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RESEARCH ARTICLE

EFFECT OF SALINITY ON Na^+, K^+ AND MICRONUTRIENTS UPTAKE IN SOME CULTIVARS OF OAT (*Avena sativa* L.) AT SEEDLING STAGE

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ABSTRACT

Salinity is a major problem in arid and semi-arid regions of the world. The objective of our study is to investigate the effect of salt stress on uptake of Na^+, K^+ and micro-nutrients at seedling stage. For this purpose seeds of different genotypes of oat (JHO-822, JHO-851, KENT and UPO-94) were grown in Petri-dishes for ten days under different saline conditions (viz. 3, 6, 7.2, 10, 12 and 14 dSm^{-1}). Distilled water was used as control. Results showed that Na^+ content in coleoptiles of oat increased with increasing salinity levels while K^+ decreased .The concentration of micro-nutrients (Fe, Mn, Zn, Cu, Pb and Cd) was differentially affected under saline conditions. Quantitatively, uptake of Fe and Mn was relatively higher in all cultivars while opposite trend was observed by Zn, Cu, Pb and Cd. However, uptake of these elements decreased with the increasing salinity.

Key words: Quantitatively, semi-arid regions, micro-nutrients, seedling, coleoptiles, increasing salinity.

INTRODUCTION

Salinity is a serious problem in arid and semi-arid regions all over the world. Up to 20% of the irrigated arable land is already affected and is still expanding (Muhling and Lauchli, 2003) whereas only in India, around 13.3 million hectares of land is affected by salinity (Consortium For Unfavorable Rice Environment, IRRI, 2003). The adverse effect of salt stress on plant growth is attributed to the specific toxic effect of excessive salt ions that are observed from the saline soil, to the process of building up the osmotic potential of cell, to the imbalance of nutritional cations in tissuses of the salt affected plants which may be because of reduction in carbon fixation during photosynthesis or increase in carbon release in respiration (El-Lawendy, 1990). Differences in salt tolerance exist not only among different genera and species, but also within the different organs of the same sp. (Flower and Haji-bagheri, 2001 and Ismail, 2003). Azevedo-Neto *et al.* (2004) reported that Na content of leaves and roots in maize increases while K content decreases with increasing salinity levels. Cicek and Cakirler (2002) reported that there was a decrease in total fresh and dry weight and plant hight in maize plant subjected to salt stress while there was an increase in the concentration of Na^+/K^+. Amini and Ehasanpour (2005) also found that salt stress increased Na^+ and decreased K^+ content in two cultivars of tomatoes. Na^+ competes with K^+ uptake through Na^+-K^+ co-transporters, and may also block the K^+ specific transporters of roots under salinity (Zhu, 2003). Salinity can differentially affect the micronutrient concentration in the plant, depending upon the crop sp. and salinity level. Salinity decreased Mn and Zn concentration in shoots of corn (Hassan *et al.*, 1970 a, b) but increased in rice (Verma and Neue, 1984). Salinity similarly increased Fe concentration in the shoots of lowland rice (Verma and Neue, 1984) but decreased it in barley and corn (Hassan *et al.*, 1970 a, b). Salinity's influence on Cu accumulation was also variable. Cu concentration in leaf and shoot was found to be decreased in salt stressed maize grown in both soil (Rahman *et al.*, 1993) and solution cultures (Izzo *et al.*, 1991). Nadia Gad (2005) and Mass *et al.* (1982) reported that increasing salinity levels in the plant media significantly decreased Mn, Zn, and Cu in shoots and roots of two tomato cultivars. Oat (*Avena sativa* L.) is an important cereal forage crop and is considered as salt tolerant. It is highly nutritious for human and cattle consumption. The purpose of present investigation is to test the Na^+, K^+, and micronutrients uptake under saline water irrigation.

