Germination and Early Seedling Growth Characteristics of *Arachis hypogaea* L. under Salinity (NaCl) Stress

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Summary

Peanut plants (*Arachis hypogaea* L.) are glycophytes indicating their vulnerability to highly saline soils. The aim of this study was to evaluate the effect of different NaCl concentrations on seed germination characteristics and early seedling growth of peanut seeds of three Bulgarian cultivars - 'Kremena', 'Kalina' and '4389'. Four different concentrations of NaCl (50, 100, 150 and 200 mM) were used as treatments and deionized water as control. To determine the salinity tolerance, the data for following germination characteristics - germination energy (%), final germination (%), coefficient of velocity of germination (% day^{-1}), germination rate index and mean germination time (day) and seedling characteristics - shoot and root length (cm), fresh weight (mg $plant^{-1}$) of shoot and root and dry weight (mg $plant^{-1}$) of shoot and root were recorded. The Vigor index, coefficients of depression of roots and shoots and salt tolerance index were also calculated. The genotype had the strongest influence on the variance of the root length, while the salinity treatment had the strongest influence on germination energy, coefficient of velocity of germination, germination rate index, mean germination time, length of shoot, fresh weight of shoot and dry weigth of shoot and root. 'Kremena' was the most tolerant at seedling growth stage, while '4389' was the most sensitive especially at high levels of salt stress. Principal component (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

peanut, germination, salinity, seedling growth, PC-analisysis

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Received: January 12, 2020 | Accepted: March 19, 2020

Abbreviations

GRE - germination energy (%), GR – final germination percentage (%), CVG - coefficient of velocity of germination (% day^{-1}), GRI - germination rate index, MGT - mean germination time (day), VI - Vigor index, LSh - length of shoot (cm), LR - length of root (cm), FWSh - fresh weigh of shoot (g), FWR - fresh weigh of root (g), DWSh - dry weight of shoot (g), DWR - dry weight of root (g), ShSTI - shoot salt tolerance index, RSTI – root salt tolerance index, TSSTI - total seedling salt tolerance index.

Introduction

Soil salinization is a process in which the content of water soluble salts and / or sodium exchange in soils is increased in quantities that adversely affect their properties or their productive potential. Salinity is known to retard plant growth through its influence on several facets of plant metabolism like osmotic adjustment, ion uptake, protein and nucleic acid synthesis, photosynthesis, enzyme activities and hormonal balance (Hammad et al. 2005; Lacerda et al., 2006; Abou-Hussien et al., 2010; Al-Khaliel, 2010; Salwa et al., 2010; Sousa et al., 2010; Alves et al., 2017). Different crops can tolerate different levels of salinity in irrigation water. The tolerance of plants to salinity is mainly influenced by: climate, particularly the abundance or lack of rainfall to leach salts from soils, as well as from soil types and drainage characteristics within the root zone which influence the ease of leaching and salt accumulation. Other factors include rootstock or cultivar, irrigation method (surface or flood, overhead sprinkler, drip), stage of plant growth and irrigation management.

Peanut (*Arachis hypogaea* L.) is an important legume crop grown in tropical and sub-tropical semi-arid regions of the world in rain-fed areas; the yield level is severely affected by shortage of soil moisture (Chakraborty et al., 2015; Stalker and Wilson, 2016). Peanut, has a good compatibility to a large number of climates. It can grow in the areas with the pH of 5.5-7. Peanut plants are glycophytes indicating their vulnerability to highly saline soils (Banjara et al., 2012; Akram et al., 2018). Salinity decreases the seed germination and the growth characteristic of the seedlings as well as the seed size and the peanut pod production (Parida and Jha, 2013; Nokandeh et al., 2015; Meena et al., 2016). Therefore, it is of great importance to identify the salinity stress resistant genes on a large scale and develop a better understanding of peanut's salt tolerance. Unfortunately, little progress has been made in this field and one important reason is the lack of germplasm with high resistance to salinity stress (Khan and Gulzar, 2003; Yu, 2008; Sui et al., 2016). Ahmed et al. (2017) point out that information about tolerance of crop cultivar at germination and early seedling growth stage will help to identify salt tolerant cultivars and/or genotypes and to develop saline soil management strategies.

