academicJournals

Vol. 12(18), pp. 2366-2377, 1 May, 2013
DOI: 10.5897/AJB2013.12161
ISSN 1684-5315 ©2013 Academic Journals
http://www.academicjournals.org/AJB

African Journal of Biotechnology

Full Length Research Paper

The effect of salinity on growth and anatomical attributes of barley seedling (*Hordeum vulgare* L.)

Saule Atabayeva[1], Akmaral Nurmahanova[1], Subhash Minocha[2], Aygul Ahmetova[1], Saule Kenzhebayeva[1]*, Saule Aidosova[1], Asil Nurzhanova[3], Anar Zhardamalieva[1], Saltanat Asrandina[1], Ravilya Alybayeva[1], and Tamara Li[3]

[1]Al-Farabi Kazakh National University, Almaty, Kazakhstan.
[2]New Hempshire University, Durham, USA
[3]Institute of Plant Biology and Biotechnology, Almaty Kazakhstan.

Accepted 11 April, 2013

The objective of the present work was to identify the tolerance of barley varieties to salinity and determine specific anatomical features of barley plants under saline conditions. Plants were grown in hydroponic conditions in three variants: control, 50 mM NaCl and 100 mM NaCl. The tolerant and sensitive varieties of barley to salinity were identified. The results show that salinity reduced the growth and biomass accumulation of plants, reduced the thickness of the upper and lower epidermis, reduced the diameter of the vascular bundles of leaves and the central cylinder of roots and increased the ratio of exodermis/endodermis roots in some varieties.

Key words: Barley, salinity, growth, biomass, epidermis, exodermis, endodermis, vascular cylinder, central cylinder.

INTRODUCTION

Saline soil is a major problem for agriculture arid and semi-arid regions. It is estimated that one third of the world's land surface is arid or semi-arid and half is affected by salinity (Bradbury and Ahmad, 1990). It is important to note that the problem of salinity increases, often due to poor agricultural practices. Irrigated land around is particularly at risk. Despite its relatively small area, irrigated land is estimated to produce one-third of the world's food (Munns, 2002). According to the Agency of the Republic of Kazakhstan on Land Management, saline soils cover 94.9 million ha (42.1%). In the steppes of Kazakhstan, groundwater is strongly mineralized and saline water penetrates into the ground water; raising its level (http://www.ca-oasis.info/oasis/?jrn=22&id=157). A major threat to water resources in the South and South-east of the country is irrigated agriculture.

Salinization of irrigated soils, as a factor in desertification, has two major aspects: the growth of saline desert and salinization of irrigated land. Glycophytes, as well as halophytes in saline conditions adapt to changes in salt stress in the physiological, biochemical and anatomical parameters (Akram et al., 2002). Plants have to cope with two major stresses, under high salinity- osmotic stress and ionic stress (Horie et al., 2012). Significant inhibitory effect of salinity on plant growth and yield was observed in different plants (Dhanapackiam and Muhammad, 2004; Ali et al., 2004; Ali et al., 2009; Chookhampaeng, 2011). Salinity leads to inhibition of water uptake (Munns and Tester, 2008) because of high cytoplasmic water potential in saline conditions compared to growth medium and impossibility of water uptake by plants (Horie et al., 2012). Salinity stress directly or via hormonal regulation (Jia et al., 2002) induces a stomatal closure, which leads to a reduction in the evaporation. The direct consequence of the lower stomata conductance is the decrease of photosynthesis, depression in carbon uptake, and inhibition

*Corresponding author. E-mail: sauleat@yandex.ru

of photochemical capacity (Kaouther et al., 2012; Horie et al., 2012). Accumulation of Na^+ in the cytoplasm develops toxicity and disturbs essential cellular metabolisms such as protein synthesis, enzyme activity, chlorophyll synthesis and photosynthesis (Glenn et al., 1999; Munns, 2002; Kaouther et al., 2012). To protect cells under salinity stress, plants evolve physiological and biochemical mechanisms that allow them to cope with them (Zhang et al., 2006) by synthesis of a number of compatible solutes like proline, glycin-betaine, etc. Compatible solutes were determined as compounds that are non-toxic even though they highly accumulate in the cytosol and contribute to decrease in the cytoplasmic water potential (Horie et al., 2012). Another way to adapt to salinity stress is to keep cytosolic Na^+ levels low at the cellular level and to keep shoot Na^+ concentrations low at the whole plant level. Maintenance of high cytosolic K^+/Na^+ ratios especially in shoots has been strongly suggested to be crucial for salt tolerance of gycophyte plants (Ren et al., 2005; Yarraguchi and Blumwald, 2005; Hauser and Horie, 2010). Besides physiological and biochemical adaptations, plants adapt to saline conditions by changes in the anatomical structure of leaves and roots as well as changes in morphology (Ola et al., 2012). Morphology and anatomy of leaf and roots are affected by salt stress. Salinity induced reduction in almost all morphological and anatomical variables (Cecoli et al., 2011). High salinity mostly causes anatomical alterations such as reduction of somata number (Çavişoğlu et al., 2007), decrease of length of bundle, xylem rows, number of vessels and increase in both spongy and palisade tissue (Hussein et al., 2012).

The study of salinity effect on anatomical structure of kallar grass leaves and stems showed a significant decrease in mid vein thickness, lamina thickness, mesophyll thickness and mesophyll area along leaf axis with increasing salinity level (Ola et al., 2012). NaCl treatment causing inhibition of growth of vascular system in mungbean seedlings was observed by Rashid et al. (2004). Under the salinity stress in plants, a decrease in cell size, changes in the number of stomata, reduction in thickness of the epidermis of leaves of the apical meristem, cortex and central cylinder diameter were shown (Reinhardt et al., 1995; Javed et al., 2001), as well as enhanced development of sclerenchymatous tissue on the adaxial and abaxial sides (Javed et al., 2001). Salinization leads to anatomical changes in the structure of the cell wall. In the experimental variants of plants, it was observed that a decrease in the ratio of the central cylinder of the cortical parenchyma (Cecoli et al., 2011) indicated reduction in the diameter of the central cylinder. In plants such as *Vracbiaria decumbens*, it was observed that there was thickening of exodermis and endodermis, increase of intercellular spaces in the cortex and strong lignifications of exodermis cells (Degenhardt et al., 2000; Gomes et al., 2011). The successful development of agriculture in disadvantaged areas depends on selection of appropriate crops and crop varieties that are resistant to the effects of salinity. Selection of salt tolerant crop varieties of agricultural crops is one of the most effective tools for improving productivity of these soils. It is important to study the effect of salinity on growth and anatomical structure and to use physiological, anatomical and molecular studies to select tolerance to salinity agricultural crop varieties for cultivation in saline soils. The present investigation was, therefore, undertaken to study the effect of salinity on the growth and anatomical structure of widely cultivated barley varieties in Kazakhstan. The objective of the present work was to determine the peculiarities of growth and anatomical structure of barley cultivars under saline conditions.

MATERIALS AND METHODS

Seven barley varieties were used in this study: Arna, Bastama, Odesskaya-100, Ilek-42, Inkar, Saule, and Asem. Seeds of plants were germinated in a growing chamber at 25°C. After 48 h, plantlets were transferred to 1 L pots filled with solutions, containing different concentrations of NaCl. Plants were grown in hydroponic conditions seven days in solutions containing various concentrations of NaCl. Three treatments were used which were defined as no NaCl added (control), 50 mM NaCl (low NaCl concentration) and 100 mM NaCl (high NaCl concentration). Measurement of biometric parameters was made according to routine methods.

