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ORIGINAL PAPER

Influence of different salt concentration on germination, seedling growth and water uptake of oat seeds (*Avena sativa* L.)

Gergana Desheva[1] • Evgenia Valchinova[1] • Albena Pencheva[1] • Svilena Tosheva[1]

[1]Institute of Plant Genetic Resources „K. Malkov „ Sadovo, 4122, Sadovo

Corresponding Author: Gergana Desheva; E-mail: gergana_desheva@abv.bg

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Abstract

Desheva, G., Valchinova E., Pencheva A., Tosheva S. (2020). Influence of different salt concentration on germination, seedling growth and water uptake of oat seeds (Avena sativa L.*). Field Crops Studies, XIII(1), 37-52.*

The oat is considered to have a high potential for mitigating saline soil conditions. However, harvest time, soil salt content and varieties can affect the oats capacity to mitigate these stress conditions. The aim of this study was to investigate the influence of different NaCl salt concentrations on germination, early seedling growth and water uptake of oat seeds (*Avena sativa* L.) The experimental design was two factors factorial (2×5) arranged in a completely randomized design; with two replications. The first factor was seed cultivars (Katan, Kaloyan and Dunav) and the second factor was different concentrations of NaCl (25, 50, 75, 100, 125 and 150 mM). The results showed that the germination percentage, root and shoot length, wet and dry weight of the seedlings and water uptake decreased significantly with increase the salinity levels. Effects of salinity on salt tolerance index of investigated oat cultivars at 150 mM NACl indicated that Katan cultivar is most tolerant at germination stage, while Dunav cultivar at seedling growth stage. PC-analysis grouped analysed cultivars at different salinity stress according to similarity on the basis of investigated germination and seedling characters in two components in the factor plane.

Key words: Oat, *Avena sativa* L., Salinity, Germination, Seedling growth, Water uptake, PC-analysis

Introduction

The oat (*Avena sativa* L.) is a cereal crop, which extremely tolerant of drought, coldness, and mineral deficiency, which can grow in many types of soil and have a high saline-alkali tolerance. It is widely grown in the arid and semi-arid areas (Yongguang et al., 2015; Mut et al., 2015). Nihed Ben Halima et al. (2014) noted that *Avena sativa* L. is considered to have a high potential for mitigating saline soil conditions. However, harvest time, soil salt content and varieties can affect the oats capacity to mitigate these stress conditions. Willenborg et al. (2005) report that salinity affects not only oat plant physiological, morphological, and biochemical processes but also seed germination, growth and water/nutrient uptake. Yongguang et al. (2015) investigated and compared the growth and physiological changes of oat seedling under salinity stress. He concluded that oat seedlings accumulated more proline, Cl^- and SO_4^{2-} to maintaining osmotic and ion balance. In addition, NaCl stress had no significant effect on the growth of roots, and the roots can play the interceptive and protective role with a stronger salt tolerance. The roots can change the distribution of Na^+, then it decreased the harm on the shoots and increased the tolerance of oat seedling. In contrast Wu et al. (2009) in a germination experiment, with 7 oat varieties and treated with NaCl and Na_2SO_4 with 11 salt concentration ranging from 0.4% to 4.4% found that salt stress inhibited seed germination and seedling growth of oats and the inhibitory effect increased with increasing salt concentration. Relative germination rate, germination index, relative simple activity index, seedling root length and plant height decreased gradually, while membrane permeability of leaves increased. Relative germination rate, germination index and relative simple activity index can be used as the main indicators of salt tolerance of the plants. Aroul et al. (2018) also reported that salt stress significantly reduced the growth of the oat grass genotypes during the seedling stage. The stomatal inhibition of photosynthesis, caused by direct effects of NaCl on the photosynthetic apparatus independent of the stomatal closure, might be responsible for the reduction in photosynthetic rate. NaCl stress inhibited plant growth and had a significant effect on the plant height, number of leaves, diameter of plant, leaf area, root length, flag leaf area, length of spike and shoot dry matter. Chauhan et al. (2016) and Brunes et al. (2013) confirmed that the rate of seed germination decreased in oat cultivars with increasing levels of salinity from 25 to 100 mM, while Mut and Akay (2010) noted that with decreasing seed size the osmotic potential increased median germination time (MGT) and decreased final germination percentage (FGP), root and shoot length. Therefore the germination and plantlet growth indices (e.g., percentage and vigor) are two of the most important criteria for selection of tolerant cultivars (Bybordi, 2010).

The purpose of this study was to determine the effect of different concentration of NaCl on seed germination, seedling growth and water uptake of oat seeds in three oat varieties.

Material and methods

Seeds of five Bulgarian oat cultivars: Katan, Kaloyan and Dunav created in the IPGR-Sadovo are used. The seeds are surface sterilized by dipping the seeds in 30% etanol solution for 3 minutes and rinsed thoroughly with distilled water and air-dried before being used in the germination tests to avoid any fungal attacks.