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MATERIAL AND METHODS

Four varieties viz. JHO-822, JHO-851, UPO-94 and KENT were used to study the effect of salinity on Na^+, K^+ and micronutrients up take. The pure line seeds of these varieties were obtained from IGFRI, Jhansi, Uttar Pradesh and G. B. Pant University of Agriculture and Technology, Pantnagar, Uttaranchal. Seeds were surface sterilized with 0.01% $HgCl_2$ for a minute and then washed repeatedly with deionized water. Twenty five seeds of each variety were grown in Petri-dishes, lined with Whatman filter paper no. 1 and moistened with 10 ml of aqueous solution of different salinity levels. Distilled water was used as control. Saline solution of different electrical conductivities viz. 3, 6, 7.2, 10, 12 and 14 dSm^{-1} were prepared by mixing the salts of NaCl, $CaCl_2$, $NaHCO_3$ and Na_2SO_4 as described by USSL Staff Hand Book (1954). This experiment was setup in a completely randomized design with three replicates to eliminate the experimental error. Ten days old seedlings of similar size were collected randomly from different saline levels including control (0-14 dSm^{-1}). The seedlings were washed in distilled water and were put on filter paper, so that water is absorbed by the paper. Coleoptile and root of each seedling were separated. The coleoptile samples were dried in hot air oven at 60^0 C for 48 hours. After drying, the samples were ground into fine powder, which were used for the estimation of Na^+, K^+ and micronutrients (Fe, Mn, Cu, Zn, Cd and Pb) uptake following the method of Trolson (1969). For the determination of elemental analysis, 1 gm of ground dry material of coleoptile was digested in the flask with 5 ml of concentrated HNO_3 and 1 ml of concentrated H_2SO_4. They were mixed well and kept overnight at room temperature, followed by digestion on hot plate until the volume of samples was reduced to one ml. In these remains, 3 ml of double acid mixture of HNO_3 and $HClO_4$ in 3:1 ratio was added and again digested until white fumes came out from the samples. These samples were diluted with 2 ml of triple distilled water and filtered through Whatman filter paper no.1. Repeated washings of digestion flask and filter paper were done by taking 0.5 ml of distilled water and finally it was made upto 50 ml. Sodium-potassium ions were estimated by Flame Photometer 128 (systronic) and microelements were analyzed by Atomic Absorption Spectrophotometer (AAS) model AAS4139 which was manufactured by Electronic Corporation of India Limited (ECIL), Hyderabad – 500062. Concentration of Na^+, K^+ and micronutrients has been expressed in ppm. The data were subjected to statistical analysis for the variance by minitab statistical program (Minitab Inc., States College, D. A.).

RESULT AND DISCUSSION

Na^+ and K^+ uptake

The effect of salt stress on uptake of Na^+ and K^+ in oat genotypes is shown in figures (A, B, C, D and F) The results indicate that concentration of Na^+ significantly increased with increasing salinity levels in all cultivars, however, concentration was relatively lower in cvs. JHO-822 and JHO-851 than cvs. UPO-94 and KENT. The cultivars JHO-822 and JHO-851 registered 0.24-2.76 ppm Na^+ concentration while cvs. UPO-94 and KENT recorded 0.28-4.06 ppm in control and in all salinity levels (3 to 14 dSm^{-1}). It is evident that 10 to 13 folds higher Na^+ content were found in cv. UPO-94 at 12 and 14 dSm^{-1} when compared with control and cv. JHO-822 had 8.0 and 9.8 folds higher Na^+ content at these levels of salinity as compared to control set. The present findings are in consistence with the findings of Haq *et al*., 2003 who reported that Na^+ concentration increased 1.2 to 15 dsm^{-1} and this increase was 13.3 folds as compared to plants grown under non-saline condition. Mohamedin *et al.* (2006) noted that Na^+ content in leaves of salt tolerant rape genotypes was higher than salt sensitive ones. It is clear from the results that K^+ exhibited an opposite trend which indicated lower concentration as salinity increased. K^+ content was significantly higher in cultivars JHO-822 and JHO-851 while cvs. UPO-94 and KENT showed lower concentrations under both saline and non-saline conditions. All the four cultivars registered significant reductions which were 13 to 141, 19 to 53, 25 to 57 and 27 to 62% respectively at 6 to 14 dSm^{-1}. These findings are similar with findings of Asraf (2002) in cotton leaves, Mohamedin *et al.* (2006) in sunflower and Demiral *et al*. (2005) in barley. Baga *et al.* (2003) also found that there is an inverse relation between K^+ and Na^+ ion of eight difffrent barley cultivars grown under increasing salinity levels. Lacerda *et al*. (2003) and Mohamedin (2006) also reported that high levels of Na^+ inhibited K^+ concentration in sunflower plants which resulted in an increase in the Na^+/K^+. Parihar *et al.* (1990) revealed the effect of salinity (4, 8, 12 and 16 mmohs/cm) on ATPase activity as well as Na^+ and K^+ uptake in seedling of *Trifolium alexandrium.* ATPase activity and K^+ uptake decreased and Na^+ uptake increased with increasing salinity regimes. Statistical analysis indicate that Na^+/K^+ in all cultivars significantly increased with increasing salinity from 3 to 14 EC as compared to controls. Cvs. JHO-822 and JHO-851 registered lower Na^+/K^+ which ranged from 0.03 to 0.62 and 0.04 to 0.64 respectively in controls as well as in all salinity levels. Cvs. KENT and UPO-94 had higher values of Na^+/K^+ which ranged from 0.04 to 1.36 and 0.05to 1.84 respectively in controls and in all salinity levels.