Anatomical analysis

Conservation of plants was carried out by the method of Strasburger-Flemming (Prozina, 1960). Preservative fluid is a mixture of alcohol-glycerol-water in a ratio of 1:1:1. Fixation was performed in 96% ethyl alcohol. Tubers and vegetative parts of the studied plants were recorded. Anatomical specimens were prepa-red with a microtome having a freezing unit TOC-2. Sections were placed in glycerine and balsam in accordance with conventional techniques of Prozina (1960), Permyakova (1988) and Barykina (2004). The thickness of the anatomical sections was 10 to 15 microns. For a quantitative analysis, morphometric parameters were measured using ocular micrometer MOV-1-15 (with lens x 9 and increase x 10.7). Micrographs of anatomic sections were made on a micro-scope with a camera MC 300 CAM V400/1.3M.

Statistical analysis

Samples for measurement of growth parameters (length and biomass accumulation) and anatomical analysis were mean of three samples for each treatment. The data of the experiment were analysed statistically using two-way analysis of variance (ANOVA), with varieties and treatments as main effects of shoots and roots length, their biomass and anatomical structure.

RESULTS AND DISCUSSION

Effect of NaCl on growth parameters of barley plants

The effect of NaCl on the growth of seven barley (*Hordeum vulgare* L.) varieties (Arna, Bastama, Odesskaya 100, Ilek-42, Inkar, Saule, Asem) was studied. The analysis of variance for shoots and root length, shoot and root biomass is presented in Table 1 and it showed significant effect ($p < 0.05$) of salinity on all studied traits (Table 1). At 50 mM NaCl, roots length of Saule variety slightly exceeded that of the control (106%); other varieties at

Table 1. Effect of NaCl on growth parameters of barley varieties

Treatment*	Height of shoots**		Length of roots***	
	Sm	%	Sm	%
Arna				
Control	11.67±0.51	100	9.17 ± 0.46	100
50 mM NaCl	10.77±0.15	92	5.81 ± 0.39	63
100 mM NaCl	4.08±0.52	41	2.06 ±0.75	23
Bastama				
Control	16.35±0.83	100	7.96±1.48	100
50 mM NaCl	13.82±0.12	85	5.03±0.82	63
100 mM NaCl	5.43±0.38	33	2.01±0.46	25
Odesskaya-100				
*Control	17.65±0.63	100	18.77±1.29	100
*50 mM NaCl	12.43±0.26	70	4.86±0.49	26
*100 mM NaCl	6.63±0.67	38	4.76±0.88	25
Ilek-42				
Control	14.47±0.27	100	5.23±1.59	100
50 mM NaCl	10.4±0.99	72	4.06±0.07	78
100 mM NaCl	7.63±1.02	53	2.01±0.76	55
Saule				
Control	14.23±0.95	100	7.46±0.48	100
50 mM NaCl	11.97±0.99	84	7.94±0.36	106
100 mM NaCl	12.26±0.15	86	6.83±0.18	91
Inkar				
Control	15.9±0.46	100	18.6±0.96	100
50 mM NaCl	7.63±0.21	48	2.53±0.27	13
100 mM NaCl	5.13±0.26	32	2.66±0.19	14
Asem				
Control	16.92±0.30	100	17.45±1.61	100
50 mM NaCl	17.52±0.52	104	10.67±0.48	61
100 mM NaCl	10.35±0.32	61	8.15±0.61	47

*Differences within variety across treatments are significant ($p<0.01$); **differences across varieties for shoots are significant ($p<0.1$); **differences across varieties for roots are not significant ($p>0.1$).

this concentration showed a decrease of roots length but at 100 mM, roots length of Saule variety decreased by 9%.

Application of intense salinity stress (100 mM) showed a decrease in length of shoots and roots as compared to control in all studied varieties ($p < 0.01$): Saule (86 and 91%, respectively); Asem (61 and 47%, respectively); Ilek - 42 (53 and 55%, respectively); Arna (41 and 23%, respectively); Odesskaya - 100 (38% and 25%, respectively); Bastama (33 and 25%, respectively); Inkar (32 and 14%, respectively). At low concentration (50 mM NaCl), shoots biomass of Arna, Bastama, Odesskaya-100, Asem varieties exceeded that of the control at 109, 130, 163, 164%, respectively. At high concentration of NaCl (100 mM), the biomass of all varieties decreased, except Asem cv. The shoot biomass of Asem variety was slightly higher than that of the control (106%). The biomass of shoots of Saule variety decreased by 33% (Figure 1). The means comparison between all varieties for the studied growth traits showed that salinity stress had significant adverse effect on biomass of shoots of Odesskaya-100 (38%), Bastama (30%) and Inkar (29%). At 100 mM NaCl, the roots length of Bastama, Odesskaya-100, Arna and Inkar varieties was reduced significantly by 75, 75, 77 and 86%, res-pectively ($p < 0.01$). At this concentration (100 mM NaCl), the root length of the varieties decreased in the following order: Saule (91%) > Ilek - 42 (55%) > Asem (47%) > Odesskaya - 100 (25%) = Bastama (25%) > Arna (23%) > Inkar (14%) ($p < 0.01$).

On shoot length varieties, the order was arranged as follows: (% to control) > Saule (86%) > Asem (61%) > Ilek - 42 (53%) > Arna (41%) > Odesskaya-100 (38%) > Bastama (33%) > Inkar (32%) ($p < 0.01$).

The observations in this study are in agreement with similar studies on different plants (Magio et al., 2007; Neocleous and Vasilakakis, 2007; Singh and Prasad, 2009). It has been observed from various studies that increasing salinity is accompanied by significant reduction

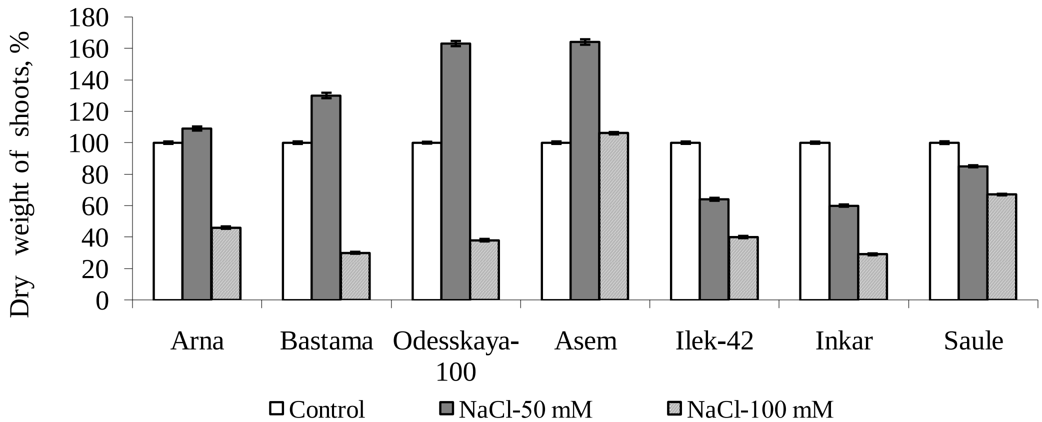

Figure 1. Effect of NaCl on shoots biomass of barley.