The aim of this study was to evaluate the effect of different NaCl concentrations on seed germination characteristics and early seedling growth of peanut seeds of three Bulgarian cultivars.

Materials and Methods

Three Bulgarian peanuts cultivars ('Kremena', 'Kalina' and '4389') created in the Institute of Plant Genetic Resources "Konstantin Malkov" were used. The seeds were surface sterilized by dipping the seeds in 30% etanol solution for three minutes and rinsed thoroughly with distilled water and air-dried before being used in the germination tests to avoid any fungal attacks. Four different concentrations of NaCl (50, 100, 150 and 200 mM) were used as treatments and deionized water was used as the control. For each variant of the experiment, two replicates of 25 seeds were germinated between rolled filter paper (Grade FT 55) with 20 ml of respective test solutions. The papers were replaced every two days to prevent accumulation of salts (Rehman et al., 1996). The rolled paper with seeds was put into sealed plastic bags to avoid moisture loss. Seeds were allowed to germinate at 25±1°C in the dark for eight days. Seeds were considered germinated when radicle had extended at least 2 mm. The number of germinated seeds was recorded daily until a constant count is achieved. From the germination counts several germination characteristics were studied including germination energy (%) as first count after four days (GRE), germination percentage (%) as final count after 8 days (GR, %), 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}) was calculated according to Kader and Jutzi (2004). Germination rate index (GRI, % day^{-1}) and mean germination time (MGT, day) were calculated according to the formula of Kader (2005).

The data for the shoot and root length (cm) (LSh and LR), fresh weigh (mg) of shoot and root (FWSh and FWR) and dry weight (mg) of shoot and root (DWSh and DWR) were recorded seven days after germination. The shoot and root lengths were measured by ruler. Dry weights were measured after drying at 80°C for 24 h in an oven.

In order to determine the seed vigor index (VI), equation from Florez et al. (2007) was used. The coefficient of depression of the roots / shoots was calculated according to the Blum et al. (1980). Salt tolerance was calculated by the formula given by Mujeeb-ur-Rahman et al. (2008).

Data were analyzed by analysis of variance (ANOVA), LSD test and Duncan's multiple range test (Duncan, 1955). The analysis of variance was calculated according to randomized complete block design with two factors: genotype and treatment (salinity). To estimate the degree of genotype and treatment (salinity) influence on different germination and seedling characteristics method described by Plochinskii (1970) was aplied. Principal component 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 were performed using the statistical program SPSS 19.0.

Results and Discussion

Effect of NaCl salinity on the germination characteristics of seeds

The ability of a seed to germinate and emerge under salt stress indicates that it has genetic potential for salt tolerance (Tejovathi et al., 1988). In our study, the influences of different salt concentrations on germination characteristics are presented in Tables 1-3. The germination energy (GRE) declined in all peanut cultivars with increased concentration of salinity from 50 to 200 mM (Table 1).

Table 1. Effects of different salinity levels on germination energy and final germination of three peanut cultivars

Salinity levels, mM	Cultivars				Salinity levels, mM	Cultivars			
	Kremena	Kalina	4389	Mean		Kremena	Kalina	4389	Mean
	Germination energy, %					*Germination, %*			
0	100b	98b	94a	97	**0**	100b	98b	94a	97
50	98b	96ab	94a	96	**50**	98b	96ab	94a	96
100	98b	96b	66*a	94	**100**	98b	96b	78*a	91
150	94*c	84*b	38*a	72	**150**	94*c	84*b	0*a	59
200	92*c	74*b	14*a	60	**200**	92*c	74*b	0*a	55
Mean	96.4	89.6	65.6		***Mean***	96.40	89.60	53.20	
LSD 5%	4.39	5.61	5.82		***LSD 5%***	4.39	5.61	1.87	

Means in the same row followed by the same letters are not significantly different ($p < 0.05$) according to Duncan's test.

