2003); but to the knowledge of authors very little attention has so far been paid to the tolerance of barley plants to various chloride salt compositions. This study reports the tolerance of barley plants against various chloride salt compositions.

MATERIALS AND METHODS

This experiment was conducted in an open environment (wire-house) using black colored plastic pots with capacity of 10 kg soil/pot and drainage holes at the bottom. The pots were placed on wooden benches of the wire-house and arranged in a CRD design. The soil filled in the pots was collected from the field previously cropped to cotton. The soil test results (CBSA Research Laboratory) indicated that it was clay loam in texture (26.30% sand, 35.09% silt and 38.61% clay), non-saline (ECe 1.04 dS m^{-1}) and non-sodic (ESP 4.89) in nature, slightly alkaline (pH 7.6), moderately calcareous ($CaCO_3$ 9.32%) in reaction to HCl, low in organic matter (0.97%) and total nitrogen (0.049%) contents. However, it was rich in extractable potassium (178.28 mg kg^{-1}). After overnight soaking barley seeds of local variety, obtained from Wheat Section of Agriculture Research Institute (ARI), Tandojam were sown in the soil. Twenty days after sowing (DAS) seedlings were thinned to five plants per pot and 6 cm apart.

Five chloride salt compositions included in the study were: T_1 = Control (without salt); T_2 = 120 *mM* NaCl T_3 = 120 *mM* $MgCl_2$; T_4 = 120 *mM* $CaCl_2$ and T_5 = 40 *mM* NaCl + 40 *mM* $CaCl_2$ + 40 *mM* $MgCl_2$ (mixture). Salt solution for each treatment was prepared by dissolving the required salt in the distilled water, following the method of Rowell (1994). In the control treatment, plants were only receiving fresh water, whereas in the salt treatments, plants were established with salt solutions. The nitrogen was applied @160 kg N ha^{-1} through urea and diammonium phosphate (DAP), phosphorus was applied @ 80 Kg P_2O_5 ha^{-1} through DAP and potassium was applied @ 80 kg K_2O ha^{-1} through sulfate of potash (SOP). Full dose of phosphorus and potash was applied at the time of sowing, nitrogen was applied in three splits i.e. 1/2 at sowing, 1/3 at 1st irrigation and 1/3 at booting stage.

At physiological maturity plants from each treatment were harvested by cutting with sharp sickle at soil level. The data on plant height (cm) and number of tillers per plant, were recorded. The ear-heads were separated from the straw. The grains were separated by threshing with hands. The data on grain and straw yields per plant were recorded. The straw and grains were then used to determine Na^+ and K^+ contents and calculate the ratio of Na^+ to K^+. The plant data were processed for the analysis of variance (ANOVA) using MINITAB statistical software version-13. Treatment means were compared using SED and LSD tests at 5% probability level.

RESULTS AND DISCUSSION

The results presented in the Table 1 indicate the effect of various chloride salt composition on plant height, number of tillers per plant and straw and grain yields per plant. It is evident from the data that compared to control, the plants stressed with NaCl, $MgCl_2$, $CaCl_2$ and equal mixture of these salts were about 10, 7, 7 and 9% shorter in height, developed 30, 25, 24 and 28 % fewer tillers $plant^{-1}$, showed 49, 43, 33 and 47% reduction in grain yield per plant and 51, 42, 39 and 48 % reduction in straw yield per pant. It appears that compared to Ca^{2+} and Mg^{2+} ions, the Cl^- are more toxic to barley plants in presence of Na^+ ions. As the plants stressed with NaCl and mixture of salts having only 40 *mM* Na^+ showed much more reductions in almost all growth and yield traits. That was possibly the phyto-toxicity jointly created by both Na^+ and Cl^- ions for barley plants in the treatments where NaCl was added. In addition to that plants were also facing dual problem of salinity i.e osmotic effect due to 120 *mM* concentration and specific ion effect due to presence of Na^+ and Cl^-. There are several evidences which indicate that Ca^{2+} detoxifies the effect of toxic ions including Na^+, particularly the Ca^{2+} improves the function of cell membrane (Lin, 2014). The results related to ion contents (Tables 2 & 3) obtained from this study also showed the association of toxic ions like Na^+ and Cl^- determined in grain and straw samples with growth and yield data. The plants stressed with NaCl and salts mixture accumulated more Na^+ and Cl^- and less K^+ both in grain and straw, which also brought down the ratio of K^+ to Na^+ ions. This suggests that Ca^{2+} and Mg^{2+} dilute the adverse effect of Na^+ for plants mainly by improving the physiology of plants.