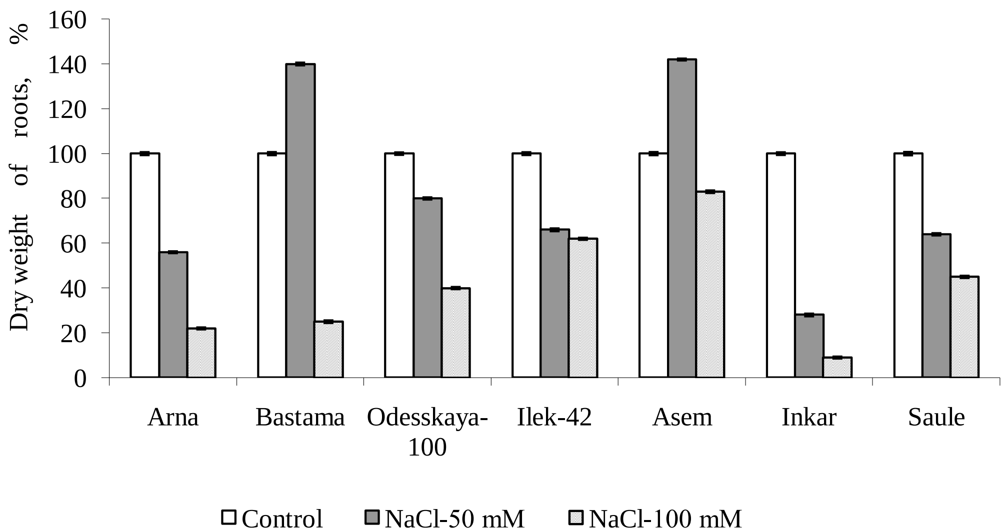

Figure 2. Effect of NaCl on root biomass of barley.

in root, shoot, leaf biomass, shoot and root length, plant height, and number of leaves per plants (Meloni et al., 2001; Maggio et., 2007).

At 100 mM NaCl, the biomass of shoots decreased in the following order: Asem (106%) > Saule (67%) > Arna (46%) > Ilek - 42 (40%) > Odesskaya - 100 (38%) > Bastama (30%) > Inkar (29%) and roots biomass - Asem (83%) > Ilek - 42 (62%) > Saule (52%) > Odesskaya - 100 (40%) > Arna (22%) > Bastama (20%) > Inkar (9%) (Figures 1 and 2).

In our experiments, ratio of shoot/root biomass in relatively tolerant varieties did not change with increasing (Asem cv) or decreasing (Saule and Ilek-42 cvs) NaCl concentration, while in other cultivars, this ratio increased. The significantly higher shoot/root ratio at the highest salt level indicated that the accumulated dry mass in roots was more affected than the one in the shoot (Ceccoli et al., 2011).

Thus, it is seen in this work that biomass accumulation by barley varieties was significantly affected by salinity. Although growth continues even at high salt concentrations, shoot dry mass was significantly reduced except for Asem variety (Table 1). The same response was observed by other authors in *Pennisetum clandestinum* Hochst (Muscolo et al., 2003). The decrease of plant growth and biomass accumulation under salinity stress have been shown by other authors (Magio et al., 2007; Neocleous and Vasilakakis, 2007; Singh and Prasad, 2009). Salinity limits plant growth and productivity (Ghazi and Al-Karaki, 2006; Ashraf and Foolad, 2007; Rewald et al., 2012). Decrease of root weight of soybean was parallel with enhancement of NaCl concentration in nutrition solution. Salinity stress diminished plant growth and decreased total dry weight (Dolatabadia et al., 2011). The reduction in growth under salinity stress could be due to the low water potential, reduction of photosynthesis (Wang et al.,

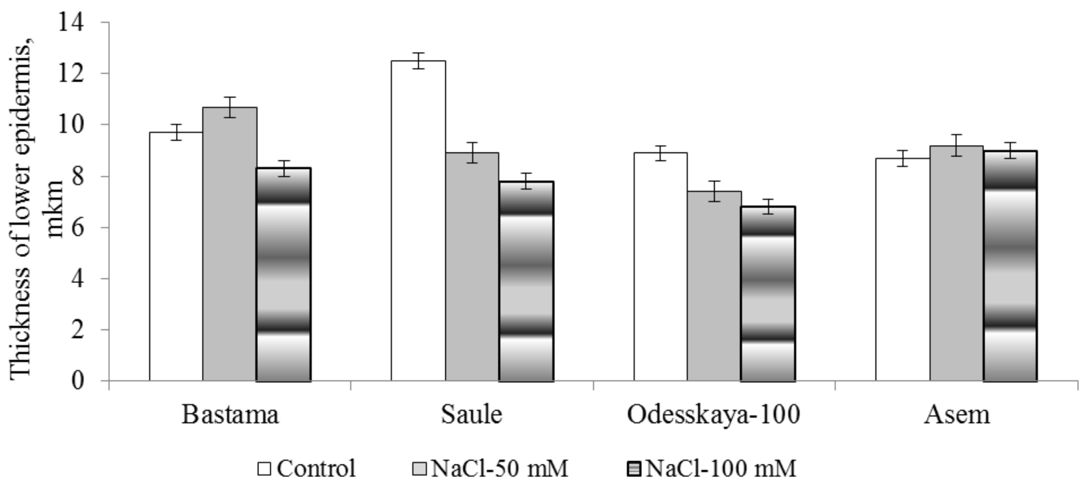

Figure 3. Effect of NaCl on thickness of lower epidermis barley leaves.

2012; Abou-Leila et al., 2012; Boughalleb et al., 2012), ion toxicity (Munns et al., 2006) and disturbance in mineral uptake (Abou-Leila et al., 2012).

Comparing the barley varieties, Asem and Saule cvs had the highest means of length and biomass of roots and shoots in relation to control under salinity stress. Inkar, Bastama and Odesskaya -100 were sensitive to salinity stress.

Anatomical peculiarities of leaf and root structure of leaf and roots of barley (*Hordeum vulgare* L.) under salinity (NaCl) stress

For anatomical studies, varieties were taken with contrasting growth parameters in resistance to NaCl: Asem, Saule, Bastama and Odesskaya-100. The results of this study show that the thickness of lower epidermis of the leaves of Bastama (110% at 100 mM NaCl) and Asem (105 and 103% at 50 and 100 mM NaCl) varieties was slightly greater than that of the control but the differences were not significant ($p > 0.05$) (Figures 3 and 4).

The leaf blade of Saule and Odesskaya-100 varieties presented a smaller thickness of lower epidermis at 100 mM NaCl (24 and 38%, respectively) compared with other varieties (Figure 3). Under intensive salinity stress of 100 mM NaCl, Saule cv had the highest level of decrease in the width of lower epidermis (by 38%).

At high concentration of NaCl (100 mM), the thickness of the upper epidermis of leaves of almost all the varieties showed a tendency to decrease, except Saule var., whose upper epidermis thickness exceeded that of the control (16 and 5% at 50 and 100 mM NaCl). At low NaCl concentration (50 mM), Odesskaya-100 variety had increase in thickness of the upper epidermis over the control variant by 40% (Figure 5). The largest decrease in the thickness of the upper epidermis was observed in Asem variety (by 52% at 100 mM NaCl).

At 100 mM NaCl, the thickness of the lower epidermis varieties can be arranged as follows (% to control): Bastama (110%) > Asem (103%) > Odesskaya-100 (76) > Saule (62); the width of the upper epidermis: Saule (105%) > Odesskaya-100 (90%) > Bastama (72%) > Asem (48%) (Figures 3 and 5).

It can be noted that the decrease in the thickness of upper epidermis in tolerant variety Asem (48%) and lower epidermis in Saule cv (62%) were compensated by high mean of the thickness of lower epidermis in Asem cv (103%) and upper epidermis in Saule cv (105%).

These results confirm the reports that salinity stress causes alterations in the structure and function of plant cells (Hernandes and Almanza, 2002). The presence of NaCl (100 mM) caused a significant decrease in the thickness of the epidermis with irregular cells and deformed buliform cells in adaxial and abaxial epidermis and decreased leaf thickness of lluteno ecotype of maize (Carcamo et al., 2012). Bastias (2005) observed a reduction of the leaf thickness as well as a decrease of the mesophyll portion in number and size. This indicates a limitation of cell growth since division and cell expansion would be more affected as a result of osmotic and water stress in the mesophyll cells (Carcamo et al., 2012).

The diameter of the vascular bundles decreased in all studied varieties except Asem cv. At 100 mM NaCl, the diameter of the vascular bundles decreased in the following order (% control): Asem (100%) > Bastama (96%) > Odesskaya-100 (92%) > Saule (69%) (Figure 6).