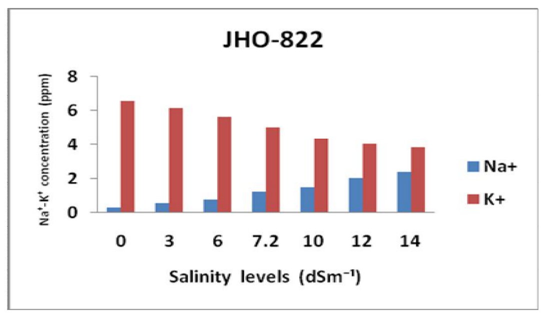


Figure-A

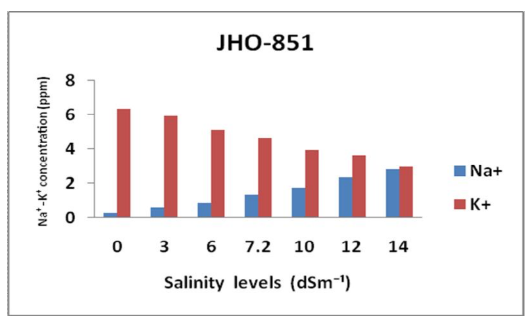
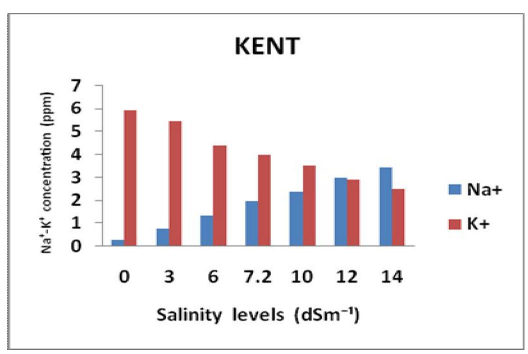


Figure-B



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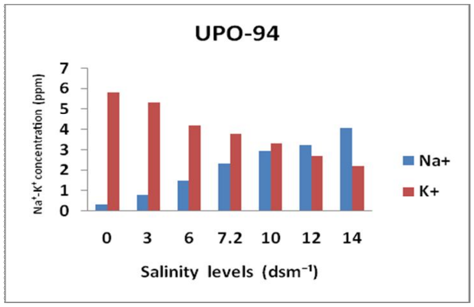


Figure-D

Figure A, B, C & D: Uptake of Na^+ and K^+ in oat (*Avena sativa* L.) cultivars at seedling stage under salt stress

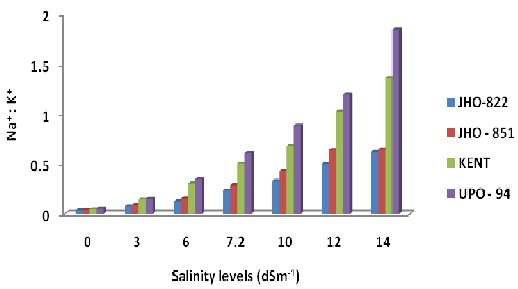


Figure - E: Na^+: K^+ in different cultivars of oat (*Avena sativa* L.) at seedling stage under salt stress

Present findings demonstrate that Na^+/K^+ significantly increases in all cultivars with increasing salinity levels. These findings are also similar to the findings of Mercum and Murdoch (1992) in tuff-grass, Naidoo and Naidoo (1998) and Bell and O'Leary (2003) in *S.virginicus*, Netado *et al.* (2004) in sorghum, Othman *et al*. (2006) in barley and Zhao *et al.* (2007) in oat. Bhivare and Nimbaker (1984) reported that the reduction in K^+ and increase in Na^+ in plant could be attributed to the effect of competition of Na^+ and K^+ on the absorptive site of the plants. Na^+/K^+ may serve as an indicator of tolerance to stress as the increase of Na^+ in salt tolerance species is generally associated with a decreased in K^+ (Greenway and Munns, 1980). The reduction in K^+ concentration causes a growth reduction by decreasing the capacity of plants for osmotic adjustment and turgor maintenance or by the negative effects on the metabolic functions such as protein synthesis (Greenway and Munns, 1998). The increase in Na^+ concentration was also accompanied by decrease in K^+ concentration and uptake. Thus, growth disruption was observed in root and shoot of the seedling either due to the increased absolute concentration of the sodium in tissue or increased Na^+/K^+ (Kumar, 2006).