*The mean difference in the same column is significant at the 0.05 level

The cultivars 'Kremena' and 'Kalina' exhibited significant differences at high salinity levels, respectively at 150 and 200 mM NaCl salinity, while in '4389' difference was found also at 100 mM NaCl salinity level. The negative effect of the application of increasing salt stress on the final germination percentage (GR) was the most clearly exhibited in '4389', where the germination at the highest salt levels was 0 (Table1). Similar results with decrease of germination of peanut seeds under salinity stress were also reported by Meena et al. (2016) and Satu et al. (2019). According to Ashraf and Harris (2004) and Khayatnezhad and Gholamin (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 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. Panuccio et al. (2014) noted that higher CVG and GRI, and lower MGT represent higher and faster germination of seed. In our study, salt stress had substantial negative effects on the CVG (%) and GRI (% day^{-1}). The MGT prolonged with increase of salinity (Table 2 and Table 3). Increase of salinity concentration from 0 to 200 mM NaCl increased MGT. At the highest salt level (200 mM NaCl), the MGT varied between 2.49 and 3.14 days (Table 3). The NaCl solutions from 50 to 200 mM significantly reduced CVG and GRI at level $p \leq 0.05$ compared with control (0 mM NaCl). The strongest decrease in CVG and GRI at 200 mM NaCl concentration was observed in '4389', respectively with 48.88% and 19.04% (Table 2). The results indicated that this cultivar was more sensitive to high level of salinity. Generally the high salinity inhibited the germination of seed and prolongs germination time in peanuts (Table 1-3).

The results of two-way analysis of variance showed that the treatments with NaCl had the strongest influence on the GRE, CVG, GRI and MGT, respectively 49.15%, 95.23%, 92.21% and 94.90%. The three factors: genotype, salinity and genotype X salinity interaction had almost the equal share on the final seed germination (Table 4).

Effect of salinity on the seedling characteristics of penuts

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 (Jamil and Rha, 2004; Chauhan et al., 2016). Effects of different salinity levels on seedling characteristics of the investigated three peanut cultivars are given in Tables 5-7. The data on the average length of shoot and root (Table 5) showed that peanut cultivars had a strong inhibition with the increasing level of salt solution particularly at high salt levels (150 and 200 mM). The longest shoot and root lengths were observed in the 50 mM NaCl variant for 'Kremena' and 'Kalina' cultivars (7.24 cm and 7.06 cm respectively). The first one ('Kremena') showed the shortest rate of decline in the shoot length at 200 mM NaCl concentration (respectively with 6.16 cm), while the second one ('Kalina') showed the shortest rate of decline in the root length at the same concentration, respectively with 3.57 cm, when compare with the control variant (Table 5). However, the effect was remarkable on shoot compared to the root growth, which is also confirmed by depression coefficients of shoot and root (Table 5). Therefore, the shoots were more sensitive to salinity than roots. The genotype had the strongest influence on the variance for the root length, while the salinity had the strongest influence on the shoot length (Table 8).

Meena et al. (2016) also reported that shoot length is more prone to the increased salinity levels as compared to root length. Taffouo et al. (2009) 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. According to Asaadi (2009) better growth of root may be due to active translocation of salt and ions from root to shoot.

Fresh and dry weights of shoot and root were significantly affected by different levels of salinity (Nokandeh et al, 2015; Satu et al., 2019). It is obvious from Table 6 and Table 7 that higher NaCl concentrations significantly reduced shoot and root fresh and dry weights.

Table 2. Effects of different salinity levels (NaCl, mM) on coefficient of velocity of germination (% day^{-1}) and germination rate index

Salinity levels, mM	Cultivars				Salinity levels, mM	Cultivars			
	Kremena	Kalina	4389	Mean		Kremena	Kalina	4389	Mean
	Coefficient of velocity of germination, % day^{-1}					*Germination rate index*			
0	83.33	85.96	80.70	83.33	**0**	22.67b	22.50b	20.25a	21.72
50	56.98*b	60.75*c	55.70*a	57.81	**50**	15.58*c	16.25*b	14.08*a	15.31
100	56.32*	57.83*	54.70*	56.28	**100**	15.00*b	15.25*b	13.25*a	14.50
150	46.53*a	52.50*b	41.18*a	46.74	**150**	12.04*b	12.04*b	5.78*a	9.95
200	35.94*a	40.22*b	31.82*a	35.99	**200**	8.88*b	7.79*b	1.21*a	5.96
Mean	55.82	59.45	52.82		***Mean***	14.83	14.77	10.91	
LSD 5%	2.88	2.70	5.43		***LSD 5%***	0.80	0.56	1.52	