The experimental design was two factors factorial (2×5) arranged in a completely randomized design; with two replications. The first factor was seed cultivars (Katan, Kaloyan and Dunav) and the second factor was different concentrations of NaCl. Five concentrations of NaCl (25, 50, 100, 125 and 150 mM) are used as treatments and deionized water is used as the control. For each variant of the experiment, two replicates of 25 seeds are germinated between rolled filter paper (Grade FT 55) with 20 ml of respective test solutions. The papers are replaced every 2 days to prevent accumulation of salts (Rehman et al., 1996). The rolled paper with seeds is put into sealed plastic bags to avoid moisture loss. Seeds are allowed to germinate at 20±1 ◦C in the dark for 10 days. Seeds are considered germinated when radicle had extended at least 1 mm. The number of germinated seeds is recorded daily until a constant count is achieved. From the germination counts several germination characteristics are studied including germination energy (%) as first count after 5 days (GE), germination percentage (%) as final count after 10 days (G, %), coefficient of velocity of germination (CVG, % day^{-1}), germination rate index (GRI), and mean germination time (MGT, day). Coefficient of velocity of germination (CVG, % day^{-1}) is calculated according to Kader and Jutzi (2004). Germination rate index (GRI, % day^{-1}) and mean germination time (MGT, day) are calculated according to the formula of Kader (2005).

The data for the shoot and root length (cm) (LSh and LR), length of seedling (LS, cm), fresh weigh (mg) of shoot and root (FWSh and FWR) and dry weight (mg) of shoot and root (DShW and DRW) are measured ten days after germination. Dry weights are measured after drying at 80°C for 24 h into an oven.

Water uptake of seeds (WU) is determined after soak the seeds for 24 h in the different concentrations of NaCl. It is calculated by the formula given from Nizam (2011).

In order to determine the seed vigor index (VI), equation from Florez et al. (2007) is used.

Salt tolerance is calculated by the formula given from Mujeeb-ur-Rahman et al. (2008).

The obtained data were examined by one-way analysis of variance (ANOVA). Tukey HSD tests were performed to determine significant difference between means at a significance level of $P < 0.05$. PC-analysis was applied to group cultivars at different salt concentrations according to similarity on the basis of investigated germination and seedling characteristics in two components in the factor plane. Statistical analyses are performed using the statistical program SPSS 19.0.

Results and discussion

Effect of salinity on the germination characteristics and water uptake of seeds

The influence of different salt concentrations on germination characteristics are presented in Table 1 and Table 2. The germination energy (GE) and germination percentage (G) declined in all oat cultivars with increased the concentration of salinity from 25 to 150 mM. The cultivars Kalojan and Dunav exhibited significant differences for both characteristics at higher salinity levels 75, 100, 120 and 150 mM NaCl salinity, while Katan variety only at 120 and 150 mM NaCl salinity levels (Table 1). Similar results with decrease of germination of oat seeds under salinity stress were also reported by Willenborg et al. (2005); Brunes et al. (2013); Kumar (2014); Chauhan (2016, 2018); Benlioglu and Ozkan (2016) and Chauhan et al. (2018). According to Hajlaoui et al. (2007) and Khayatnezhad et al. (2011) reduction in final germination percentage is result of the increase of external osmotic pressure which affects the absorption of water by the seed and also due to the accumulation of Na+ and Cl- in the embryo which lead to an alteration in the metabolic processes of germination and causes cells death in embryo.

Kumawat et al. (2017) noted that generally, germination is delayed and the period of delay increases with the concentration of salinity. This was also confirmed by our results obtained for the mean germination time (MGT). There was positive relation between salt concentrations and MGT. Increasing salinity concentration from 0 to 150 mM NaCl increased mean germination time. At the highest salt level (150 mM NaCl), the MGT varied between 2,60 and 3,04 days, respectively. Compared with control (distilled water), high NaCl solutions of 125–150 mM significantly reduced coefficient of velocity of germination (CVG) and germination rate index (GRI) at level $p \leq 0.05$. The strongest decrease in CVG and GRI at 150mM NaCl concentration was observed in Kalojan, respectively with 15,22% and 4,46%. Panuccio et al. (2014) noted that higher CVG and GRI, and lower MGT represent higher and faster germination of seed. Our results also showed that high salinity inhibited the germination of seed and prolong germination time in oat (Table 2).

Brunes et al.(2013) and Mut et al. (2010) reported that oat germination characteristics are affected by cultivar; seed size and moisture stress. Willenborg et al. (2005) reported that salinity affects not only oat plant physiological,

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morphological, and biochemical processes but also seed germination, growth and water/nutrient uptake. At high level of salt concentration, the osmotic pressure of the environment increased so water absorption of the seed decreased (Nizam, 2011). Kaydan and Yagmur (2008) noted also that high NaCl levels lead to lower water uptake by seed. In this study water uptake of seeds was the highest at 25 mM salt concentration. The lowest water uptake was determined at the highest salt level (150mM). Compared with the control variant, seeds from Dunav variety had the highest water uptake after 24 h at 150 mM salt level, respectively 28,10%, while water uptake of Katan seeds was the lowest (10.44%) at the same concentration (Table 1).