Micro-nutrients uptake

Micro elements are also essential for plant growth like macro elements. They occur in very small quantities in both plant and soil, but their deficiencies cause harmful effect on plants. Most of the mineral elements inhibit plant growth when their concentration exceeds a certain level. Some of the mineral elements antagonize the usual effect of other elements. Present findings indicate that concentration of micro-nutrients (Fe, Mn, Zn, Cu, Cd and Pb) declined with increasing salinity levels. Uptake of Fe and Mn was quite higher in all genotypes than Zn, Cu, Cd and Pb. The concentration of micro nutrients present in four genotypes was in order of Fe> Mn> Pb> Zn> Cu> Cd. Reduction in plant growth due to the decrease in micro and macro nutrients under salinity has been reported in several other plants species (Reuthur *et al.* 1998; Thanunathan *et al.*, 2000; Malarvizhi and Rajamannar, 2001 in *Sorghum*; Nadia Gad, 2005 in tomato; Hasan *et al.*, 1970 in corn and barley). Sharma *et al*. (1990) reported that saline irrigation decreased Fe uptake in *Sesamum indicum* and *Phaseolus vulgaris*. This may be due to the formation of $CaCO_3$ which react with Fe^{3+} resulting in $Fe(CO)_3$ as Fe^{3+} is not available for plant growth (Dahiya and Singh, 1986). On the other hand Lazof and Bernstein (1999) have determined that salinity had no effects on Fe concentration in lettuce leaf. In general, iron content was invariably higher in cv. UPO-94 and KENT when compared with JHO-851 and JHO-822. The iron content was 132 and 123 ppm in control sets of UPO-94 and KENT while cvs. JHO-851 and JHO-822 contained 87 and 82 ppm. At 3 and 6 dSm^{-1}, all genotypes registered 7-21% reductions. It is apparent that cv. UPO-94 showed 43-55% and KENT registered 42-56% reductions at 10-14dSm^{-1}. JHO-851 registered 41-59% while JHO-822 recorded 42-61% reductions at the same levels of salinity. This clearly indicates that the general reductions in iron concentration raised from 40-60% in all genotypes but the values have differed significantly in different varieties.

It was further interesting to observe that all varieties have shown gradual reductions in Fe content but at 14 dS m^{-1}, JHO-851 and JHO-822 recorded 59 and 61% while sensitive genotypes (UPO-94 and KENT) registered 55 and 56% reduction. Analysis of variance indicates that Mn concentration was significantly reduced in all genotypes at all salinity levels. It is observed that cvs. JHO-822, UPO-94 and JHO-851 showed marginal reductions (10-11%) at 3dSm^{-1} while KENT registered a drastic reduction (25%). As level of salinity raised from 6 to 7 dSm^{-1}, JHO-851, JHO-822, UPO-94 showed 24-31, 18-32 and 19-38% reductions while KENT recorded 33-45% at this salinity levels. At higher levels of salinity (10, 12 &14 dSm^{-1}), cultivar JHO-851 and JHO-822 registered 38-65% while UPO-94 and KENT registered 48 to 70% reductions but the Mn content differed significantly in different genotypes. The data indicate 15 to 28 ppm in JHO-851, JHO-822 and KENT whereas the most sensitive genotype UPO-94 registered 18-29 ppm at 10-14 dSm^{-1} (figure -F). These results are similar to that of Nadia Gad (2005) and Tuncturk *et al*. (2008) who also reported reduction in Mn content under salinity stress in shoot and root of tomatoes and soybean respectively. Contrary to this, Wang and Han (2007) reported that salinity significantly increased the concentration of Mn in the shoots and leaves of alfalfa plant.