Means in the same row followed by the same letters are not significantly different ($p < 0.05$) according to Duncan's test.
*The mean difference in the same column is significant at the 0.05 level

Table 3. Effects of different salinity levels (NaCl, mM) on mean germination time (day) and vigor index

Salinity levels, mM	Cultivars				Salinity levels, mM	Cultivars			
	Kremena	Kalina	4389	Mean		Kremena	Kalina	4389	Mean
	Mean germination time, day					*Vigor index*			
0	1.2	1.16	1.24	1.20	**0**	1601.60b	1599.0b	1151.5a	1450.7
50	1.76*b	1.65*a	1.83*c	1.74	**50**	1493.4*c	1373.3*b	781.4*a	1216.0
100	1.78*	1.73*	1.80*	1.77	**100**	1129.5*c	960.0*b	531.3*a	873.58
150	2.15*b	1.90*a	2.42*b	2.16	**150**	806.64*c	659.40*b	0.00*a	488.68
200	2.78*b	2.49*a	3.14*c	2.81	**200**	540.04*c	420.57*b	0.00*a	320.20
Mean	1.93	1.79	2.10		***Mean***	1114.22	1002.46	492.84	
LSD 5%	0.10	0.07	0.13		***LSD 5%***	66.40	117.43	47.40	

Means in the same row followed by the same letters are not significantly different ($p < 0.05$) according to Duncan's test.
*The mean difference in the same column is significant at the 0.05 level according to LSD test

Table 4. Analysis of variance for the characteristics: germination energy (GRE, %), germination percentage (GR, %), coefficient of velocity of germination (CVG, % day^{-1}), germination rate index (GRI, % day^{-1}) and mean germination time (MGT, day)

Source of Variation	*Mean square*					
	df	*GRE*	*GR*	*CVG*	*GRI*	*MGT*
Genotype	2	1239.2***	7317.6***	118.76***	33.60***	0.16***
Salinity	4	1070.8***	4021.2***	2485.38***	263.55***	2.66***
Interaction	8	197.2***	1983.6***	6.84	0.87	0.015*
			Degree of influence, %			
Genotype	2	28.44	**31.25**	2.28	5.88	2.80
Salinity	4	**49.15**	**34.34**	**95.23**	**92.21**	**94.90**
Interaction	8	18.10	**33.88**	0.52	0.61	1.04

Table 5. Effects of different salinity levels (NaCl, mM) on length of shoot and root (cm)

Salinity levels, mM	Cultivars				Salinity levels, mM	Cultivars			
	Kremena	Kalina	4389	Mean		Kremena	Kalina	4389	Mean
	Length of shoot, cm					*Length of root, cm*			
0	7.26a	8.17b	7.75ab	7.73	**0**	8.76b	8.15b	4.50a	7.14
50	7.24b	7.06*b	4.56*a	6.29	**50**	8.00b	7.24*b	3.75*a	6.33
100	4.40*c	4.33*b	4.25*a	4.33	**100**	7.12*c	5.67*b	1.79*a	4.86
150	2.64*b	3.29*c	0.00*a	1.98	**150**	5.95*c	4.56*b	0.00*a	3.50
200	1.11*b	1.10*b	0.00*a	0.74	**200**	4.76*b	4.58*b	0.00*a	3.11
Mean	4.53	4.79	3.31		***Mean***	6.92	6.04	2.02	
LSD 5%	0.44	0.48	0.29		***LSD 5%***	1.02	0.61	0.47	
	Depression coefficient of shoot, %					*Depression coefficient of root, %*			
50	0.34	13.54	41.13	18.34	**50**	8.59	11.12	16.67	12.13
100	39.39	46.94	45.16	43.83	**100**	18.63	30.47	60.28	36.46
150	63.70	59.70	100	74.47	**150**	32.10	44.07	100	58.72
200	84.71	86.53	100	90.41	**200**	45.64	43.76	100	63.13

