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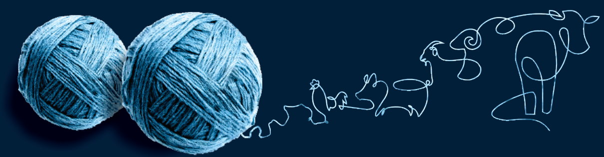
MODERN TRENDS IN LIVESTOCK PRODUCTION



PROCEEDINGS

9 -11 October 2019, Belgrade, Serbia

Institute for Animal Husbandry
Belgrade - Zemun, SERBIA

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SALINITY STRESS EFFECT ON SEED GERMINATION AND SEEDLING GROWTH OF SOME CROP PLANTS

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Invited paper

Abstract: Soil salinity is one of the most important factors limiting crop productivity. It is known that the agricultural soils with high concentrations of salts increase day by day. For this reason, it is imperative to monitor the tolerance of crops and genotypes to salt stress because they have different threshold sensitivity. Generally, higher salinity levels in the media negatively affect the germination of seeds and seedling growth of most crops. Germination, germination speed and seedling growth parameters significantly decrease with increasing salt concentrations in the media. Soil salinity adversely affects germination, resulting in poor plant stand. Therefore, the development of salt tolerant genotypes of crops with promising yields would be an ideal solution for growing plants on these soils, as well as sustainable food and feed production.

Key words: germination, seedling growth, osmotic stress, crop

Introduction

Soil is the most limiting factor for crop production in the worldwide. Therefore, the production of food for humans and feed for animals is limited. The soil salinization is big problem for agricultural productivity worldwide. Generally, crop plants are sensitive to soil salinity. Soil salinity is the abiotic factor that limits the germination and early seedling growth of most crop plants. *Jamil et al. (2011)* estimate that more than 50% of the arable land will be salinized because of low rainfall, high surface evaporation, weathering of native rocks, irrigation with saline water and poor agricultural practices, by 2050. In Serbia, about 4.6% of agricultural soils are saline and alkaline soils. Saline soils are contaminated with 40 mM NaCl salts and have ECe > 4 dS m^{-1} and osmotic potential < 0.117 MPa *(Ashraf, 2009)*. High levels of soil salinity reduce the ability of plants to absorb water and plant growth *(Munns, 2002)*, impair ions absorption *(Karimi et al.,* *2005)*, increase accumulation of a toxic ions (*Nawaz et al., 2010).* The salinity negatively affects seed germination, seedling growth and enzyme activity *(Seckin et al., 2009)*, growth, development, yield and quality of plants *(Jouyban, 2012)*. *Shahbaz and Ashraf (2013)* conclude that soil salinity reduces cultivated land area, productivity and quality of crops. *Ashraf (2004)* points that the saline soil causes osmotic stress due to low osmotic potential of soil solution, ionic stress because specific toxicity effect on ions, nutritional imbalances or a combination of mentioned factors. Also, *Muscolo et al. (2013)* has proved that the high soil salinity has a strong impact on plants because it causes osmotic stress, oxidative stress, ion toxicity, nutritional disorders, alteration of metabolic processes, membrane disorganization and reduction of cell division and expansion. *Mandić et al. (2011)* conclude that testing of genotypes at early seedling growth would be especially helpful in identification and selection of genotypes for particular soil. In this paper, we characterize the effect of the induced water deficit by NaCl (osmotic stress) on germination and seedling growth of a few crops commonly sowed in areas of Serbia. Testing of genotypes of crops at the early seedling stage under different concentrations of NaCl in the growing medium could be helpful in the identification and selection of genotypes for cultivation on saline soils.