Table 1. Effect of different chloride salts composition on the growth and yield of barley plants.

Salt composition/ treatments	Plant height (cm)	No. of tillers ($plant^{-1}$)	Grain yield (g $plant^{-1}$)	Straw wt. (g $plant^{-1}$)
T_1: Control (without salt)	49.75	4.58	5.76	6.67
T_2: NaCl (120 *mM*)	44.59	3.21	2.96	3.30
T_3: $MgCl_2$ (120 *mM*)	46.08	3.33	3.30	4.06
T_4: $CaCl_2$ (120 *mM*)	46.19	3.50	3.86	3.50
T_5: Mixture of NaCl + $CaCl_2$ + $MgCl_2$ (120 *mM*)	45.16	3.31	3.03	3.26
SED	1.98	0.69	0.51	1.82
LSD (0.05%)	4.41	1.53	1.15	4.08

Table 2. Effect of different chloride salts on Na^+ and K^+ contents (%) and K^+/Na^+ ratio determined in the grains of barley.

Salt composition/ treatments	Na^+ (%) in grains	K^+ (%) in grains	K^+/Na^+ in grains	Ca^{2+} (%) in grains	Mg^{2+} (%) in grains	Cl^- (%) in grains
T_1: Control (without salts)	0.60	2.12	3.53	0.28	0.29	0.46
T_2: NaCl (120 *mM*)	1.69	0.89	0.53	0.27	0.30	0.84
T_3: $MgCl_2$ (120 *mM*)	0.68	1.14	1.67	0.47	0.48	0.59
T_4: $CaCl_2$ (120 *mM*)	0.65	1.21	1.86	0.65	0.27	0.61
T_5: Mixture of NaCl + $CaCl_2$ + $MgCl_2$ (120 *mM*)	0.89	0.92	1.04	0.58	0.31	0.69
SED	0.04	0.04	0.177	0.20	0.037	0.04
LSD (0.05%)	0.10	0.10	0.396	0.045	0.084	0.089

Table 3. Effect of different chloride salt composition on ion content (%) and K^+/Na^+ ratio determined in straw of barley.

Salt treatments	Na^+(%) in straw	K^+ (%) in straw	K^+/Na^+ in straw	Ca^{2+} (%) in straw	Mg^{2+} (%) in straw	Cl^- (%) in straw
T_1: Control (without salts)	0.61	2.23	3.64	0.24	0.26	0.39
T_2: NaCl (120 *mM*)	2.12	0.92	0.44	0.22	0.27	0.70
T_3: $MgCl_2$ (120 *mM*)	0.68	1.20	1.75	0.39	0.44	0.49
T_4: $CaCl_2$ (120 *mM*)	0.64	1.28	1.99	0.55	0.27	0.51
T_5: Mixture of NaCl + $CaCl_2$ + $MgCl_2$ (120 *mM*)	1.12	1.02	0.92	0.48	0.26	0.57
SED	0.073	0.030	0.007	0.015	0.036	0.033
LSD (0.05%)	0.162	0.067	0.016	0.031	0.081	0.074

CONCLUSION

The study presented here demonstrates that Na eithr alone or in mixtures is much more toxic to rice plants than $CaCl_2$ and $MgCl_2$.

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(Received November 19, 2013; Accepted February 28, 2014)