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EFFECT OF SALINITY AND DROUGHT STRESS ON GERMINATION AND EARLY SEEDLINGS GROWTH OF BREAD WHEAT (*Triticum aestivum* L.)

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Salinity is one of the most important environmental stresses that limits soil fertility and has adverse effects on plant growth. In order to increase wheat production under saline conditions, it is necessary to better understand genotypic difference, the physiological and biochemical processes of salt tolerance in wheat. The aim of this study was to determine the most tolerant winter wheat varieties against salinity and osmotic stress at germination stage and early seedlings growth. The salinity and osmotic stress were simulated in controlled environmental conditions by adding different concentrations of NaCl and mannitol solution to the growing media of five winter wheat variety. In all studied varieties the benchmark water potential in which they had germinated and had a good seedlings growth was of -0.3MPa. Under the stronger stress, -0.6 MPa, all varieties showed reduction in the all examined parameters. The variety Bosanka, had the highest final germination and germination energy under both mannitol and salt stress treatments. The parameters defining the development or percentage of strong seeds, coleoptile and root length, fresh and dry weight of root and coleoptile of a seed were more affected by water deficit stress and salt stress than germination and germination energy. Biplot analysis showed that wheat cultivars grown under -0.6MPa osmotic had higher values of root/coleoptile ratio in relation to control and -0.3MPa treatment which is the most reliable for screening properties of the genotypes for drought resistance in seedling stage.

Key words: Biplot analysis, genotype, germination, mannitol, NaCl, tolerance, *Triticum aestivum*

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INTRODUCTION

Salinity is one of the most important environmental factors limiting soil fertility, crop growth and productivity (ZAHEDI *et al*., 2011). The main sources of the high salt level in the soil are the extensive use of fertilizers, irrigation and the high level of evapotranspiration in summer (SARMUGAM and WORSLEY, 2014). SHRIVASTAVA *et al.*, (2015) reported that more than 20% of all cultivated lands around the world containing increased levels of salts. A high salt stress affects 7% of the world's land area, which amounts to 930 million ha (BEGUM *et al.*, 2013). The negative effect of increased substrate salinity on crop growth and development can be observed from the cellular to the whole plant level. Plant reaction to increased soil salinity manifests in stopping or reducing the rate, duration of vegetative growth and leaf development (LÄUCHLI and GRATTAN, 2007). Reduction in growth is a consequence of more physiological responses including modifications of ion balance, water status, mineral nutrition, stomatal behavior, photosynthetic efficiency (TAVAKKOLI *et al*., 2010). The rate of photosynthetic CO_2 assimilation is generally reduced by salinity, as a result of a reduced stomatal conductance and reduced availability of CO_2 concentration (KALAJI *et al*., 2011).

Drought stress is also a globally widespread and ever growing environmental phenomenon encountered by wheat crop which cause severe reduction in overall crop production (NEZHADAHMADI *et al*., 2013). Therefore it is necessary through various studies to better understand genotypic difference and the physiological and biochemical processes that make the plant tolerant to drought.

Under drought stress condition decreasing pattern was experienced in morphologically yield contributing characters like plant height, grains per spike, spikes per plant, thousand grain weight, and reduction in number of fertile tillers per plant, which ultimately caused noticeably low grain productivity in wheat (KILIC and YAGBASANLAR, 2010; JOUDI, 2017). Generally drought and other stress factors cause the formation of reactive oxygen compound essentially in plants (Reactive Oxygen Species, ROS), which results in biomembranes and macromolecules damage (SHARMA *et al*., 2012). The availability of water and its movement in the seed are important for the process of germination, early growth and elongation of coleoptile and root. These processes are under the influence of chemical potential, texture and the contact area of seed and soil. Many factors can affect plants responses to drought stress such as genotype, growth stage, severity and duration of stress, developmental stage (CHAVES *et al*., 2003), different patterns of genes expression (DENBY, 2005), different patterns of the respiration activity (RIBAS–CARBO, 2005), activity of photosynthesis machinery (FLEXAS, 2004), and environmental factors (RIHZSKY, 2002). Drought can also cause pollen sterility, grain loss, accumulation of abscisic acid in spikes of drought-susceptible wheat genotypes, and abscisic acid synthesis genes in the anthers (JI, 2010).