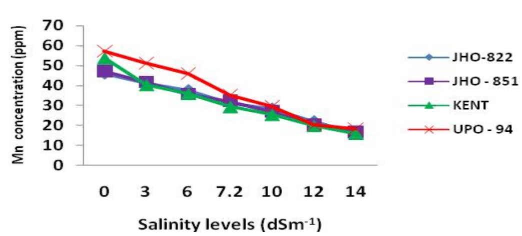
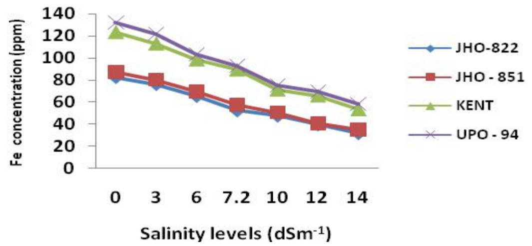


Figure-F



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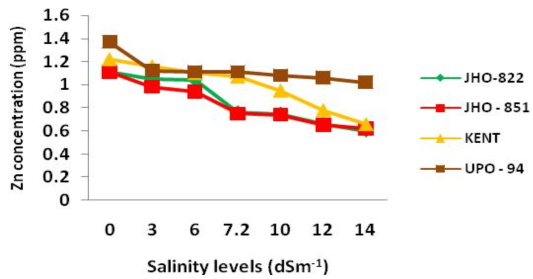

Figure-H

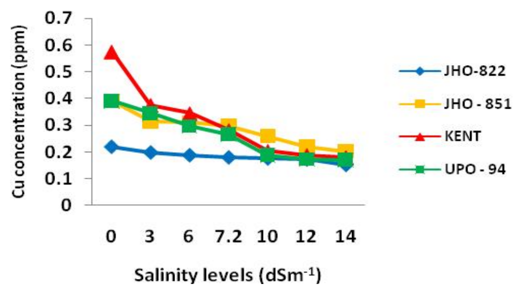

Figure-I

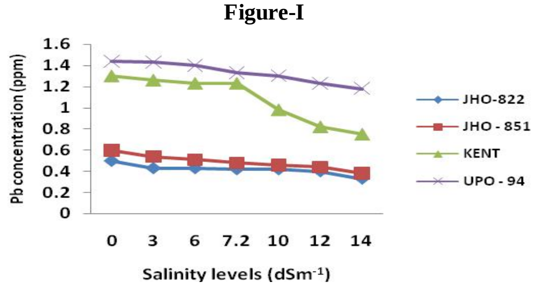

Figure-J

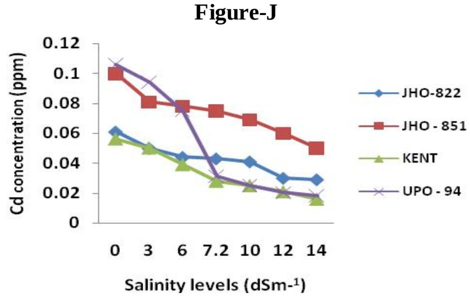

Figure-K

Figures: Effect of salinity on Fe concentration in different cultivars of oat (*Avena sativa* L.) at seedling stage

Zn accumulation in oat genotypes exposed to various salinity levels has been shown in figure (H). Zn content was higher in sensitive cultivars as compared to the tolerant genotypes. Under non-saline condition, concentration of zinc in sensitive cultivars was 1.37 and 1.22 ppm whereas in both tolerant cultivars, the concentration was 1.11 ppm. As the salinity increased from 6 to 14 dSm^{-1}, Zn accumulation was significantly reduced in different genotypes, however, it was less affected in UPO-94. It is observed that JHO-851, JHO-822 and KENT contained 0.6 -1.0 ppm of Zn whereas UPO-94 registered 1.0-1.1 ppm at these levels of salinity. Tolerant varieties JHO-851 and JHO-822 registered higher reductions (32-41%) as compared to UPO-94 and KENT (12-36%) at 7.2, 10 and 12 EC. At 14 dSm^{-1}, cv. UPO-94 showed least reduction (25.16%) while KENT, JHO-851 and JHO-822 revealed 43.6, 45.68 and 45.64% respectively. Present findings indicate significant reduction in zinc concentration in all oat genotypes which confirm the findings of Al-Harbi (1995) who also reported decreased Zn concentration in cucumber leaves.