Asem variety had no change in diameter of vascular bundles. Diameter of the vascular bundles of Bastama variety decreased to a lesser extent than the other varieties, by 4%. Javed et al. (2001) reported that maintenance of greater vascular bundle size and lesser reduction in interveinal distance was also noted in tolerant pearl millet genotypes in response to NaCl salinity. But in our experiments, the clear correlation between the diameter of vascular bundles and plants' tolerance to NaCl on growth parameters was not found.

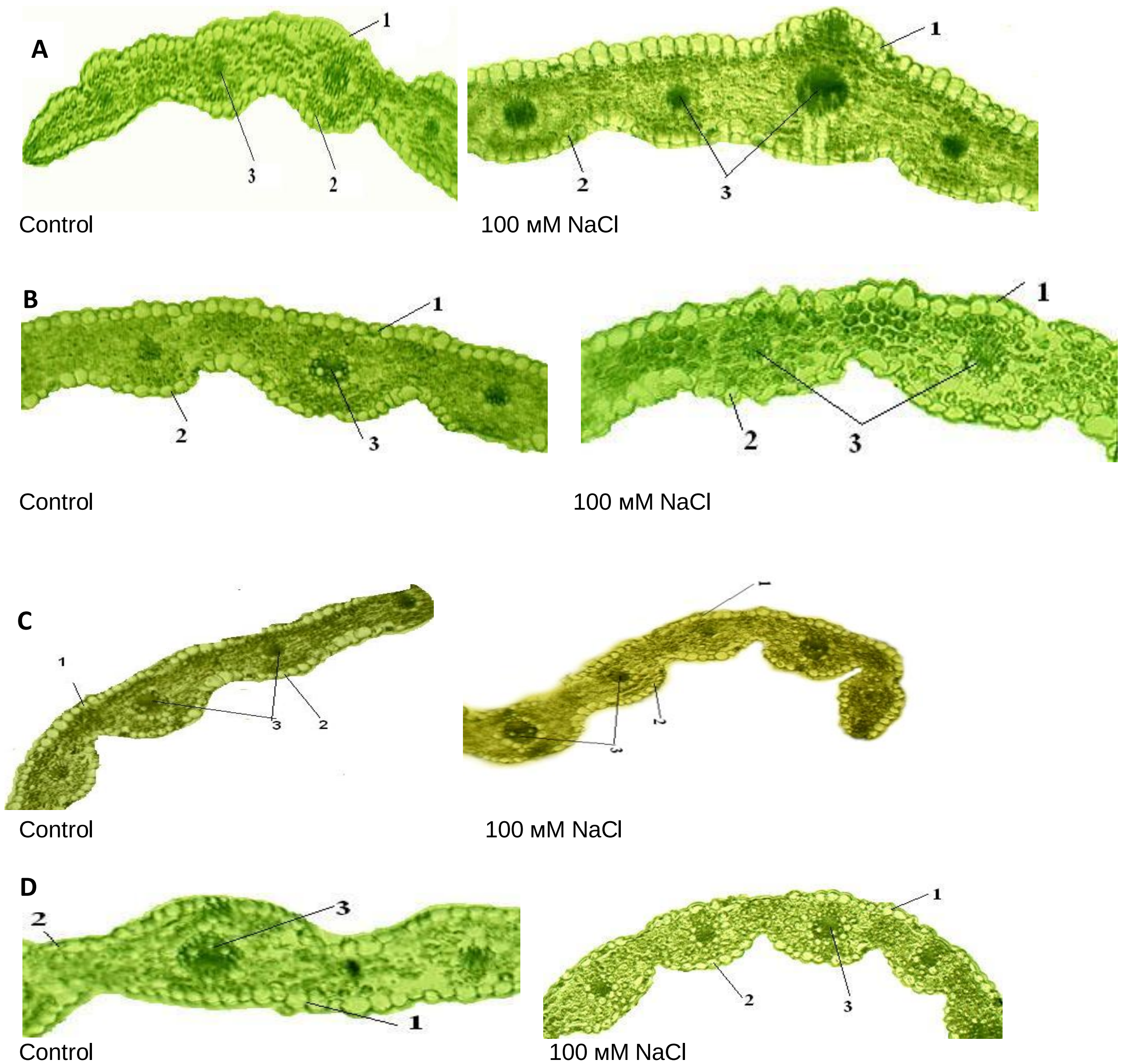

Figure 4. Anatomical structure of barley leaves under salinity stress. A, Asem; B, Bastama; C, Odesskaya-100; D, Saule; 1, lower epidermis; 2, upper epidermis; 3, vascular bundle.

In the diameter of the vascular bundles of relatively tolerance to salinity on growth parameters, Saule variety was reduced greatly compared to other varieties (by 31%) (Figure 6).

Reducing the vascular bundles diameter is directly related to decreasing the area xylem vessels, which as conductive elements are clearly responsible for holding various elements by changing their diameter (Ortega et al., 2006). It is supposed that reduction in the number of conducting elements has been reported in literature as being an adaptive measure for securing water flow (Baas et al., 1983). Reduction in size and number of conducting elements of the xylem in response to heavy metals was reported by Sandalio et al. (2001).

Munns (2002) indicated that the reduction of leaf, sheath thickness and stem area might be because Salinity reduces the ability of plants to take up water and this causes reduction in growth rate. If excessive amounts of salt enter the plant they will eventually rise to toxic levels, transpiring leaves and reducing the photosynthetic capacity of the plant.

Anatomical features of the structure of the roots of barley plants under salinity stress (NaCl)

The roots of barley seedlings grown in the presence of different concentrations of NaCl consisted of primary tissues. On cross-section, anatomical and topographical

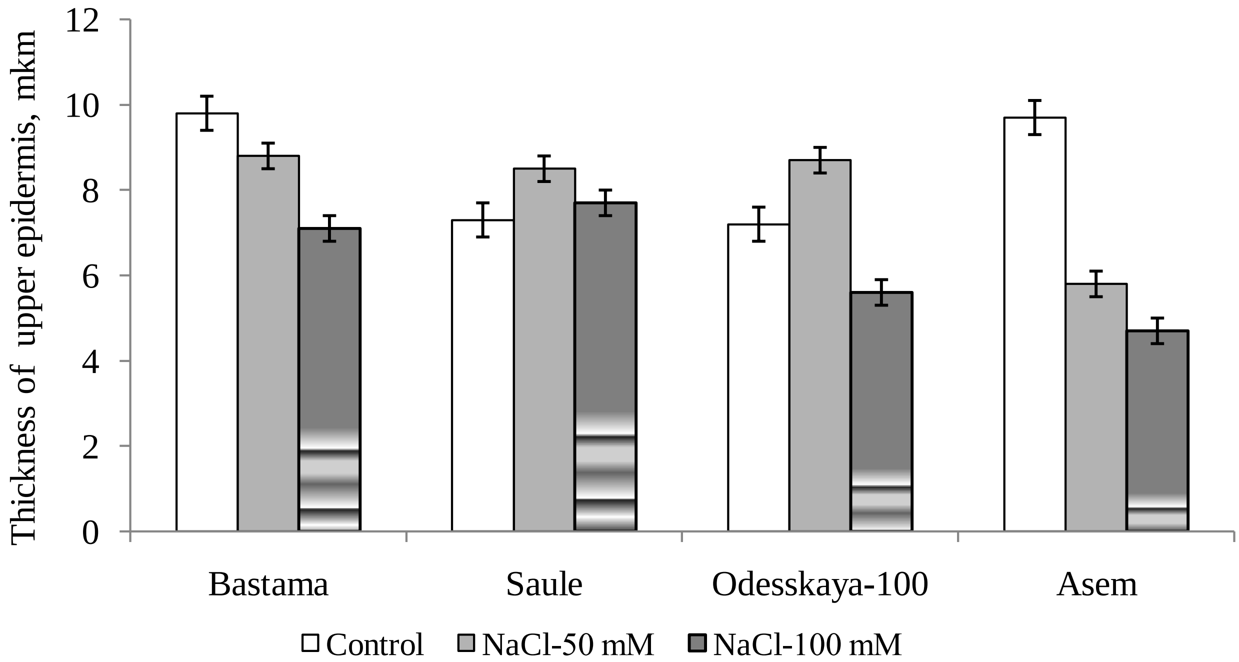

Figure 5. Effect of NaCl on thickness of upper epidermis of barley plants leaves.