Germination is the basic indicator of seed quality and highly depends on biotic an abiotic factors (VUJAKOVIC *et al.,* 2011). The salinity of the soil affects the germination of both sides, either as osmotic stress or a toxic effect of ions. Considering that the germination process is not possible without water, the main negative effect of salt in soils is reflected in creating osmotic potentials that will prevent the seeds from absorbing a sufficient amount of water and sprouts. Also, in saline conditions, seeds and seedlings absorb the high amounts of Na^+ and Cl^- ions, which exert their toxic effects in plant cells (KHAJEH-HOSSEINI *et al*., 2003).

Wheat (*Triticum aestivum* L.) is regarded as one of the most important cereal crop, grown in different regions that can be characterized by drought occurrence or increased salt level in the soil (RANA *et al*., 2013). It is a cereal grain that belongs to *Poaceae* family, which has been known as a semi-tolerant plant to drought and moderately salt-tolerant (TESTER *et al*., 2003). Winter wheat is more salt tolerant compared to other crops such as durum wheat (*Triticum turgidum* ssp. *durum* L.), maize (*Zea mays* L.) and sorghum (*Sorghum bicolor* L.) (FITA *et al.*, 2015). The selection of tolerant wheat genotypes against drought and salt stress at seedling stage is important, especially if the tolerance at the germination stage correlated with tolerance to drought and salt in grain filling period.

The aim of this study was to examine the seed viability of selected winter wheat cultivars in saline and osmotic stress conditions and determine the most tolerant cultivars to salinity and osmotic stress at germination stage and early seedlings growth.

MATERIALS AND METHODS

The experiment was conducted to examine parameters of germination in five diverse varieties of winter wheat (Jelena, Kristina, Orion, Bosanka and Nova Bosanka) under controlled conditions in the laboratory of the Faculty of Agriculture in East Sarajevo, Bosnia and Herzegovina. Three replicates of 50 uniform, healthy wheat seeds were sterilized in 96 % alcohol for 30 seconds, washed with distilled water several times, and transferred to sterile Petri dishes. A double layered filter paper put in a dish saturated with solution determined concentration (mannitol and salt, Table 1) and it is dissolved with water potential close to zero (control), then -0.3 and -0.6MPa. In each petri dish 15 ml of solution was dispensed. Control petri dishes were filled with distilled water. Alcohol mannitol was used to induce water stress and sodium chloride to induce stress of salt. Petri dishes were incubated for 7 days at 25°C. During this experiment, the following parameters were determined: germination energy, final germination, Vigour Test or percentage of strong seeds, coleoptile and root length, fresh and dry weight of root and coleoptile, and root/coleoptile dry weight ratio. To determine the dry weight of the root and coleoptile seedlings were dried for 24 hours at 80 °C.

Data was analyzed using two-way analysis of variance (ANOVA) through Infostat 10 software. Means were compared using Duncan's multiple range test. Principal component analysis (PCA) was used to determine interdependence between the traits.

Table 1. Amounts of sodium chloride and mannitol in different levels of water deficit

Ψ_O the level of MPa	NaCl (g/l distilled water)	Mannitol (g/l distilled water)
0	0	0
-0.3	4.20	22.29
-0.6	8.40	44.58

RESULTS AND DISCUSSION

Results from our study showed that increase in osmotic potential (NaCl and mannitol) predicted an adverse effect on germination energy (Table 2). Generally, germination energy was lowest in the presence of the lowest osmotic potential (-0.6MPa). Further, a significant difference among diverse wheat varieties under different treatments was observed. The variety Orion was the most sensitive variety under the lowest osmotic potential (-0.6MPa) and its germination energy compared to control reduced from 97% to 8% and from 92% to 5% under the NaCl and mannitol treatment, respectively. Decrease and delay in germination of winter wheat in saline medium, have also been reported by RAHMAN *et al.* (2000). Under salt stress, the germination of durum wheat seeds could be delayed both in durum and bread wheat (ALMASOURI *et al.*, 2001).

Table 2. Germination (%), Germination energy (%), and Vigor (%) of five winter wheat varietes exposed to water deficits induced by diferrent concentration of mannitol and sodium chloride during germination

Germination energy

Treatment	NaCl				Mannitol			
	0 MPa	-0.3 MPa	-0.6 MPa	average	0 MPa	-0.3 MPa	-0.6 MPa	average
Bosanka	84.33^{b}	84.67^{b}	70.33^{d}	79.78^{A}	90.00^{a}	89.00^{a}	86.33^{a}	88.44^{A}
Jelena	92.00^{a}	77.33^{c}	49.67^{f}	73.00^{B}	90.00^{a}	64.00^{def}	69.33^{bcde}	74.44^{B}
Kristina	76.33^{c}	76.33^{c}	41.67^{g}	64.78^{C}	75.67^{b}	73.33^{bc}	72.00^{bcd}	73.67^{B}
Nova Bosanka	49.67^{f}	78.00^{c}	58.00^{e}	61.89^{D}	60.00^{f}	65.67^{cdef}	62.67^{ef}	62.78^{C}
Orion	96.67^{a}	66.67^{d}	8.00^{h}	57.11^{E}	92.00^{a}	72.67^{bcd}	5.00^{g}	56.56^{D}
Average	79.80^{A}	76.60^{B}	45.53^{C}	67.31	81.53^{A}	72.93^{B}	59.07^{C}	71.17