Table 1. Effects of different salinity levels on germination energy (GE, %), germination (G, %) and water uptake of seeds (WU,%) in three oat cultivars

NaCl, mM	KE, %			K,%			WU, %		
	Katan	Kalojan	Dunav	Katan	Kalojan	Dunav	Katan	Kalojan	Dunav
0	98cAB	100dB	94bA	98abA	100cA	98cA	62,42bA	73,95aA	85,15dA
25	100cA	98cdA	96bA	100cA	98bcA	96bcA	63,32bA	71,02aB	73,28cB
50	100cB	92cdA	93bAB	100cA	92abcA	96bcA	61,31bA	65,88aAB	67,59bcB
75	96bcB	84bcAB	78aA	96abA	90abA	86aA	60,99bA	63,21aA	66,26bcA
100	90abcA	84bcA	78aA	98abA	90abA	88abA	57,86abA	61,97aA	66,19bcA
125	84abB	72aA	74aA	90aA	86aA	86aA	57,22abA	60,11aA	63,51abA
150	78aA	74abA	68aA	90aA	86aA	84aA	51,98aA	59,76aB	57,05aAB
Total	92,29	86,29	82,86	96,00	91,71	90,57	59,30	65,13	68,44

Subscripts (a-d) with different letters in the column indicated significant difference among mean ($p \leq 0,05$, using Tukey HSD)

Subscripts (A-B) with different letters in the row indicated significant difference among mean ($p \leq 0.05$, using Tukey HSD)

In the figure 1 is presented the effect of salinity on germination salt tolerance index (GSTI) of investigated three oat cultivars at different NaCl concentrations (25-150 mM). Katan cultivar is most tolerant at germination stage at all levels of salt stress. At the highest salinity level -150mM NaCl, GSTI varied between 91.84 for Katan and 85.71 for Dunav.

Effect of salinity on the seedling characteristics

Effects of different salinity levels on seedling characteristics of the investigated three oat cultivars are given in Tables 3-5. The shoot and root length are the most important parameters for salt stress because roots are in direct contact with soil and absorb water from soil and shoot supply it to the rest of plant (Chauhan et al., 2016). The data on the average length (table 3) of shoot and root showed that oat cultivars had a strong inhibition with the increasing level of salt solution particularly at high salt levels (125 and 150 mM).

Table 2. Effects of different salinity levels on coefficient of velocity of germination (CVG, % day^{-1}), germination rate index (GRI) and mean germination time (MGT, day) in three oat cultivars

NaCl mM	CVG,%			GRI,%			MGT, day		
	Katan	Kalojan	Dunav	Katan	Kalojan	Dunav	Katan	Kalojan	Dunav
0	52,17 bAB	49,09 cAB	45,37 cA	13,92 cA	13,08 eA	13,10 cA	1,91 aA	2,04 aA	2,20 aB
25	51,02 bB	47,63 cA	45,28 cA	13,00 bcB	12,37 deAB	11,58 bcA	1,96aA	2,10 aAB	2,21 aB
50	50,63 bB	45,99 cA	43,24 bcA	13,08 bcA	11,58 cdA	11,74 bcA	1,98 aA	2,17 aB	2,31 abB
75	50,06 bB	40,90 bA	41,65 bcA	12,50 bcA	10,36 bcA	11,10 abcA	1,99 aA	2,44 bA	2,44 abA
100	41,92 aA	38,77 bA	37,62 abA	12,28 bB	9,74 abA	9,97 abA	2,39 bA	2,58 bA	2,66 bcA
125	38,49 aB	34,67 aA	34,67 aA	10,04 aB	9,36 abA	8,71 aA	2,59 c A	2,88 cB	2,88 cdB
150	38,42 aB	33,87 aA	32,82 aA	10,13 aB	8,62 aA	8,92 aA	2,60 cA	2,95 cB	3,04 dB
Total	46,11	41,57	40,10	12,14	10,73	10,74	2,21	2,46	2,54

Subscripts (a-d) with different letters in the column indicated significant difference among mean (p≤0,05, using Tukey HSD)
Subscripts (A-B) with different letters in the row indicated significant difference among mean (p≤0,05, using Tukey HSD)

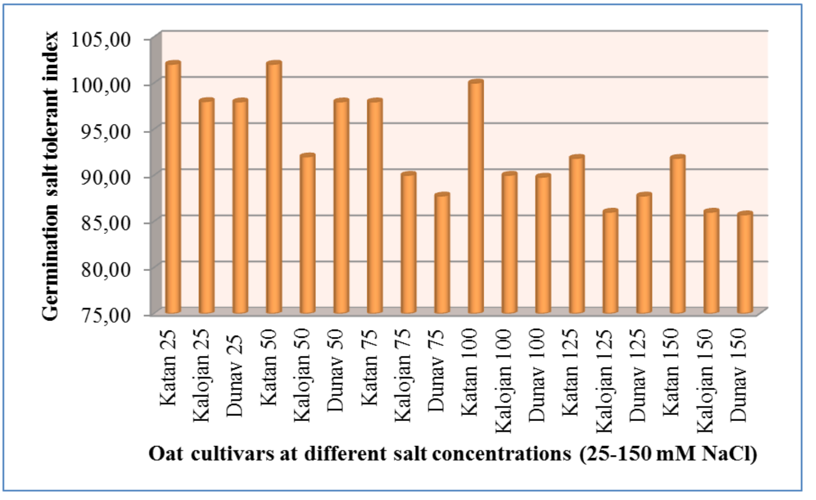

Figure 1. Effect of NaCl concentrations on the germination salt tolerant index of investigated oat cultivars