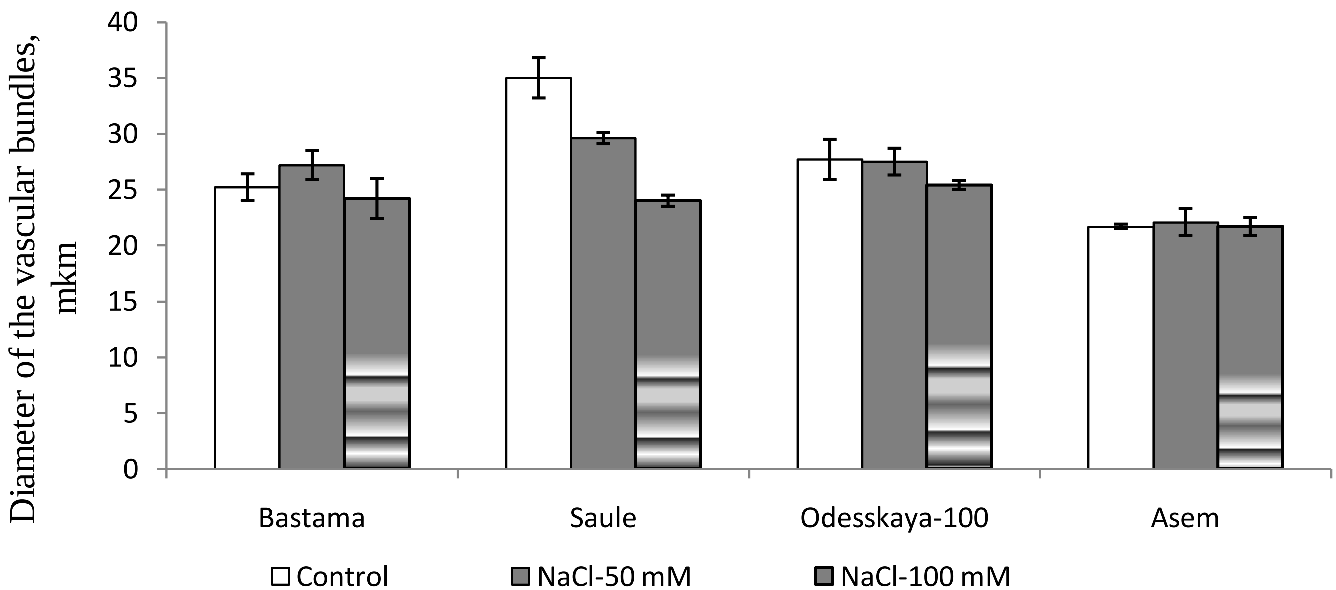

Figure 6. Effect of NaCl on diameter of vascular bundle of barley plants.

areas were clearly visible: exodermis, primary cortex and central cylinder (Figure 7).

On thickness of exodermis and endodermis under the influence of NaCl (100 mM), the varieties are arranged as follows: exodermis - Saule (94%) > Odesskaya - 100 (86%) = Bastama (86%) > Asem (71%); endodermis: Odesskaya - 100 (121%) > Bastama (89%) > Asem (84%) > Saule (66%) ($p < 0.05$) (Figures 8 and 9).

It can be indicated that the varieties which had the highest level of reduction in thickness of exodermis had the lowest level of reduced endodermis. This could be to compensate for the decrease in exodermis thickness. Exodermis of root cells protects against penetration of excess toxic agents from the environment into the cells of the root. Exodermis thickening showed the development of an anatomical adaptation to stress conditions (Lux et

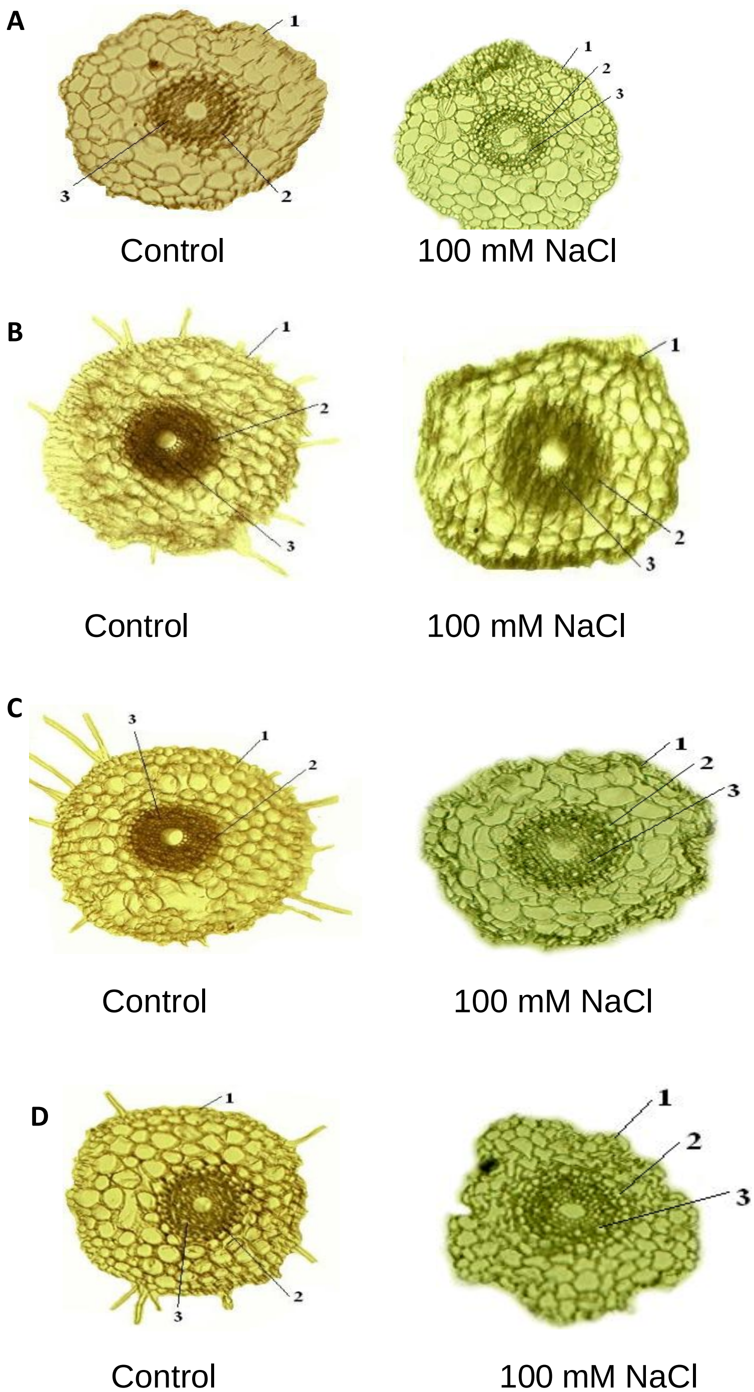

Figure 7. Anatomical structure of barley leaves under salinity stress. A, Asem; B, Bastama; C, Odesskaya-100; D, Saule: 1, exodermis, 2, endodermis, 3, central cylinder.

al., 2004).