Germination

Treatment	NaCl				Mannitol			
	0 MPa	-0.3 MPa	-0.6 MPa	average	0 MPa	-0.3 MPa	-0.6 MPa	average
Bosanka	87.67^{bc}	86.67^{c}	71.67^{efg}	82.00^{A}	92.33^{ab}	92.33^{ab}	86.67^{b}	90.44^{A}
Jelena	94.33^{ab}	78.67^{d}	51.67^{h}	74.89^{B}	90.00^{ab}	66.33^{e}	70.67^{de}	75.67^{B}
Kristina	77.33^{de}	76.33^{de}	66.67^{g}	73.44^{B}	76.67^{cd}	74.67^{cd}	73.00^{cde}	74.78^{B}
Nova Bosanka	74.00^{def}	79.00^{d}	69.00^{fg}	74.00^{B}	78.67^{c}	77.00^{cd}	69.67^{de}	75.11^{B}
Orion	96.67^{a}	71.00^{efg}	30.00^{i}	65.89^{C}	94.67^{a}	72.67^{cde}	8.00^{f}	58.44^{C}
average	86.00^{A}	78.33^{B}	57.8^{C}	74.04	86.67^{A}	76.6^{B}	61.6^{C}	74.89

Vigor

Treatment	NaCl				Mannitol			
	0 MPa	-0.3 MPa	-0.6 MPa	average	0 MPa	-0.3 MPa	-0.6 MPa	average
Bosanka	60.33^{b}	11.33^{f}	0^{g}	23.89^{C}	60.33^{b}	25.00^{f}	0^{h}	28.44^{C}
Jelena	80.33^{a}	21.33^{e}	11.00^{f}	37.56^{A}	80.33^{a}	28.00^{ef}	0^{h}	36.11^{A}
Kristina	47.67^{c}	25.33^{e}	0^{g}	24.33^{C}	49.67^{c}	43.67^{d}	2.33^{h}	31.89^{B}
Nova Bosanka	25.67e	25.33^{e}	0^{g}	17.00^{D}	25.67^{f}	9.33^{g}	0^{h}	11.67^{E}
Orion	47.00^{c}	33.67d	11.33^{f}	30.67^{B}	47.67^{c}	30.33^{e}	0^{h}	26.00^{D}
average	52.20^{A}	23.40^{B}	4.47^{C}	26.89	52.73^{A}	27.27^{B}	0.47^{C}	26.82

Different letters indicate significant difference at $P < 0.05$ level.

Results from our study showed a significant effect of NaCl and mannitol concentration on wheat final germination. By increasing NaCl and mannitol concentration (decreasing osmotic potential), germination percent decreased almost linearly in studied wheat cultivars. For example, in the variety Orion with a higher water deficit (-0.6MPa) the percentage of germination decreased by 69% in salt stress and 95% in mannitol stress compared to the control. The cultivar with highest germination percentage at zero potential, -0.3MPa and -0.6 MPa was Bosanka. Therefore, this cultivar could be grown under decreased osmotic conditions. Salt stress causes adverse physiological and biochemical changes in germinating seeds. It can affect the seed germination and stand establishment through osmotic stress, ion-specific effects and oxidative stress. Salinity delays or prevents the seed germination through various factors, such as reduction of water availability, changes in the mobilization of stored reserves and affecting the structural organization of proteins (TEMEL *et al*., 2015). MUJEEB *et al.* (2008), showed that salinity affects germination in two ways: 1) salt in the medium decrease the osmotic potential resulting in retardation or prevention of water uptake necessary for mobilization of nutrients during germination and 2) the salt constituents or ions may be toxic to the embryo. REJILI *et al.* (2010), found that the decrease in the percentage of germination caused by the osmotic effect of salt did not damage the embryo and not germinated seeds were able to germinate when the stress is removed. According to AL – TAISAN (2010) results like this could be attributed to absence of energy to start a germination process, as energy was obtained by increments in the respiratory pathway after the imbibition and in low levels of water potential tax water absorption was processed slowly. Similar results were obtained by BRAGA *et al*. (1999), in seeds of bean where the potentials between -0.4 and - 0.6MPa, led to a decline in the value of parameters examined as germination percentage and germination.