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The longest shoot length (LSh) is observed in the 25 mM NaCl variant for Katan variety (10,64 cm). The shortest shoot length is 4,38 cm at 150 mM NaCl concentration for Dunav, but the highest rate of decline in shoot length at the same concentration is recorded for Kalojan variety , when compare with the control variant, respectively with 4,99 cm (Table 3).

Root length (LR) provides an important clue to the response of plants to salt stress (Kaya et al., 2003). Among the varieties, the longest root length was determined in variety Katan (7,76 cm) at 25mM NaCl, while Kalojan gave the shortest root length (2,75 cm) at 150mM NaCl. Generally, increasing salinity levels decreased root length. The rate of decline in root length for Dunav variety was the lowest only with 3,43 cm in compared with the control variant at 150 mM NaCl (Table 3).

Seedling growth (LS) significantly decreased at higher salinity level (Table 3). However, the effect was remarkable on shoot compared to the root growth (Table 3, Table 5). This is in agreement with previous reports in oat (Chauhan et al., 2016). Yousofinia et al. (2012) and Jamil et al. (2016) assume that this reduction with increasing salinity may be due to limited supply of metabolites to young growing tissues because metabolic production is significantly perturbed at high salt stress, probably due to the toxic effects of salt.

Table 3. Effects of different salinity levels on seedling characteristics of three oat cultivar

NaCl, mM	LSh, cm			LR, cm			LS, cm		
	Katan	Kalojan	Dunav	Katan	Kalojan	Dunav	Katan	Kalojan	Dunav
0	9,45 dB	9,48 eB	8,21 eA	8,78 dB	7,90 eB	6,69 dA	18,24 dB	17,39 fB	14,90 fA
25	10,64 eB	8,38 dA	8,03d eA	7,76 cdC	5,91 dB	5,27 cA	18,40 dB	14,29 eA	13,30 eA
50	9,92 dB	7,97 dA	7,45 cdA	7,15 cB	5,57 dA	3,97 bA	17,07 dB	13,81 eA	11,23 dA
75	8,01 cA	7,28 cA	7,08 cA	5,39 bB	5,26 cdB	3,74 abA	13,4 cB	12,55 dB	10,82 cdA
100	6,56 bA	6,11 bA	6,12 bA	4,77 abA	4,28 bcA	3,68 abA	11,33 bcA	10,39 cA	9,80 bcA
125	6,31 bA	6,03 bA	6,13 bA	4,56 abB	3,25 abA	3,32 aA	10,87 abB	9,28 bA	9,45 bA
150	5,21 aA	4,49 aA	4,38 aA	3,62 aB	2,75 aA	3,26 aB	8,84 aB	7,25 aA	7,65 aA
Total	8,02	7,15	6,75	6,01	4,99	4,28	14,02	12,14	11,02

Subscripts (a-f) with different letters in the column indicated significant difference among means ($p<0.05$, using Tukey HSD)

Subscripts (A-C) with different letters in the row indicated significant difference among means ($p<0.05$, using Tukey HSD)

In oat salt treatments also caused reduction in seedling fresh and dry weight, which is similar to several reports (Agarwal and Panday, 2004; Ramezani et al., 2011; Akbarimoghaddam et al., 2011; Jamil et al., 2016; Chauhan et al., 2016). Shoot and root fresh and dry weights were significantly affected by different levels of salinity. It is obvious from table 4 and table 5 that at higher NaCl concentrations has significantly reduced shoot and root fresh and dry weight. The highest shoot and root dry weight reductions at 150 mM NaCl level in compare with control variants are obtained for Katan, respectively with 3,55 mg $plant^{-1}$ and 3,05 mg $plant^{-1}$, while the lowest are noted for Dunav (with 2,22 mg $plant^{-1}$ for shoot and 1,45 mg $plant^{-1}$ for root) (Table 5).

Vigor index (VI) as indicator of the germination capacity and growing tendency of seedling (Deng et al., 2014) considerable decrease depending of the increase in the concentration of NaCl (Table 5). The highest VI is observed in the 25 mM NaCl variant for Katan variety (1401,78), while the lowest is noted at 150mM NaCl (624) for Kalojan. The VI increased when the NaCl concentration decreased, which shows that increased NaCl concentration caused a harmful effect in the seed (Table 5).