Effect of NaCl-induced osmotic stress on seed germination and seedling growth of maize

The high-quality seeds are essential for successful crop production. However, water availability and movement in the medium are important factors which promote germination, root and shoot elongation. The germination is not possible under conditions of low water potential *(Singh et al., 2013)*. Minimum moisture in the soil is necessary for germination of seeds, i.e. for the restart of embryonic axis growth, the intensification of breathing and other metabolic activities and releasing of energy and nutrients *(Carvalho and Nakagawa, 1988)*. However, high salt content of the soil causes lower osmotic potential in the soil solution than in the seed cells which prevents the absorption of water. Therefore, the key to problem is osmoregulation in the first phase of salt stress. Na toxicity affects the seedling growth in the second phase of salt stress *(Schubert et al., 2009)*. The soil limits germination and early seedling growth, crop growth and productivity *(Flowers, 2004)*.

Maize is moderately sensitive to salinity *(Ouda et al., 2008)*, but the maize genotypes differ in resistance and tolerance to salt *(Khodarahmpour, 2012)*. The maize hybrids vary in their tolerance and phytotoxicity to high soil salinity. Thus, *Mandić et al. (2014a)* have concluded that Serbian maize hybrids cannot tolerate high salt concentrations in the medium, where the hybrid ZP 666 showed better tolerance than hybrid ZP 560 (Table 1 and 2). These authors find that the germination energy, germination, root length, shoot length, root fresh weight, shoot fresh weight, root dry weight and shoot dry weight of maize seedling decrease significantly with increasing osmotic stress induced by NaCl. Authors have concluded that he germination sensitivity threshold of maize is treatment with -0.3 MPa. The osmotic stress causes loss of turgidity of the cells involved in elongation which inhibits the growth of root.

If salinity levels in the soil increases, seed germination of maize decreases *(Khayatnezhad and Gholamin, 2011; Mirosavljević et al., 2013)*. Generally, under salinity conditions, the root elongation is more sensitive than shoot elongation *(Demir and Arif, 2003). Leishman and Westoby (1994)* find that maize genotypes with longer root systems have higher resistance to low osmotic stress. Salt stress reduces germination and parameters of maize seedlings due to ion toxicity, osmotic and oxidative stress *(Sozharajan and Natarajan, 2014)*. Generally, Na+ and Cl- are metabolically toxic to cell *(Taiz and Zeiger, 2002)*. Many researches have showed that increased salt concentration in the medium reduces germination rate, germination speed, root and shoot length, germination index, root and shoot dry weight of maize seedling and seedling vigor index *(Carpici et al., 2009; Idikut, 2013).*

Table 1. The effects of hybrid and different osmotic stress on germination energy (GE), germination (G), root length (RL), shoot length (ShL), root fresh weight (RFW), shoot fresh weight (ShFW), root dry weight (RDW) and shoot dry weight (ShDW).

Factor	GE %	G %	RL cm	ShL cm	RFW mg	ShFW mg	RDW mg	ShDW mg
	Hybrid (A)							
ZP 560	16.9	63.2	4.2^{b}	1.1^{b}	45.8	32.5^{b}	6.5^{b}	4.2^{b}
ZP 666	15.8	65.3	6.4^{a}	2.1^{a}	45.9	43.9^{a}	7.6^{a}	6.0^{a}
F test	ns	ns	**	**	ns	**	*	**
	Osmotic stress, MPa (B)							
0	34.9^{a}	97.2^{a}	12.2^{a}	4.7^{a}	82.3^{a}	135.6^{a}	10.7^{a}	12.5^{a}
-0.3	30.5^{ab}	94.0^{ab}	7.8^{b}	2.0^{b}	61.8^{b}	48.9^{b}	8.9^{b}	6.9^{b}
-0.6	24.8^{b}	83.0^{b}	5.2^{c}	1.8^{b}	48.3^{c}	15.3^{c}	7.9^{bc}	3.9^{c}
-0.9	6.2^{c}	60.8^{c}	3.1^{d}	0.6^{c}	39.4^{c}	13.3^{c}	6.8^{c}	3.0^{cd}
-1.2	1.2^{d}	37.8^{d}	2.0^{e}	0.4^{c}	26.4^{d}	10.9^{c}	4.9^{d}	2.6^{d}
-1.5	0.2^{e}	13.0^{e}	1.3^{e}	0.2^{c}	16.9^{d}	5.1^{c}	3.2^{e}	1.5^{e}
F test	**	**	**	**	**	**	**	**
A × B	ns	ns	**	**	ns	**	ns	**