There was a significant difference in the parameter vigor classification (Table 2) and by decreasing osmotic potential vigor percent declined gradually from 0MPa to -0.3MPa and further drastically at -0.6MPa under both treatment salt and mannitol. Generally, most wheat varieties were sensitive to the influence of osmotic potential of -0.6 MPa where their values drastically fall close to zero. Variety Jelena presented the highest vigor classification at 0 MPa, but values of these parameters decreased at water deficits stress of -0.3MPa and -0.6MPa. SINGH *et al.* (2000), KHATUN *et al.* (2013), and MOUD and MAGHSOUDI (2008) also found differential sensitivity of wheat genotypes based on seedling growth in their studies and they suggested that seedling growth is one of the most important characters for screening salt tolerance during early stage of the growth.

Coleoptile and root length (Table 3) in our experiment interfered differently. At zero potential, both coleoptiles and root lengths reached their highest values. Other treatments gradually reduced seedling growth. At zero potential the highest root length was reported in the variety Orion followed by variety Jelena and Kristina. Under mannitol treatment reduction in root and coleoptile length was less pronounced as compared to the NaCl treatments. The Nova Bosanka variety showed highest coleoptile length at zero potential. On the other hand Nova Bosanka variety was most sensitive varieties under decreased osmotic potential since its coleoptiles length significantly decreased at -0.6 MPa. High salt concentration inhibits plant growth (CUARTERO *et al*., 1999) and affects many aspects of plant metabolism resulting in reduced growth and grain yield. Seed vigour and seedling length were the most sensitive to drought stress (HANDAS *et al.,* 2004). DATTA *et al.* (2009) showed that different levels of salinity significantly affected the growth attributes by reducing root and shoot length for salinity below 125mM. MOUD and MAGHSOUDI (2008) found significant differences among wheat cultivars in terms of coleoptiles and root growth under salt-stress conditions and stated that salt stress inhibited coleoptile growth more than root growth. BAHRANI and JOO (2011) also found that increased concentrations of NaCl reduced germination percentage, radical, hypocotyl length, fresh and dry seedling weight and radicle and hypocotyl dry weight of wheat. Related result is also published by QAYYM, (2011) in investigation of the effect of water deficiency on germination of different wheat genotypes who found that the length of the coleoptile was significantly decreased due to the water potential of -0.8 bar.

Table 3. Coleoptile length (mm) and root length (mm) of five winter wheat varietes exposed to water deficits induced by diferrent concentration of mannitol and sodium chloride during germination

Coleoptile length								
Treatment	NaCl				Mannitol			
	0MPa	0.3MPa	0.6MPa	average	0MPa	0.3MPa	0.6MPa	average
Bosanka	69.4^{b}	34.00^{f}	3.73^{h}	35.71^{C}	69.4^{c}	56.77^{de}	5.00^{j}	43.72^{C}
Jelena	59.05^{c}	41.40^{e}	2.98^{h}	22.058^{D}	59.37^{d}	35.67^{g}	13.27^{i}	36.1^{D}
Kristina	69.7^{b}	47.9^{de}	20.83^{g}	46.144^{A}	88.97^{a}	49.90^{f}	31.70^{g}	56.86^{A}
Nova Bosanka	80.2^{a}	47.73^{de}	7.93^{h}	45.29^{A}	80.18^{b}	23.97^{h}	9.00^{ij}	37.72^{D}
Orion	52.3^{d}	44.47^{e}	20.33^{g}	39.03^{B}	53.95^{def}	49.17^{f}	52.07^{ef}	51.73^{B}
average	66.13^{A}	35.648^{B}	11.17^{C}	37.64	70.37^{A}	43.09^{B}	22.21^{C}	45.22
Root lenght								
Treatment	NaCl				Mannitol			
	0MPa	0.3MPa	0.6MPa	average	0MPa	0.3MPa	0.6MPa	average
Bosanka	67.70^{b}	54.17^{c}	17.73^{e}	46.53^{C}	67.37^{c}	79.23^{a}	30.83^{g}	59.14^{A}
Jelena	71.07^{b}	57.70^{c}	21.33^{e}	50.03^{B}	71.10^{bc}	38.56^{f}	30.30^{g}	46.65^{C}
Kristina	71.23^{b}	67.27^{b}	35.93^{d}	58.14^{A}	72.47^{b}	47.40^{e}	45.10^{e}	54.99^{B}
Nova Bosanka	53.33^{c}	53.73^{c}	30^{d}	45.69^{C}	52.5^{d}	39.80^{f}	21.00^{h}	37.77^{E}
Orion	79.13^{a}	70.00^{b}	19.87^{e}	56.33^{A}	78.1^{a}	20.93^{h}	31.67^{g}	43.5^{D}
average	68.49^{A}	60.57^{B}	24.97^{C}	51.35	68.31^{A}	45.19^{B}	31.78^{C}	48.43

Different letters indicate significant difference at $P < 0.05$ level.