Table 4. Effects of different salinity levels on seedling characteristics of three oat cultivars

NaCl, mM	FShW, mg			FRW			DShW		
	Katan	Kalojan	Dunav	Katan	Kalojan	Dunav	Katan	Kalojan	Dunav
0	80,8 bcB	61,95 eA	50,95 dA	39,5 bC	28,35 cA	32,4 bB	7,6 eB	6,55 cAB	5,55 cA
25	86,15 cC	59,95 deB	48,05 cdA	37,75 abB	26,75 bcA	31,65 bAB	8,35 fC	6,40 cB	5,5 cA
50	82,85 cB	52,7c deA	47,65 cdA	35,6 abB	26,35 bcA	30,75 bAB	7,95 efB	5,85 bcA	5,3 cA
75	64,75a bB	48,85 bcdA	47,15 bcdA	35,4 abB	24,75 bcA	27 abA	6,7 dB	5,2 abcA	5,15 bcA
100	53,5 aA	44,3 bcA	42,1 bcA	33,4 abB	23,55 bcA	20,85 aA	5,7 cB	4,5 abA	4,75 bcA
125	51,9 aA	39,0 abA	38,65 abA	32,95 abA	22,15 bA	21,55 aA	4,9 bA	4,3 abA	4,3 abA
150	49,7 aB	30,4 aA	31,10 aA	26,05 aC	16,45 aA	20,55 aB	4,05 aB	3,55 aA	3,35 aA
Total	67,09	48,16	43,66	34,38	24,05	26,39	6,46	5,19	4,84

Subscripts (a-f) with different letters in the column indicated significant difference among means ($p<0.05$, using Tukey HSD)

Subscripts (A-C) with different letters in the row indicated significant difference among means ($p<0.05$, using Tukey HSD

Table 5. Effects of different salinity levels on seedling characteristics of three oat cultivars

NaCl, mM	DRW			VI			R/Sh		
	Katan	Kalojan	Dunav	Katan	Kalojan	Dunav	Katan	Kalojan	Dunav
0	6,5 cC	5,4 dB	4,4 bA	1789,4 dB	1739 eB	1460,04 eA	0,92 bB	0,83 bA	0,81 cA
25	5,65 bcB	4,9 cdAB	4,25 bA	1840,5 dB	1401,78 dAB	1276,98 dA	0,72 aB	0,70 abAB	0,65 bA
50	5,4 abcA	4,25 bcA	4,05 bA	1707,5 dB	1270,92 cdA	1078,56 cA	0,72 aA	0,68 abA	0,54 aA
75	4,1 abA	3,95 bcA	3,95 bA	1285,92 cB	1129,52 cB	936,02 bcA	0,67 aB	0,72 abB	0,53 aA
100	3,9 abA	3,6 bA	3,2 aA	1113,7 bcA	940,2 bA	863,7 bA	0,72 aA	0,70 abA	0,60 abA
125	3,5 abA	3,3 abA	3,1 aA	979,6 abB	798,58 abA	811,94 abA	0,72 aB	0,53 aA	0,54 aA
150	3,45 aC	2,55 aA	2,95 aB	790,62 aB	624 aA	642,6 aA	0,69 aB	0,61 aA	0,74 cB
Total	4,64	3,99	3,70	1358,18	1129,14	1009,98	0,74	0,69	0,63

Subscripts (a-d) with different letters in the colon indicated significant difference among means ($p<0.05$, using Tukey HSD)
Subscripts (A-C) with different letters in the row indicated significant difference among means ($p<0.05$, using Tukey HSD)

Shoot salt tolerance index (ShSTI), root salt tolerance index (RSTI) and total seedling salt tolerance index (TSTI) of the investigated three oat cultivars at different NaCl concentrations (25-150 mM) are given in figure 2 and figure 3. Genotypes showed significant variation. At the low levels of salinity (25-50 mM NaCl) Katan cultivar showed the highest ShSTI and RSTI, respectively the highest total seedling salt tolerance index. At the higher salinity level between 100 and 150mM NaCl, Dunav variety is the most tolerant at the early seedling growth stage. At the 150mM NaCl salinity, TSTI varied between 41,69 for Kalojan and 51,32 for Dunav.

Principal factors were carried out using principal component (PC) method for factor extraction. In the present investigation, only the first two principal components showed eigen values more than one and cumulatively they explained 92,88% variability. The first principal component explained 79,03% of the total variation and the second principal component explained 13,85% variation, respectively. The first factor was connected to the all germination and seedling characteristics, while the second factor was formed by the water seed uptake (Table 6).