Means in the same row followed by the same letters are not significantly different ($p < 0.05$) according to Duncan's test.
*The mean difference in the same column is significant at the 0.05 level

Table 6. Effects of different salinity levels (NaCl, mM) on fresh weight of shoot and root

Salinity levels, mM	Cultivars				Salinity levels, mM	Cultivars			
	Kremena	Kalina	4389	Mean		Kremena	Kalina	4389	Mean
	Fresh weight of shoot (g plant^{-1})					*Fresh weight of root (g plant^{-1})*			
0	1.811b	1.674b	1.440a	1.642	**0**	0.429c	0.341b	0.129a	0.300
50	1.622*b	1.523*b	1.06*a	1.401	**50**	0.366b	0.245*b	0.115*a	0.242
100	1.134*b	1.217*c	1.04*a	1.130	**100**	0.201*b	0.235*c	0.069*a	0.168
150	0.563*b	0.707*c	0.00*a	0.423	**150**	0.138*b	0.160*b	0.000*a	0.099
200	0.236*b	0.231*b	0.00*a	0.156	**200**	0.081*b	0.095*c	0.000a	0.059
Mean	1.073	1.070	0.708		***Mean***	0.243	0.215	0.063	
LSD 5%	0.090	0.083	0.120		***LSD 5%***	0.074	0.030	0.011	

Means in the same row followed by the same letters are not significantly different ($p < 0.05$) according to Duncan's test.
*The mean difference in the same column is significant at the 0.05 level

Table 7. Effects of different salinity levels (NaCl, mM) on dry weight of shoot and root

Salinity levels, mM	Cultivars				Salinity levels, mM	Cultivars			
	Kremena	Kalina	4389	Mean		Kremena	Kalina	4389	Mean
	Dry weight of shoot (g plant^{-1})					*Dry weight of root (g plant^{-1})*			
0	0.165c	0.150b	0.121a	0.145	**0**	0.047c	0.038b	0.018a	0.034
50	0.150*c	0.142b	0.120a	0.137	**50**	0.042b	0.031*b	0.016a	0.030
100	0.107*a	0.122*b	0.115*ab	0.115	**100**	0.024*b	0.027*c	0.014a	0.022
150	0.063*b	0.078*c	0.000*a	0.047	**150**	0.016*b	0.021*b	0.000*a	0.012
200	0.033*b	0.031*b	0.000*a	0.021	**200**	0.009*b	0.011*c	0.000*a	0.007
Mean	0.104	0.105	0.071		***Mean***	0.028	0.026	0.009	
LSD 5%	0.009	0.009	0.004		***LSD 5%***	0.007	0.004	0.004	

Means in the same row followed by the same letters are not significantly different ($p < 0.05$) according to Duncan's test.
*The mean difference in the same column is significant at the 0.05 level

Table 8. Analysis of variance for the seedling characteristics: length of shoot (LSh), length of root (LR), fresh weight of shoot (FWSh), fresh weight of root (FWR), dry weight of shoot (DWSh), dry weight of root (DWR) and vigor index (VI)

Source of Variation	*Mean square*							
	df	*LSh*	*LR*	*FWSh*	*FWR*	*DWSh*	*DWR*	*VI*
Genotype	2	9.33***	102.87***	0.66***	0.14***	0.005***	0.0015***	1647246.58***
Salinity	4	75.91***	27.35***	3.65***	0.09***	0.028***	0.001***	2033715.03***
Interaction	8	2.09***	0.54	0.05***	0.01***	0.001***	0.0001***	17956.65***
				Degree of influence, %				
Genotype	2	5.47	**62.93**	8.06	38.84	8.46	33.75	28.24
Salinity	4	**88.97**	33.46	**88.56**	**48.63**	**86.00**	**54.58**	**69.73**
Interaction	8	4.89	1.33	2.56	8.42	4.90	7.38	1.23

The analysis of variance also showed that the effect of genotype, salinity and genotype x salinity interaction are significant at $p \leq 0.001$ for the investigated seedling characteristics (Table 8). The salinity had the strongest influence on the variance of fresh and dry weight of shoot (88.56% and 86%, respectively), following by dry weight of root (54.58%) and wet weight of root (48.63%). The degree of influence of salinity on vigor index as indicator of the germination capacity and growing tendency of seedling was also high, 69.73% (Table 8).