The ratio of the thickness of exodermis and endodermis is an important indicator of plant's resistance (Mikovilovi et al., 2003). Thickening of exodermis is an indicator of adaptive responses against stressors (Singh et al., 2009; Gomes et al., 2011). The ratio of thickness to exodermis and endodermis is an important indicator of adaptive reactions to stress (Ceccoli et al., 2011).

In our experiments, the absolute value of the ratio of exodermis/ endodermis thickness are as follows: Saule (1.9) > Odesskaya-100 (0.98) > Bastama (0.85) > Asem (0.55); in relation to control - Saule (146%) > Bastama (96%)

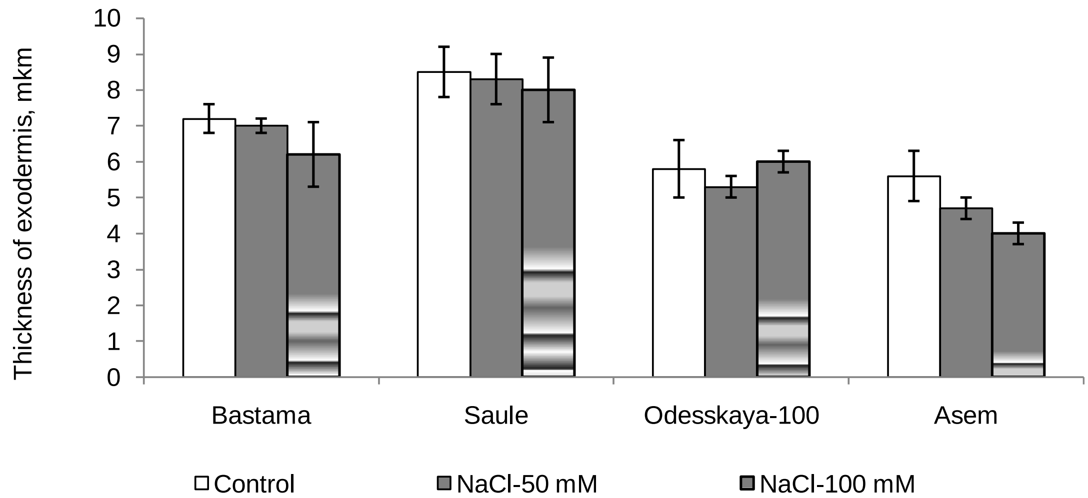

Figure 8. Effect of NaCl on thickness of root exodermis of barley plants.

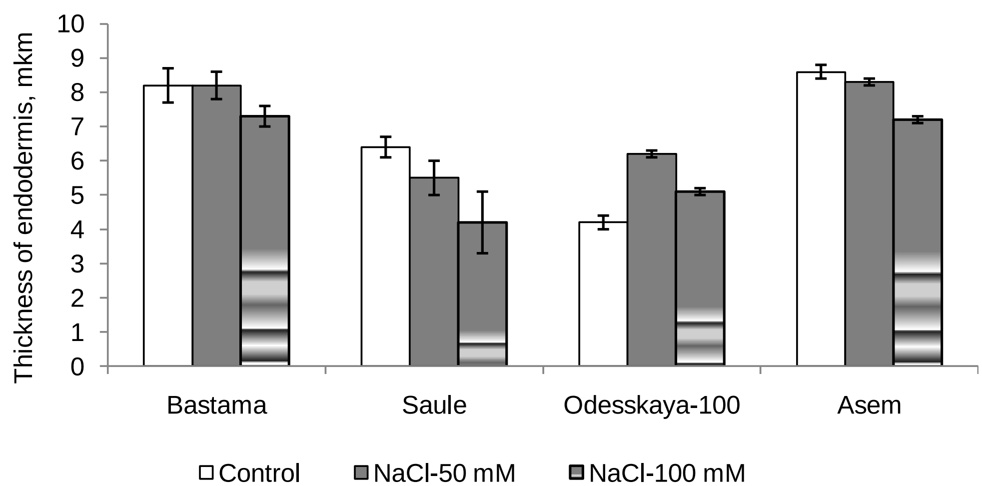

Figure 9. Effect of NaCl on thickness of root endodermis of barley plants.

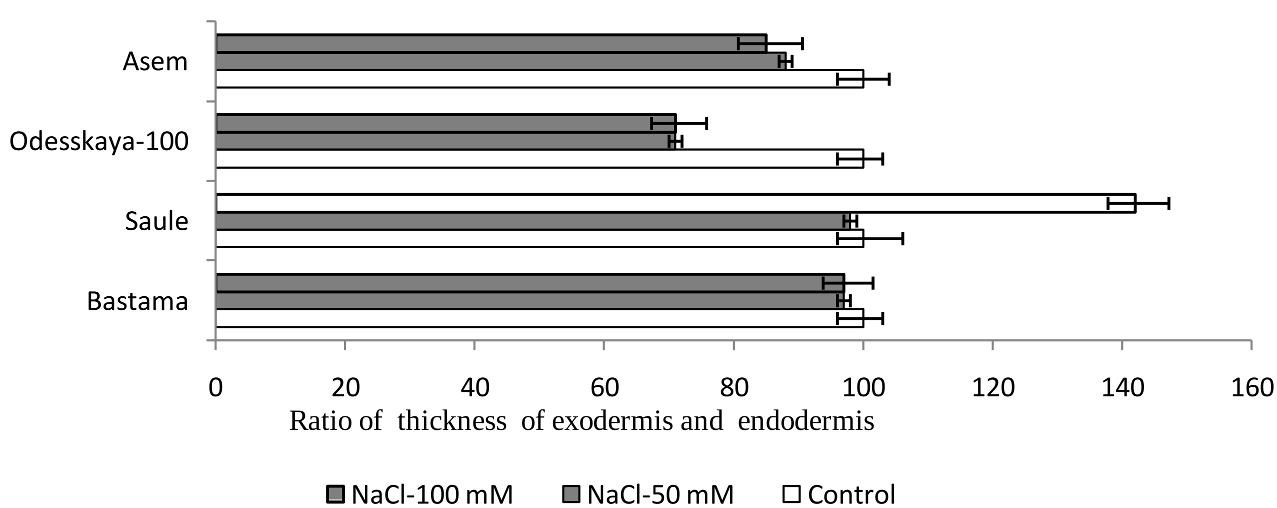

Figure 10. Ratio of thickness of exodermis and endodermis of barley roots.

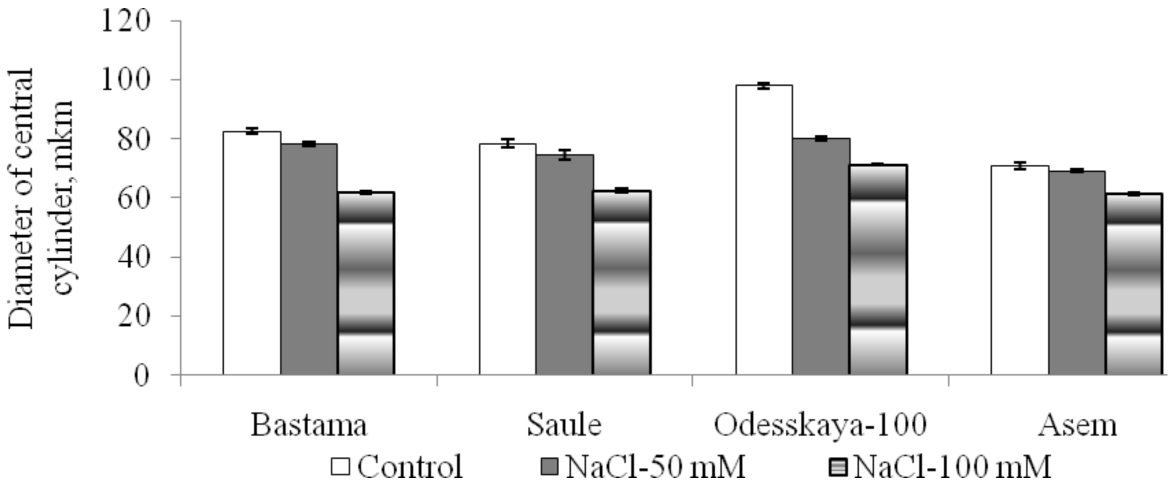

Figure 11. Effect of NaCl on diameter of central cylinder of barley roots.