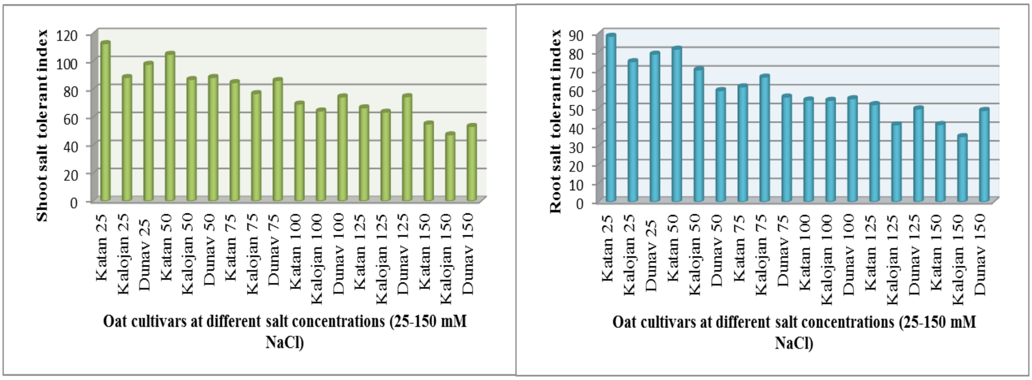

Figure 2. Effect of NaCl concentrations on the shoot and root salt tolerant index of investigated oat cultivars

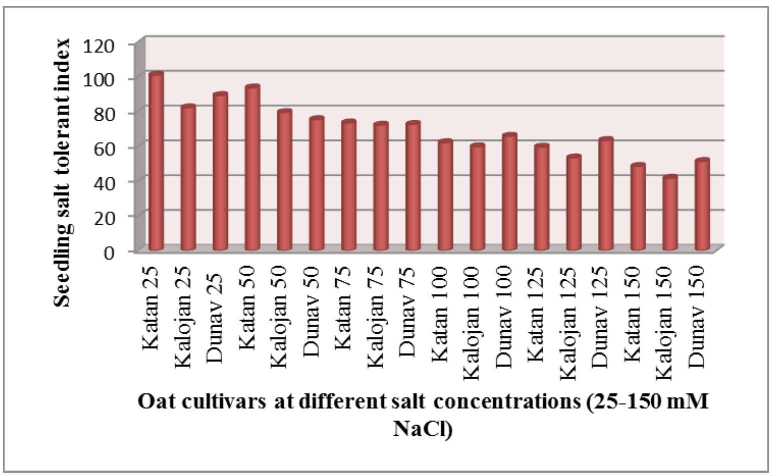

Figure 3. Effect of NaCl concentrations on the total seedling salt tolerant index of investigated oat cultivars

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Table 6. Weighted factors (PC1 and PC) of descriptive characteristics on the rotated matrix with two factors

Characteristics	**PC 1**	**PC 2**
Coefficient of velocity of germination (CVG)	***0,941***	0,269
Germination rate index (GRI)	***0,902***	0,335
Mean germination time (MGT)	***-0,923***	-0,302
Germination energy (GE)	***0,886***	0,368
Germination percentage (G)	***0,867***	0,327
Water uptake of seeds (WU)	0,142	***0,979***
Length of shoot (LSh)	***0,908***	0,335
Length of root (LR)	***0,905***	0,288
Length of seedling (LS)	***0,927***	0,319
Fresh weigh of shoot (FShW)	***0,983***	-0,068
Fresh weigh of root (FRW)	***0,896***	-0,016
Dry weight of shoot (DShW)	***0,970***	0,115
Dry weight of root (DRW)	***0,934***	0,210
Vigor index (VI)	***0,933***	0,320
Eigenvalues	11,944	1,059
% of Variance	79,027	13,850
Cumulative %	**79,027**	**92,876**

Distribution of evaluated cultivars at different salinity stess in the coordinate system of PC1 and PC2, present the grouping of them according to similarity of analysed germination and seedling characteristics (Fig. 4). The cultvars Katan treated with salinity concentrations from 0 to 100mM NaCl and Kalojan at 50 mM NaCl grouped in the upper left quadrants had positive values for PC1 and negative values for PC2. Kalojan at 0 and at 25 mM NaCl salinity levels classified in the upper right quadrants had positives values for both factors (PC1 and PC2). Accessions in the below left quadrants (Katan at 120-150 mM NaCl, Kalojan at 75-150 mM NaCl and Dunav at 150 mM NaCl) had respectively negative values for both factors. The samples in the below right quadrants are characterized with negative values for PC1 and positive values for PC2. In this group is separated Dunav cultivar at 0 to 125 mM NaCl salinity stress.