Fresh weight of coleoptiles and root (Table 4) were significantly affected by water deficits. Under salt treatment coleoptiles fresh weight decreased with increase of osmotic stress. Under NaCl stress root average fresh weight at water deficit of -0.3MPa showed higher weight (0.059g) than at zero potential (0.047g). Alcohol mannitol significantly reduced coleoptile fresh weight across treatments (Table 4). Moreover, the varieties Bosanka and Nova Bosanka were the most sensitive varieties against the lowest osmotic potential (-0.6 MPa). There was no significant difference in root fresh weight of all wheat varieties between control and -0.3 MPa mannitol treatments. Our results are in agreement with DEMIR *et al.* (2008) who had examined the effect of polyethylene glycol on the germination of seeds of pepper and BRAGA *et al*. (1999) in the tests on the beans. WANG *et al.* (2009) determined that the fresh weight, root length and the above-ground part in the two varieties of alfalfa were significantly inhibited by 35% PEG solution.

Table 4.Coleoptile fresh weight (g) and root fresh weight (g) of five winter wheat varietes exposed to water deficits induced by diferrent concentration of mannitol and sodium chloride during germination

Coleoptile fresh weight								
Treatment	NaCl				Mannitol			
	0MPa	0.3MPa	0.6MPa	average	0MPa	-0.3 MPa	-0.6 MPa	average
Bosanka	0.527^{b}	0.334^{d}	0.047^{f}	0.297^{C}	0.545^{c}	0.280^{g}	0.096^{i}	0.307^{D}
Jelena	0.680^{a}	0.413^{c}	0.222^{e}	0.438^{B}	0.683^{b}	0.372^{e}	0.175^{h}	0.410^{B}
Kristina	0.743^{a}	0.571^{b}	0.202^{e}	0.505^{A}	0.737^{a}	0.490^{d}	0.160^{h}	0.463^{A}
Nova Bosanka	0.690^{a}	0.506^{b}	0.058^{f}	0.418^{B}	0.689^{b}	0.324^{f}	0.093^{i}	0.369^{C}
Orion	0.553^{b}	0.528^{b}	0.224^{e}	0.435^{B}	0.553^{c}	0.371^{e}	0.296^{fg}	0.407^{B}
average	0.635^{A}	0.471^{B}	0.151^{C}	0.419	0.641^{A}	0.367^{B}	0.164^{C}	0.391
Root fresh weight								
Treatment	NaCl				Mannitol			
	0MPa	-0.3 MPa	-0.6 MPa	average	0MPa	-0.3 MPa	-0.6 MPa	average
Bosanka	0.031^{ef}	0.026^{efg}	0.020^{g}	0.026^{D}	0.031^{g}	0.035^{f}	0.016^{j}	0.027^{D}
Jelena	0.054^{b}	0.090^{a}	0.055^{b}	0.066^{A}	0.054^{cd}	0.056^{cd}	0.055^{d}	0.055^{A}
Kristina	0.061^{b}	0.035^{de}	0.042^{cd}	0.046^{BC}	0.062^{b}	0.047^{e}	0.057^{c}	0.055^{A}
Nova Bosanka	0.053^{b}	0.052^{bc}	0.021^{g}	0.042^{C}	0.053^{d}	0.027^{h}	0.019^{i}	0.033^{C}
Orion	0.036^{de}	0.091^{a}	0.023^{fg}	0.050^{B}	0.036^{f}	0.075^{a}	0.017^{ij}	0.043^{B}
average	0.047^{B}	0.059^{A}	0.032^{C}	0.046	0.048^{A}	0.047^{A}	0.033^{B}	0.043

Different letters indicate significant difference at $P < 0.05$ level.