Means followed by the same letter within a row are not significantly different by Duncan's Multiple Range Test at the 5% level; ** - significant at 1% level of probability, * - significant at 5% level of probability and ns - not significant

Table 2. The effects of hybrid and different osmotic stress on rate germination index (RGI), seedling vigor index (SVI), relative seedling water content (RSWC), phytotoxicity of root (PhR), phytotoxicity of shoot (PhSh) and dry matter stress tolerance index (DMSI).

Factor	RGI %		SVI	RSWC %	PhR %	PhSh %	DMSI %
	Hybrid (A)						
ZP 560	2.7		457.6[b]	83.8[a]	55.4	69.8[a]	48.9[b]
ZP 666	3.3		706.6[a]	81.2[b]	57.6	62.5[b]	55.9[a]
F test	ns		**	*	ns	**	**
	Osmotic stress, MPa (B)						
0	10.3[a]		1642.2[a]	89.2[a]	0[a]	0[a]	100.0[a]
-0.3	4.0[b]		920.4[b]	85.5[a]	35.4[b]	57.6[b]	68.3[b]
-0.6	2.2[bc]		583.9[c]	81.3[b]	56.8[c]	65.0[b]	51.0[c]
-0.9	0.8[c]		223.5[d]	80.9[b]	74.0[d]	88.3[c]	42.1[d]
-1.2	0.8[c]		97.9[de]	79.2[b]	83.6[e]	91.1[c]	32.4[e]
-1.5	0[c]		24.4[e]	78.9[b]	89.4[f]	94.8[c]	20.3[f]
F test	**		**	**	**	**	**
A × B	ns		**	*	ns	**	**

Means followed by the same letter within a row are not significantly different by Duncan's Multiple Range Test at the 5% level; ** - significant at 1% level of probability, * - significant at 5% level of probability and ns - not significant

Effect of NaCl-induced osmotic stress on seed germination and seedling growth of red clover

The legumes, especially red clover, are highly salt-sensitive. *Asci (2011)* concludes that that the germination and seedling growth of legume on saline soils determines the degree of crop establishment. Salinity resistance to germination seeds of legume is heritable trait important for the selection of salt-resistant genotypes *(Ashraf et al., 1987).* In general, high salt concentration in the germination medium negatively affects the germination and seedling growth of most legumes, such as Egyptian, red and Persian clovers *(Gravandi, 2013),* strawberry clover *(Can et al., 2013),* white clover and alfalfa *(Zhanwu et al., 2011), Medicago ruthenica (Guan et al., 2009)* and yellow sweet clover *(Ghaderi-Far et al., 2010)*. *Mandić et al. (2014b)* have reported that the Serbian red clover cultivars (Kolubara, K-32, K-17 and K-39) are very sensitive to salt, especially cv. K-32 (Table 3). Authors report that germination, seedling growth and vigor index significantly decrease with increasing salt concentration in the germination medium. In general, salinity lowers osmotic potential, resulting in decreased availability of water. Increasing salinity levels significantly decrease vigor index, and hence the ability of a seed to produce normal seedlings.

In another study, *Mandić et al. (2019)* have found that the cv. K-17 has higher germination energy, germination and vigor index than cv. K-32 and that the tested parameters have not differed between 0 and 50 mM NaCl. However, increases in salt concentration over 100 mM NaCl significantly reduce these parameters.