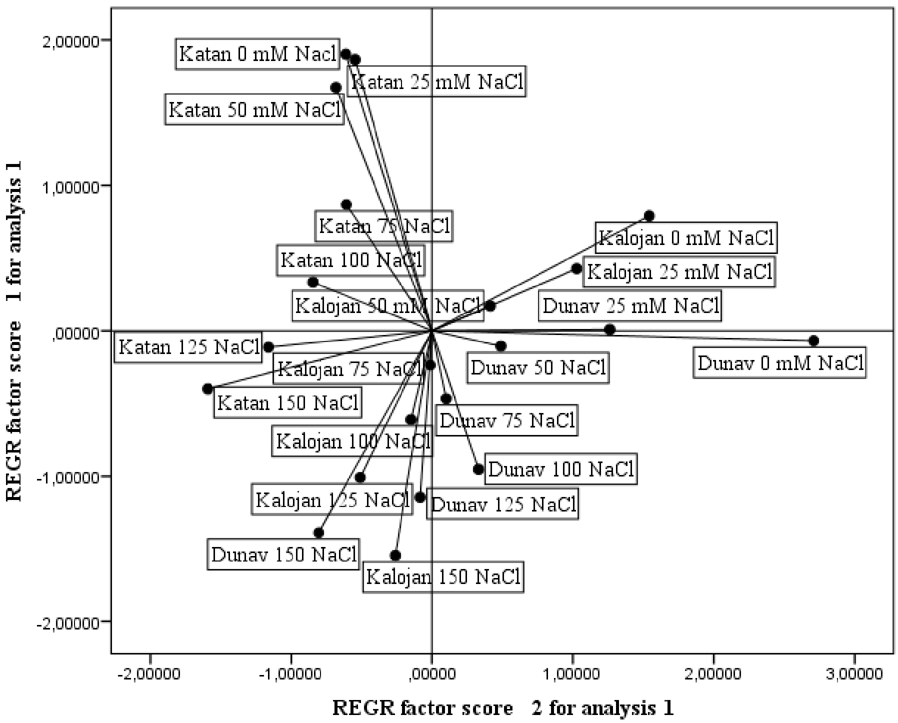

Figure 4. Distribution of evaluated oat cultivars within the factor plane according to similarity of germination and seedling characteristics at different salt concentrations

Conclusions

The results showed that increasing salinity concentration from 0 to 150 mM NaCl inhibited the germination of oat seeds and prolong germination time. Higher NaCl levels lead to lower water uptake by seed. Seedling growth significantly decreased at higher salinity levels. However, the effect was remarkable on shoot compared to the root growth. At the higher salinity concentrations Katan cultivar is the most tolerant at germination stage, while Dunav variety is the most tolerant at the early seedling growth stage.

PC-analysis grouped analysed cultivars at different salinity stress according to similarity on the basis of investigated germination and seedling characters in two components in the factor plane.

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References

Akbarimoghaddam, H., Galavi, M. Ghanbari, A. & Panjehkeh, N. (2011). Salinity effects on seed germination and seedling growth of bread wheat cultivars. *Trakia Journal of Sciences*, Vol. 9, No 1, pp 43-50, 2011.

Anju, C., Rajput, N. Kumar, D. Kumar, A. & Chaudhry, K. (2016). Effect of different salt concentration on seed germination and seedling growth of different varieties of oat (*Avena sativa* L.). *International Journal of Information Research and Review*, 03(07), pp. 2627-2632, July, 2016.

Anju, C., Rajput, N. Kumar, A. Verma, J.S. & Chaudhry, A.K. (2018). Interactive effects of gibberellic acid and salt stress on growth parameters and chlorophyll content in oat cultivars. Journal of Environmental Biology, 2018, 39,639-646.

Agarwal, S. & Pandey, V. (2004): Antioxidant enzyme responses to NaCl stress in Cassia angustifolia. *Biologia Plantarum*, 48: 555–560.

Aroul, M., Sargul, A. Khudhur, A. & Mustafa, Y.H. (2018). Effect of NaCl on Some Morphological Characters of Oat (*Avena sativa L.*) Plants. International Conference on Pure and Applied Sciences (ICPAS 2018), 80-85. DOI: http://dx.doi.org/10.14500/icpas2018.

Benliglu, B. & Ozkan, U. (2016). Determination of responses of some oat cultivars (*Avena sativa* L.) to salt and drought stress at the germination period. *Ciencia e ecnica Vitivinicola J.*, 31, 6-25, 2016.

Bybordi, A. (2010). The Influence of salt stress on seed germination, growth and yield of canola cultivars. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 38, 128-133.

Chauhan, A., Rajput, N., Kumar, D., Kumar, A. & Chaudhry, A.K. (2016). Effect of different salt concentration seed germination and seedling growth of different varieties of oat (*Avena sativa L.). Int. J. Inform. Res. Rev.*, 3, 2627-2632, 2016.

Deng, Y., Yuan, F., Feng, Z., Ding, T., Song, J. & Wang, B. (2014). Comparative study on seed germination characteristics of two species of Australia saltbush under salt stress. *Acta Ecologica Sinica*, 34, 337-341.

Florez, M., Victoria, C.M. & Martinez, E. (2007). Exposure of maize seeds to stationary magnetic fields: Effects on germination and early growth. *Environmental and Experimental Botany*, 59(1), 68-75.

Hajlaoui, H., Denden, M. & Bouslama, M. (2007). Etude de la variability interaspecifique de tolerance au stress du pois chiche *Cicer arietinum* L. au stade germination. *Tropicultura*, 25:168- 173.

Halima, N.B., Saad, R. B., Slima, A. B., Khemakhem, B., Fendri, I. & Abdelkafi, S. (2014). Effect of Salt Stress on Stress-associated Genes and Growth of Avena Sativa L. *Isesco Journal of Science and Technology*, 10(18), 73-80.