Salinity caused a significant reduction of coleoptile and root dry weight at the higher NaCl treatment and significant differences were determined between wheat varieties and applied treatment (-0.6MPa) (Table 5). Under these treatment wheat varieties significantly differed in coleoptile dry weight. One of the varieties, with highest average of coleoptile dry weight, was Jelena, as it showed the highest coleoptile dry weight under the conditions of -0.6MPa. There were no differences between control and low salt stress in root dry weight. At -0.6 MPa the variety Kristina showed lowest root dry weight. These results indicate that low salt concentrations stimulate the roots growth. Significant reduction of root growth occurred only at highest NaCl concentration. Our results are in agreement with MACHADO NETO *et al*. (2004) they reported that in soybean roots dry weight decrease under conditions of high salinity in soybean.

The results showed that different mannitol concentration showed a significant effect on wheat coleoptile and root dry weight (Table 5). Coleoptile dry weight gradually decreased with water deficit increase, while the highest root dry weight was recorded under conditions of -0.3 MPa. The highest average result of shoot dry weight under conditions of the highest mannitol concentration was reported in the variety Kristina. The variety Bosanka was more sensitive to water stress and had the lowest shoot dry weight at -0.6 MPa. Root dry weight did not suffer any decrease until -0.6 MPa, and the variety Orion presented lowest result (Table 5). According to MARUR *et al.* (1994), the lack of water slows physiological and biochemical processes of soybean seeds and low water deficit affected poor growth and reduced the accumulation of dry matter. Osmotic stress in the initial stage of salinity stress causes various physiological changes, such as interruption of membranes, nutrient imbalance, impairs the ability to detoxify reactive oxygen species (ROS), differences in the antioxidant enzymes, decreased photosynthetic activity, and decrease in stomatal aperture (RAHNAMA *et al.,* 2010). Under salt stress, plant may had an early flowering which dry matter, increased the ratio root/shoot and decreased the leaves size may be considered as possible ways of decreasing yield in wheat under salt stress conditions BAHRANI, (2013).

Table 5.Coleoptile dry weight (g) and root dry weight (g) of five winter wheat varietes exposed to water deficits induced by diferrent concentration of mannitol and sodium chloride during germination

Coleoptile dry weight								
Treatment	NaCl				Mannitol			
	0 MPa	-0.3 MPa	-0.6 MPa	average	0 MPa	-0.3 MPa	-0.6 MPa	average
Bosanka	0.066^{d}	0.026^{g}	0.009^{h}	0.034^{E}	0.066^{d}	0.040^{h}	0.008^{j}	0.038^{C}
Jelena	0.079^{b}	0.069^{d}	0.034^{f}	0.060^{A}	0.077^{c}	0.060^{e}	0.033^{i}	0.057^{A}
Kristina	0.083^{b}	0.029^{g}	0.003^{i}	0.038^{D}	0.083^{b}	0.042^{gh}	0.042^{gh}	0.056^{A}
Nova Bosanka	0.089^{a}	0.067^{d}	0.012^{h}	0.056^{B}	0.090^{a}	0.052^{f}	0.011^{j}	0.051^{B}
Orion	0.074^{c}	0.058^{e}	0.003^{i}	0.044^{C}	0.073^{c}	0.045^{g}	0.030^{i}	0.049^{B}
average	0.078^{A}	0.050^{B}	0.012^{C}	0.047	0.078^{A}	0.048^{B}	0.025^{C}	0.050
Root dry weight								
Treatment	NaCl				Mannitol			
	0 MPa	-0.3 MPa	-0.6 MPa	average	0 MPa	-0.3 MPa	-0.6 MPa	average
Bosanka	0.012^{h}	0.010^{i}	0.007^{j}	0.010^{D}	0.012^{g}	0.016^{cd}	0.007^{h}	0.011^{C}
Jelena	0.018^{ab}	0.017^{bc}	0.016^{cd}	0.017^{A}	0.018^{b}	0.014^{ef}	0.017^{c}	0.016^{B}
Kristina	0.014^{ef}	0.011^{hi}	0.008^{j}	0.011^{C}	0.014^{f}	0.024^{a}	0.017^{bc}	0.018^{A}
Nova Bosanka	0.015^{de}	0.013^{fg}	0.008^{j}	0.012^{B}	0.015^{e}	0.012^{g}	0.006^{i}	0.011^{D}
Orion	0.012^{gh}	0.019^{a}	0.005^{k}	0.012^{B}	0.012^{g}	0.011^{g}	0.008^{h}	0.010^{E}
average	0.014^{A}	0.014^{A}	0.009^{B}	0.012	0.014^{B}	0.015^{A}	0.011^{C}	0.013

Different letters indicate significant difference at $P < 0.05$ level.