Effects of salinity on Salt tolerance index

Sun et al. (2013) noted that peanut plants had genotypic difference for salinity tolerance exists within the species. This was confirmed by our research. At the levels of salinity between 50 and 100 mM NaCl, 'Kremena' cultivar showed the highest ShSTI, RSTI and TSSTI (Fig. 1). At the 150 mM NaCl the highest ShSTI was noted in 'Kalina', while the highest RSTI was registered in 'Kremena'. At the highest salinity level of 200 mM NaCl, 'Kremena' and 'Kalina' showed approximately close values for ShSTI and RSTI (ShSTI -15.29 and 13.47, RSTI-54.36 and 56.34, respectively) (Fig. 1). Generally, the cultivar 'Kremena' was the most tolerant to salinity, at the early seedling growth stage, while '4389' was the most sensitive (Fig. 2).

Principal Component Analysis (PC-analysis)

Principal factors were carried out using principal component (PC) method for factor extraction. In the present study, only the first two principal components showed eigen values more than one and cumulatively they explained 92.016% variability. The first principal component explained 83.382% of the total variation and the second principal component explained 8.634% variation. The first factor was connected to the germination and seedling characteristics, while the second factor was formed by the GRE, GR and LR (Table 9).

Table 9. Weighted factors (PC1 and PC) of descriptive characteristics on the rotated matrix with two factors

Characteristics	Principal component	
	1	2
Coefficient of velocity of germination (CVG)	**0.94**	0.22
Germination rate index (GRI)	**0.83**	0.51
Mean germination time (MGT)	**-0.90**	-0.34
Germination energy (GRE)	0.31	**0.91**
Germination percentage (GR)	0.31	**0.90**
Vigor index (VI)	**0.76**	0.63
Length of shoot (LSh)	**0.89**	0.40
Length of root (LR)	0.49	**0.82**
Fresh weigh of shoot (FShW)	**0.88**	0.44
Fresh weigh of root (FRW)	**0.70**	0.58
Dry weight of shoot (DShW)	**0.84**	0.47
Dry weight of root (DRW)	**0.74**	0.58
Eigenvalues	**10.006**	**1.036**
% of Variance	**83.382**	**8.634**
Cumulative %	**83.382**	**92.016**

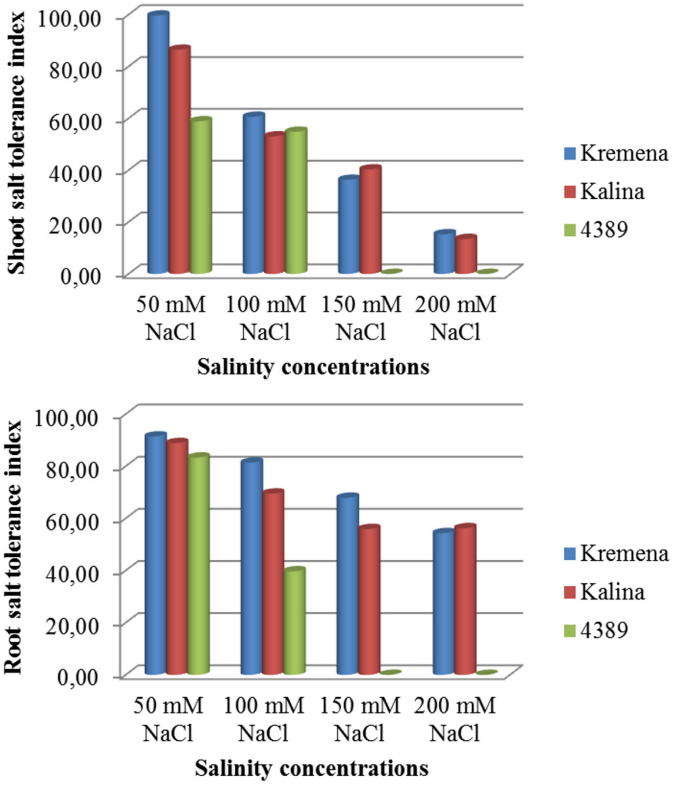

Figure 1. Variation of shoot and root salt tolerance index in three peanut cultivars at four different salinity levels