Jamil, M., Lee, D. B., Jung, Y.K., Ashraf, M., Lee, C.S. & Rha, E.S. (2016). Effect of different salt concentration on seed germination and seedling growth of different varieties of oat (*Avena sativa* L.). *International Journal of Information Research and Review*, 3(7), 2627-2632, 2016.

Kader, M.A. & Jutzi, S.C. (2004). Effects of Thermal and Salt Treatments during Imbibition on Germination and Seedling Growth of Sorghum at 42/19 C. *Journal of Agronomy and Crop Science*, 190(1), 35–38.

Kader, M.A. (2005). A comparison of seed germination calculation formulae and the associated interpretation of resulting data. *Journal and Proceeding of the Royal Society of New SouthWales*, 138, 65–75.

Kaya, M. D., Üpek, A. & RK. ZT.A. (2003). Effects of Different Soil Salinity Levels on Germination and Seedling Growth of Safflower (*Carthamus tinctorius* L.). *Turk J Agric For.*, 27, (2003) 221-227.

Kaydan, D. & Yagmur, M. (2008). Germination, seedling growth and relative water content of shoot in different seed sizes of triticale under osmotic stress of water and NaCl. Afr. J. Biotechnol., 7(16): 2862-2868.

Khayatnezhad. M. & Gholamin, R. (2011). Effects of salt stress levels on five maize (*Zea mays* L.) cultivars at germination stage. *African Journal of Biotechnology*, Vol. 10(60), 2011.

Kumar, A., Agarwal, S. & Singh, A. (2014). Salinity effects the germination and seedling growth in some cultivars of oat (*Avena sativa L.). Indian J. Adv. Plant Res*, 1, 1-10.

Kumawat. S., Gothwal, DK. Kumawat, R. K. Kumawat, R. & Sharma, M. (2017). Effect of salt stress on seed germination and early seedling traits in fenugreek (*Trigonella foenum-graecum* L.) genotypes grown under different salinity levels. *Journal of Pharmacognosy and Phytochemistry*, 2017; 6(5): 776-781.

Mujeeb-ur-Rahman, U., Soomro A., Zahoor-ul-Haq, M. & Gul, Sh. (2008). Effects of NaCl salinity on wheat (*Triticum aestivum* L.) cultivars. *World Journal of Agricultural Sciences*, 4 (3), 398-403.

Mut, Z., Akay, H. & Aydin, N. (2010). Effects of seed size and drought stress on germination and seedling growth of some oat genotypes (*Avena sativa* L.) *African Journal of Agricultural Research*, 5: 1101-1107.

Mut, Z. & Akay, H. (2010). Effect of seed size and drought stress on germination and seedling growth of naked oat (*Avena sativa* l.). *Bulgarian Journal of Agricultural Science*, 16(4) 2010, 459-467.

Nizam, I. (2011). Effects of salinity stress on water uptake, germination and early seedling growth of perennial ryegrass. *African Journal of Biotechnology*, Vol. 10(51), pp. 10418-10424.

Panuccio, M.R., Jacobsen, S.E., Akhtar, S.S. & Muscolo, A. (2014). Effect of saline water on seed germination and early seedling growth of the halophyte quinoa.

ISSN: 2535-1133 (Online)
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AoB PLANTS, 6: plu047; doi:10.1093/aobpla/plu047.

Pich, B.A., Fonseca, D.Â.R., Rufino, C. de A., Tavares, L.C., Tunes. L.M. & Villela, F.A. (2013). Seedling growth of white oats submitted to salt stress. *Semina: Ciências Agrárias, Londrina*, 34(6), suplemento 1, p. 3455-3462, 2013.

Ramezani, E., Sepanlou, M.G. and Badi, H.A.N. (2011). The effect of salinity on the growth, morphology and physiology of *Echium amoenum* Fisch & Mey, *African Journal of Biotechnology*, 8765-8773 (2011).

Rehman, S., Harris, P.J.C., Bourne, W.F. & Wilkin, J. (1996). The effect of sodium chloride on germination and the potassium and calcium content of Acacies seeds. *Seed Science and Technology*, 25, 45-57.

Willenborg, C.J., Wildeman, J.C., Miller, A.K. Rossnagel, B.G. & Shirtliffe, S.J. (2005). Oat germination characteristics differ among genotypes, seed sizes, and osmotic potentials. *Crop Science*, vol. 45, pp. 2023-2029.

Wu, J.Y., Liu, J.H., Li, Q. & Fu, Z.J. (2009). Effect of salt stress on oat seed germination and seeding membrane permeability. *J. Triticeae Crops*, 29, 341–345.

Yongguang, MU., Lin, J., Mu, C. & Gao, Z. (2015). Effects of NaCl Stress on the Growth and Physiological Changes in Oat (*Avena sativa*) Seedlings. *Not Bot Horti Agrobo*, 2015, 43(2):468-472.

Yousofinia, M., Ghassemian, A., Sofalian, O. & Khomari, S. (2012). Effects of salinity stress on barley (*Hordeum vulgare* L.) germination and seedling growth. *International Journal of Agriculture and Crop Sciences*, 4(18): 1353-1357.