> Asem (86%) > Odesskaya-100 (70%) (Figure 10).

In our studies, Saule variety had the highest value of this ratio (1:9 at 100 mM NaCl and the relative value to the control is 146%). It indicates that, in response to increased stress, thickness of the exodermis increased compared with the control. In the other varieties, means of this ratio were less than 1 and less than that in the control.

The lowest absolute value of this ratio was for Asem variety - 0.55 (86% in relation to control); the lowest value (relative to control) was for Odesskaya-100 (70% to control). Tolerant Saule variety had the highest mean of the ratio of exodermis/endodermis, but another tolerant Asem variety had the lowest mean of this ratio. In our experiments, we observed the activation of defense reactions as anatomical changes that are not always reflected on the organismal level.

Salinity stress increases thickness of exodermis, which reduces the absorption of toxins by root cells. Under stress conditions, exodermis provides peripheral barrier to the penetration of solutes in the apoplast. Exodermis represents a barrier of variable resistance to the flow of both water and nutrients to internal root cells and conducting elements (Hose et al., 2001).

The diameter of the central cylinder in barley plants also decreased under the influence of salinity. The greatest decrease of the central cylinder at high NaCl concentration was observed in Odesskaya-100 (27%) cv and the smallest decline in Asem cv (13%) (Figure 11).

A clear correlation was found between the mean of the diameter of central cylinder and tolerance of salinity stress. Sensitive to NaCl effects, varieties Odesskaya-100 and Bastama cvs showed low diameter of central cylinder in comparison with the tolerant varieties (Saule and Asem cvs). This phenomenon was observed by other authors with cotton plants (Reinhardt et al., 1995) and perennial forage plants, *Pappophorum philippianum* Parodi (Ramos et al., 2004) and sorghum (Baum et al., 2000). The decrease in diameter of the central cylinder is possibly a prerequisite for low growth parameters under the influence of salinity in the varieties.

The diameter of the central cylinder of different varieties is arranged as follows (% to control): Asem (87%) > Saule (80%) > Bastama (75%) > Odesskaya-100 (73%). Reducing the diameter of the vascular bundles is an indicator of decrease in conductivity for water and minerals (Ortega et al., 2006). It was shown that the water flow densities of *Citrus* root orders were caused by a significant reduction of the water uptake by first order roots (Rewald et al., 2012). Previous studies on cotton roots of herbaceous plants found smaller xylem vessels and altered cambial activity (Boughalleb et al., 2009). NaCl treatment caused inhibition of growth of vascular system in mungbean seedlings; in treated plants vascular cylinder was very poor (Rashid et al., 2004).

So, barley varieties were screened for resistance to salinity on growth parameters and anatomical structures of leaves and roots. The tolerant and sensitive barley varieties to NaCl salinity stress and anatomical peculiarities of leaf and root structure of these varieties of barley plants (*Hordeum vulgare* L.) were determined.

Conclusion

During the current study, we examined seven varieties of barley in two concentrations of NaCl in order to present impact of NaCl on growth and biomass accumulation of barley and select tolerant varieties. The results show that NaCl inhibits the growth of aboveground biomass and roots of barley. It can be concluded that the varieties Saule and Asem were most resistant to NaCl and Bastama and Odesskaya-100 varieties are more sensitive to growth parameters.

The anatomical studies showed that the lower and upper epidermis, and the diameter of vascular bundles of leaves of some varieties decreased under salinity stress. Anatomical structure of the roots of the studied varieties of barley changed. In some varieties, the thickening of exodermis as adaptive response was observed. Other varieties observed thinning of exodermis and endodermis. Reduction in the diameter of the vascular bundles was observed in all studied varieties. Under the effect of NaCl, the diameter of the central cylinder of the roots of barley plants reduced. A correlation between the mean of the diameter of central cylinder and tolerance to NaCl salinity stress by barley varieties was found.

REFERENCES

Abou-Leila B, Metwally SA, Hussen MM, Leithy SZ (2012). The combined effect of salinity and ascorbic acid on anatomical and physiological aspects of jatropha plants. Austr. J. Basic Appl. Sci. 6(3): 533-541.

Ali Y, Aslam Z, Ashraf MY, Tahir GR (2004). Effect of salinity on chlorophyll concentration, leaf area, yield and yield components of rice genotypes grown under saline environment. Int. J. of Environ. Sci & Techn. 1(3): 221-225.

Ali I, Abbas SQ, Hamee DM, Zafar S, Kanwal S (2009). Leaf anatomical adaptation in some exotic species of *Eucaliptus* l'her. (*Myrtaceae*). Pakistan J. Bot. 41(6) 2717-2727.

Akram M, Akhtar S, Javed I-ul-H, Wahid A, Rasul E (2002). Anatomical attributes of different wheat accessions/varieties NaCl salinity. Int. J. Agri. Biol. 4(1): 165-168.

Asharf M, Foolad MR (2007). Roles of glycine betaine and proline in improving plant abiotic stress resistance. Environ. Exp. Bot. 59:206-216.

Baas P, Werker E, Fahn A (1983). Some ecological trends in vessel characters. IAWA Bulletin. 4: 141-159.

Bastias E, Gonzales-Moro MB, Gonzales-Murua C (2005). *Zea mays* L. amylacea from the Lluta Valley (Arica Chile) tolerates salinity stress when high levels of boron are available. Plant and Soil. 267: 73-84.

Barykina RP (2004). Guide on botanical microtechique. Base and methods. MSU, Moscow, Russia. 312 p.

Baum SF, Tran PN, Silk WK (2000). Effects of salinity on xylem structure and water use in growing leaves of sorghum. New Phytol. 146: 119-127.

Baughalleb F, Denden M, Tiba B (2009). Anatomical changes induced by increasing NaCl salinity in three fodder shrubs, *Nitraria retusa*, *Atriplex halimus* and *Medicago arborea*. Acta Physiol. Plantar. 31: 947-960.

Boughalleb F, Hajlaoui H, Denden M (2012). Effect of salt stress on growth, water relations, solute composition and photosynthetic capacity of hero-halophyte *Nitraria retusa* (L.). Environ. Res. J. 6(1): 1-13.

Bradbury M, Ahmad R (1990). The effect of silicon on the growth of *Prosopis juliflora* growing in saline soil. Plant and Soil. 125: 71-74.

Carcamo HJ, Bustos MR, Fernandez FE, Bastias EI (2012). Mitigating effect of salicylic acid in the anatomy of the leaf of *Zea mays* L. lluteno ecotype from the Lluta Valley (Arica-Chile) under NaCl stress. IDESIA (Chile) Volumen. 30(3): 55-63.

Çavişoglu KS, Kiliç S, Kabar K (2007). Some morphological and anatomical observations during alleviation of salinity (NaCl) stress on seed germination and seedling growth of barley by polyamines. Acta Physiol. Plant. 29: 551-557.

Ceccoli G, Ramos J C, Ortega LI, Acosta JM, Perreta MG (2011). Salinity induced anatomical and morphological changes in *Chloris gayana* Kunth roots. Biocell. 35(1): 9-17.

Chookhampaeng S (2011). The effect of salt stress on growth, chlorophyll content, proline content and antioxidative enzymes of pepper (*Capsicum annuum* L.) seedlings. European J. of Sci. Res. 49 (1): 103-109.