Root/coleoptile ratio (RCR) is one of the several ratios which give estimates of the distribution of dry matter between the different plant organs (HUNT, 1990). It is a measure of distribution of dry matter between the root and the shoot systems and it is a good indicator for effects on root and shoot dry weights. Under NaCl treatment RCR across varieties increased from 0.180 (control) to 0.308 (-0.3MPa) and to 1.194 (-0.6MPa) (Table 6). Across treatment wheat varieties significantly differed in RCR. The variety with highest RCR ratio was Kristina and also had highest RCR under conditions of -0.6 MPa. Our results are in agreement with MAGHSOUD *et al.* 2008 who reported increase of RCR in wheat cultivars under the conditions of salt stress. This kind of an increase in RCR indicates that proportion of dry matter allocated to the coleoptile was decreased compared to the roots.

Under mannitol treatment average of RCR raised from 0.182 (control) to 0.340 (-0.3 MPa) and to 0.534 (-0.6MPa). In relation to the other varieties, the variety Bosanka had the highest RCR under -0.6MPa. High ratio RCR in the germination of winter wheat is a good indicator of resistance to drought (BAALABAKI *et al.,* 1999).

Table 6. Root / coleoptile ratio of five winter wheat varietes exposed to water deficits induced by diferrent concentration of mannitol and sodium chloride during germination

Root /coleoptile ratio								
Treatment	NaCl				Mannitol			
	0 MPa	-0.3 MPa	-0.6 MPa	average	0 MPa	-0.3 MPa	-0.6 MPa	average
Bosanka	0.173^{f}	0.386^{de}	0.825^{c}	0.462^{C}	0.179^{fg}	0.401^{d}	0.898^{a}	0.493^{A}
Jelena	0.231^{ef}	0.248^{ef}	0.481^{d}	0.320^{D}	0.231ef	0.236^{e}	0.513^{c}	0.327^{C}
Kristina	0.167^{f}	0.375^{de}	2.536^{a}	1.026^{A}	0.165^{g}	0.578^{b}	0.403^{d}	0.382^{B}
Nova Bosanka	0.169^{f}	0.198^{ef}	0.689^{c}	0.352^{D}	0.170^{g}	0.230^{ef}	0.587^{b}	0.329^{C}
Orion	0.161^{f}	$0.332d^{ef}$	1.439^{b}	0.644^{B}	0.163^{g}	0.254^{e}	0.269^{e}	0.229^{D}
average	0.180^{C}	0.308^{B}	1.194^{A}	0.560	0.182^{C}	0.340^{B}	0.534^{A}	0.352

Different letters indicate significant difference at $P < 0.05$ level.

The biplot of the principal component analysis (PCA) illustrates the relationships between the means of the studied traits in wheat cultivars grown under different level of NaCl and mannitol (Figure 1a and 1b). The cultivar × treatment points and traits vector are placed on biplot according to their PCA scores. Distributions of points represent the means of cultivars grown under different levels of drought stress. Under different levels of NaCl both axes accounted 78.26%, while under different level of mannitol PCA1 and PCA2 together captured 74.34% of the total variation in the data.

Biplot revealed similar interrelationship between studied traits in wheat cultivars at different NaCl and mannitol levels. Germination (Ger) and germination energy (GerEng) were in high positive association on both biplot, as indicated by acute angles. Moreover, root fresh (RFW) and dry weight (RDW) and coleoptile fresh weight (CFW) and dry weight (CDW) were highly associated under influence of different mannitol and NaCl level. There was positive association between root and coleoptile weight (both dry and fresh). Root length was in positive association with GerEng, indicating an early germination improves root growth. An increase in root growth is an indicator of the ability of plants to withstand under water stress as well as to screen plant cultivars for drought tolerance. On the other hand under the conditions of NaCl treatment coleoptiles length (CL) was in positive association with Ger and GerEng, while under conditions of mannitol treatment there was no association between these traits. Ger and GerEng had near zero (Fig 1a) and negative association (Fig 1b) with coleoptiles dry weight (CDW) and coleoptiles fresh weight (CFW). Biplot 1a and biplot 1b showed that wheat cultivars grown under lowest osmotic potential (-0.6MPa) had higher values of root/coleoptiles ratio (RCR) in relation to control and -0.3MPa treatment. This data indicates that coleoptile growth is more suppressed than root under condition of low osmotic potential. Moreover, cultivars grown under control treatment had higher values of most studied traits (except RCR) as previously shown in Table 2, 3, 4, 5 and 6.