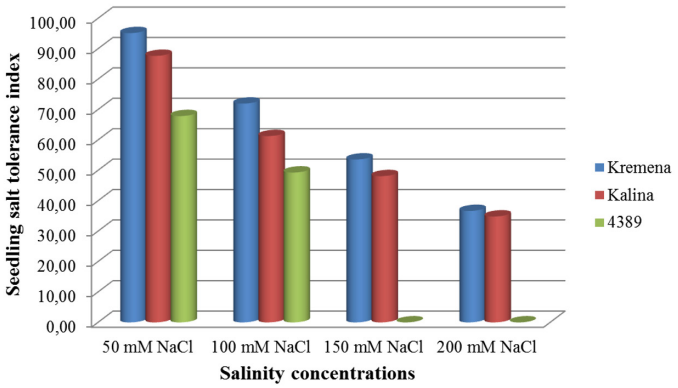

Figure 2. Variation of shoot and root salt tolerance index in three peanut cultivars at four different salinity levels

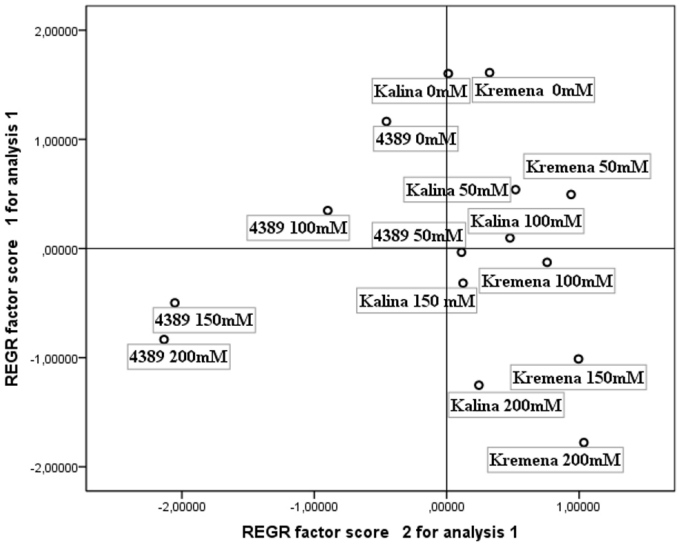

Figure 3. Distribution of evaluated peanut cultivars within the factor plane according to similarity of germination and seedling characteristics at salt concentrations from 0 to 200 mM NaCl

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. 3). The '4389' cultivar treated with salinity concentrations 0 and 100 mM NaCl was grouped in the upper left quadrant and had positive values for PC1 and negative values for PC2. 'Kalina' at 0, 50 and 100 mM NaCl salinity levels and 'Kremena' at 0 and 50 mM NaCl were classified in the upper right quadrant and had positive values for both factors (PC1 and PC2). Cultivar in the lower left quadrants ('4389' at 150 and 200 mM NaCl) had respectively negative values for both factors. The samples in the lower right quadrants were characterized with negative values for PC1 and positive values for PC2. In this group 'Kremena' was separated at 100 to 200 mM NaCl and 'Kalina' at 200 mM NaCl.

Conclusion

Increasing salinity concentration from 50 to 200 mM NaCl prolonged mean germination time and have an inhibitory effect on the initial seedling growth of peanuts. The shoots are more sensitive to salinity stress than roots. The genotype have the strongest influence on the variance of the root length, while the salinity have the strongest influence on the following germination and seedling characteristics: GRE, CVG, GRI, MGT, LSh, FWSh, DWSh and DWR. The three factors: genotype, salinity and genotype x salinity interaction have almost the equal influence on the final seed germination. 'Kremena' is the most tolerant at seedling growth stage, while '4389' is the most sensitive, especially at very high levels of salt. The negative effect of the application of increased salt concentration on the final germination percentage is the most clearly exhibited in '4389' where the germination at the highest salt levels is zero. Principal component 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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aCS85_13