Zinc concentration in shoot tissues of wheat and tomato has been found to decrease with increasing salinity (Khoshgofter, 2004 & Nadia Gad, 2005). Tolerant genotypes (JHO-851 and JHO-822) registered higher reductions (32-41%) while sensitive genotypes (UPO-94 and KENT) showed lower (12-36%) reductions at 7.2, 10 and 12 EC. Tuncturk *et al.* (2008) found that zinc content decreased in shoot and leaves of some cultivars of *Glycine max*. In most of the cases, salinity increases the content of Zn in plant tissues of maize (Rahman *et al.*, 1993), wheat and rice (Alpaslan *et al.*, 1998), strawberry (Turhan and Eris., 2005) and alfalfa (Wang and Han., 2007). Analysis of variance indicates significant reductions in Cu at all salinity levels in all cultivars. Under non-saline conditions Cu concentration was similar in cvs.JHO-851 and UPO-94 (0.39 ppm) whereas JHO-822 and KENT registered 0.21and 0.57 ppm respectively. At lower salinity level (3dSm^{-1}), cvs.JHO-851 and KENT registered higher content (19-34%) while cvs.JHO-822 and UPO-94 revealed lesser reductions (9 and 12%). Accumulation of Cu in JHO-851 and KENT was higher at 6 to 14 dSm^{-1} when compared with JHO-822 and UPO-94 (figure-I). It was also observed that tolerant cultivars (JHO-851 and JHO-822) registered lower reductions (14 - 48%) while sensitive genotypes (KENT and UPO-94) showed higher reductions (24-68%).

Rahman *et al.* (1993) and Izzo *et al*. (1991) also reported that Cu concentration in shoots and leaves was decreased in salt stressed maize grown in both soil and solution cultures. Cu content in shoots and roots of two cultivars of tomato was also found to decrease significantly with increasing salinity levels (Nadia Gad, 2005). Wang and Han (2007) also determined that salinity reduced the uptake and concentration of Cu in alfalfa plants. Figure (J) indicates that salt treatment reduced the accumulation of Pb in all four cultivars of oat, however the varietal differences were evident. The most sensitive cultivar UPO-94 registered highest Pb content at different levels of salinity. Under non-saline condition, JHO-851, JHO-822, KENT and UPO-94 contained 0.6, 0.5, 1.3 and 1.4 ppm. At 3EC level, non-significant reductions were observed in all genotypes except for JHO-822. Irrigation with 6 EC water had no significant effect on Pb content in cvs. UPO-94 and KENT while rest two cultivars showed significant decline (14-15%). As the level of salinity raised from 7.2 to 14 dSm^{-1}, significant decline was observed in all genotypes except for KENT at 7.2 EC. Similar results were obtained by Kadukova and Kalogerakis (2007) who found that low salinity did not affect the uptake of lead by roots of *Tamarix smyrnensis* but at high salt concentration in soil, Pb accumulation was decreased by 21% in comparison with the amount of lead accumulated without salt addition into soil. The opposite trend was observed in the leaves where more Pb was accumulated at high salt concentration in soil. In contrast, Fitzgerald *et al.* (2003) observed that monocotyledonous species contained higher concentration of Pb in the roots as compared to shoots. The effect of salinity on Cd concentration in oat cultivars is shown in figure (K). All investigated genotypes indicate that Cd content reduced with increasing salinity levels. Accumulation of Cd differed in different cultivars at different salinity levels. Under non-saline condition, both JHO-851 and UPO-94 registered 0.10 ppm while JHO-822 and KENT recorded 0.06 and 0.05 ppm respectively. At 3EC level, non-significant reduction was observed in different varieties except for UPO-94. As salinity raised from 6 to 7.2 dSm^{-1}, cv.JHO-851 showed non-significant reductions while JHO-822, UPO-94 and KENT registered significant reductions.

It was interesting to observe that JHO-851 and JHO-822 exhibited gradual reductions (22-25 and 27-29%) while KENT and UPO-94 showed drastic reductions (30-50 and 29-70%). It is clearly indicated that cvs. JHO-851 and JHO-822 registered 31-52% reduction at 10-14 dSm^{-1}. UPO-94 showed 76-83% while KENT recorded 55-71% reduction at same salinity levels. This clearly indicates that the sensitive varieties UPO-94 and KENT registered higher reductions while the tolerant varieties (JHO-851 and JHO-822) registered lower reductions at higher levels of salinity. This is in accordance with findings of Huang *et al.*, (2007) who found that addition of NaCl in Cd containing medium caused remarkable reduction in Cd in barley. The tolerant genotypes (JHO-851 and JHO-822) had lower reductions (31-52%) at higher levels of salinity (10-14 EC) while sensitive ones (UPO-94and KENT) registered higher reductions (55-83%). In contrast, salinity increased Cd concentration in roots of spinach (Helal *et al.*, 1998). Higher concentration of heavy metals (Pb and Cd) is toxic and would certainly kill the common non accumulator plants (Baker *et al.* 1994). Dahdoh *et al.* (2005) pointed out that the variation in this element may also depend on soil type, the type of irrigation water and plant species.

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