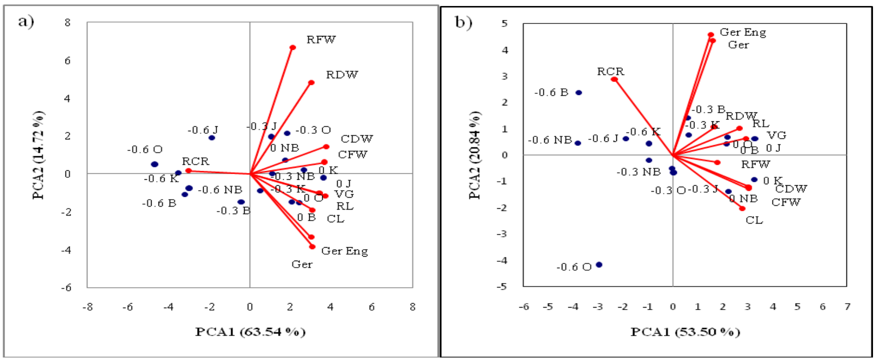

Figure 1. PCA analysis of trait association of winter wheat cultivars (Bosanka – B, Kristina – K, Jelena – J, Nova Bosanka – NB and Orion – O) grown under different level (0 MPa – O, -0.3 MPa – -0.3 and -0.6 MPa – -0.6) of NaCl (a) and mannitol (b)

CONCLUSION

The knowledge of genetic variation in plant tolerance to salinity and drought has a special role from the environmental and economic point of view in order to ensure the proper use of agricultural soils that are facing this problem. Based on the results of this study it can be concluded that there are significant differences between the examined cultivars in their response to drought tolerance. Generally a gradual increase of the NaCl and mannitol treatments was followed by a reduction in all the analyzed parameters in selected cultivars. Highest decrease occurred at increased salt and mannitol treatments (-0.6MPa) and it could be an indication of the tested varieties sensitivity to stressful conditions. In order to enhance plant tolerance to stressful environmental conditions, especially salinity and drought stress, studying the reaction of different cultivars in stressful environments is great importance in improving the efficiency of breeding and selection. The limit values of water resources when plant, under the influence of mannitol and sodium chloride, can germinate quite well and have a good increase in seedling was at -0.3MPa , i.e. in low stress. Increase in dry weight seedlings maintained a significant positive correlation with rate of germination, germination vigour index, shoot length, and root length, which indicates that these parameters could be used as a selection criteria for screening wheat genotypes against salt stress. Besides the standard techniques and commonly used data analysis, biplot offer additional options, preferably in the portion of a visual representation and understanding important interactions shown in the present data sets from surveys seed science research.

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UTICAJ SALINITETA I STRESA SUŠE NA KLIJANJE I RANI PORAST KLIJANACA HLEBNE PŠENICE (*Triticum aestivum* L.)

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Izvod

Salinitet je jedan od važnijih stresnih faktora okoline koji ograničava zemljišnu plodnost što ima uticaja na rast biljaka. Cilj ovog istraživanja je bio da se ispita životna sposobnost semena odabranih sorti ozime pšenice pod uticajem saliniteta i osmotskog stresa i da se utvrdi koje su najviše tolerantne sorte na salinitet i osmotski stres u fazi klijanja i ranog porasta klijanaca. Eksperiment je obuhvatio pet sorti ozime pšenice. Salinitet i osmotski stres je izazvan u kontrolisanim uslovima uz dodavanje različitih koncentracija NaCl i manitola u podlogu za rast semena pšenice. Kod svih ispitivanih sorti, vodni potencijal pri kojem sve sorte mogu da klijaju i imaju dobar rast klijanaca su pri -0.3MPa u uslovima niskog stresa. Pod uticajem jačeg stresa (-0,6MPa) sve sorte su pokazale smanjenje svih merenih parametara. Sorta Bosanka je pokazala najbolji rezultat klijanja i energija klijanja pod uticajem manitola i soli u odnosu na druge sorte. Parametri koji opisuju razvoj semena ili postotak snažnih semena, dužinu koleoptila i korena, sveže i suve mase korena i koleoptila) bila su više pogođene nedostatkom vode i stresom od soli nego klijanje i energija klijanja. Biplot analiza je pokazala da sorte pšenice gajene u uslovima najnižeg osmotskog potencijala (-0,6MPa) imale su više vriednosti odnosa koren/koleoptil u odnosu na kontrolu i -0.3MPa tretman, i ona je najpouzdanija analiza za skrining osobina genotipova za otpornost na sušu u fazi kljanaca.

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