Degenhardt B, Gimmler H (2000). Cell wall adaptations to multiple environment stresses in maize root. J. Exp. Bot. 51: 595-603.

Dhalnapackiam S, Muhammad Ilyas MH (2010). Effect of salinity on chlorophyll and carbohydrate contents of *Sesbania grandiflora* seedlings. Ind. J. Sci. Biotechnol. 3(1): 64-66.

Dolatabadian A, Modarreressanavy SAM, Ghanati F (2011). Effect of salinity on growth, xylem structure and anatomical characteristics of soybean. Nat. Sci Biol. 3(1): 41-45.

Glenn EP, Brown JJ, Blumwald E (1999). Salt tolerance and crop potential of halophytes. Crit. Rev. Plant Sci. 18 : 227-255.

Gomes MP, de Sá e Melo Marques TC, Nogueira MO, de Castro EM, Soares AM (2011). Ecophysiological and anatomical changes due to uptake and accumulation of heavy metal in *Brachiaria decumbens*. Sci. Agric. (Piracicaba, Braz.). 68 (5): 566-573.

Ghazi N, Al-Karaki GN (2006). Nurcery inoculation of tomato with arbuscular mycorrhizal fungi and subsequent performance under irrigation with saline water. Sci. Horr. 109: 1-7.

Hauser F, Horie T (2010). A conserved primary salt tolerance mechanism mediated by HKT transporters: a mechanism of ion sodium exclusion and maintenance of high K^+ /Na^+ ratio in leaves during salinity stress. Plant Cell Environ. 33: 552-565.

Hernandes JA, Almanza MS (2002). Short term effects of salt stress on antioxidant systems and leaf water relations of pea leaves. Physiol. Plantar. 115: 251-257.

Horie T, Kahara I, Katsuhara M (2012). Salinity tolerance mechanisms in glycophytes: An overview with central focus on rice plants. Rice. 5: 1-11.

Hose E, Clarkson DT, Steudle E, Schreiber L, Hartung W (2001). The exodermis: variable apoplastic barrier. J. Exp. Bot. 52(365): 2245-3364.

Hussein MM, Abo-Leila BH, Metwally SA, Leithy SZ (2012). Anatomical structure of jatropha leaves affected by proline and salinity conditions. J. Appl. Sci. Res. 8(1): 491-496.

Javed I-ul-H, Wahid A, Rasul E (2001). Selection of pearl millet lines for tolerance to increased salinity. JAPS, 11: 18–23.

Jia W, Wang Y, Zheng S, Zhang J (2002). Salt-stress induced ABA accumulation is more sensitive triggered in roots than in shoots. J. Exp. Bot. 53: 2201-2206.

Kaouther Z, Ben FM, Mani F, Hannachi C (2012). Impact of salt stress (NaCl) on growth, chlorophyll content and fluorescence of Tunisian cultivars of chili pepper (*Capsicum frutescens* L.). J. Stress Physiol.& Biochem. 8 (4): 237-252.

Lux AA, Sottnikova A, Opatrna J, Greger V (2004). Differences in structure of adventitions roots in *Salix* clones with contrasting characteristics of cadmium accumulation and sensitivity. Physiol. plantarum. 120: 537-545.

Maggio A, Raimondo G (2007). Salt stress response in tomato beyond the salinity tolerance threshold. Environ. Exp. Bot. 59(3): 276-282.

Maggio A, Raimondi G (2007). Salt stress response in tomato beyond the salinity tolerance threshold. Environ. Exp. Bot. 59 (3): 276-282.

Mtloni DA, Oliva MA (2001). Contribution of proline and inorganic solutes to osmotic adjustement in cotton under salt stress. J. Plant Nutr. 24(3): 599-612.

Mikovilovi VS, Dragosavac D (2003). Environmental impact on morphological and anatomical structure of *Tansy stevovi*. Afr. J. Biotechnol. 9(16): 2413-2421.

Munns R (2002). Comparative physiology of salt and water stress. Plant Cell. Environ. 25: 239-250.

Munns R, James RA, Lauchli A (2006). Approaches to increasing the salt tolerance of wheat and other cereals. J. Exp. Bot. 57: 1181-1199.

Munns R, Tester M (2008). Mechanisms of salinity tolerance. Annu. Rev. Plant Biol. 59: 651-681.

Muscolo A, Panuccio MR, Sidari M (2003). Effects of salinity on growth, carbohydrate metabolism and nutritive properties of kikuyu grass *(Pennisetum clandestinum* Hochst). Plant Science. 164: 1103-1110.

Neocleous D, Vasilakakis M (2007). Effects of NaCl on red raspberry (*Rubus idaeus* L 'Autumn bliss'). Sci. Hort. 112:282-289.

Ola HAE, Reham EF, Eisa SS, Habib SA (2012). Morpho-anatomical changes in salt stressed kallar grass (*Leptochloa fusca* L. Kunth). Res. J. Agric. Biol. Sci. 8(2): 158-166.

Ortega L, Fry SC, Taleisnik E (2006). Why are *Chloris gayana* leaves shorter in salt-affected plants? Analyses in the elongation zone. J. Exp. Bot. 57: 3945-3952.

Permyakova AI (1988). Microtechnique. MSU, Moscow, Russia. 62 p.

Prozina MN (1960). Botanical microtechnique. MSU, Moscow, Russia. 208 p.

Ramos J, Perreta MG, Tivano JC, Vegetti AC (2004). Variaciones

anatómicas en la raíz de Pappophorum philippianum inducidas por salinidad. Phyton (USA). 103-109.
Rashid P, Karmoker JL, Chakrobortty S, Sarker BC (2004). The effect of salinity on ion accumulation and anatomical attributes in mungbean (*Phaseolus radiatus* L. cv. BARI-3) seedlings. Int. J. Agri. Biol. 6 (3): 495–498.
Reinhardt DH, Rost TL (1995). Salinity accelerates endodermal development and induces an exodermis in cotton seedlings roots. Environ. Exp. Bot. 35: 563-574.
Ren ZH, Gao JP, Li LG, Cal XL, Huang W, Chao DY, Zhu MZ, Wang ZY, Luan S, Lin NX, (2005). A rice quantitative trait locus for salt tolerance encodes a sodium transporter. Nat. Genet. 37: 1141-1146.
Rewald B, Raveh E, Gendler T., Ephrath JE, Rachmilevitch S (2012). Phenotipic plasticity and water flux rates of *Citrus* root orders under salinity. J. Environ. Bot. 1:1-11.
Sandalio LM, Dalurzo HC, Gómes M, Romero-Puertas MC, Del Rio LA (2001). Cadmium-induced changes in the growth and oxidative metabolism of pea plants. J. Exp. Bot. 52: 2115-2126.
Singh A, Prasad S (2009). Salt stress effects growth and cell wall bound enzymes in *Arachis hypogaea* L. seedlings. IJIB. 7(2):117-123.
Xu XW, Xu HL, Wang YL, Wang XJ, Qiu YZ, Xu B (2008). The effect of salt stress on the chlorophyll level of the main sand-binding plants in the shelterbelt along the Tarim Desert Highway. Chin. Sci. Bulletin. 53 (Supp. II): 109-111.
Yarraguchi T, Blumwald E (2005). Developing salt-tolerant crop plants challenges and opportunities. Trends Plant Sci. 10: 615-620.
Zhang J, Jia W, Yang J, Ismail AM (2006). Role of ABA in integrating plant responses to drought and salt stresses. Field Crop Research. 97: 111-119.
Wang WY, Yan XF, Jiang Y, Qu B, Xu YF (2012). Effects of salt stress on water content and photosynthetic characteristics in *Iris lactea* var. *Chinensis* seedlings. Middle-East J. Sci. Res. 12(1): 70-74.