Table 3. The effects of cultivar and NaCl concentration level on germination energy (GE), germination (G), percentage of dead or infected seeds (DIS), percentage of hard seed (HS), normal (NS) and abnormal seedlings (AS), root length (RL), shot length (ShL), fresh (FW) and dry weight of seedling (DW) and seedling vigor index (SVI)

Factor	GE %	G %	DIS %	HS %	NS %	AS %	RL cm	ShL cm	FW g	DW g	SVI
	Cultivar (A)										
Kolubara	53.6^{a}	63.6^{a}	36.2^{b}	0.2^{c}	52.4^{a}	11.2	1.5^{b}	4.8	9.15	1.12	472.9^{b}
K-32	24.4^{c}	34.3^{c}	60.7^{a}	5.0^{b}	21.7^{c}	12.6	1.7^{ab}	5.2	10.42	1.44	285.8^{d}
K-17	49.2^{a}	62.6^{a}	35.2^{b}	2.2^{c}	51.6^{a}	11.0	1.9^{a}	5.4	9.80	1.33	530.6^{a}
K-39	34.3^{b}	46.6^{b}	24.4^{c}	29.0^{a}	38.2^{b}	8.4	1.8^{a}	5.0	9.38	1.22	388.0^{c}
F test	**	**	**	**	**	ns	*	ns	ns	ns	**
	NaCl concentration effects mM NaCl (B)										
0	86.1^{a}	88.6^{a}	3.6^{a}	7.8	78.1^{a}	10.5	2.4^{a}	$7,6^{a}$	16.27^{a}	1.71^{a}	888.6^{a}
50	60.0^{b}	69.8^{b}	21.0^{b}	9.2	58.8^{b}	11.0	2.3^{ab}	$6,9^{b}$	15.36^{a}	1.59^{a}	638.7^{b}
100	36.5^{c}	52.0^{c}	38.8^{c}	9.2	40.8^{c}	11.2	2.0^{b}	$5,4^{c}$	9.80^{b}	1.34^{ab}	382.3^{c}
150	14.2^{d}	30.8^{d}	60.0^{d}	9.2	21.0^{d}	9.8	1.3^{c}	$3,4^{d}$	5.61^{c}	1.12^{b}	136.1^{d}
200	5.0^{e}	17.8^{e}	72.2^{e}	10.0	6.2^{e}	11.5	0.7^{d}	$2,1^{e}$	1.39^{d}	0.61^{c}	50.7^{e}
F test	**	**	**	ns	**	ns	**	**	**	**	**
A × B	**	**	**	ns	**	ns	ns	ns	ns	ns	**

Means followed by the same letter within a row are not significantly different by Duncan's Multiple Range Test at the 5% level; ** - significant at 1% level of probability, * - significant at 5% level of probability and ns - not significant

Tavakkoli et al. (2010) point out that the high concentrations of NaCl reduce seedling growth due to increased concentration of Na^{+} and Cl^{-}. For this reason, the seedling growth is reduced (length of root and shoot and fresh and dry weight of root and shoot). Red clover seedlings at the medium with high salt content have lower accumulation of dry matter due to which the seedlings are short and small weight.

Effect of NaCl-induced osmotic stress on seed germination and seedling growth of field pea

Field pea genotypes differ in salinity tolerance at seedling stage. They can be classified into three groups: sensitive, intermediate and resistant to salinity. Previous research shows that Serbian cultivars of field pea are tolerant to salt stress during germination and early embryo growth *(Jovičić et al., 2010; Petrović et al. 2016)*. These authors conclude that the germination and seedling quantitative parameters of field pea significantly decrease with increasing NaCl in the medium. The seedling grows slowly under high levels of salinity due to a slow water uptake by seeds, ions are involved in the physiological processes and damage the cell. Thus, *Mer et al. (2000)* report that the Na^+ in the large amounts negatively affects cell division, metabolism and imbalance of other nutrients. *Mandić et al. (2016)* have found genetic variability between field pea cultivars Kosmaj and Letin for germination, seedling parameters, seedling vigor index, relative seedling water content and phytotoxicity of root (Table 4 and 5). According to their results, cv. Kosmaj has significantly higher germination energy, shoot length, shoot fresh and dry weight, relative seedling water content and phytotoxicity of root, while lower germination, root length, root fresh and dry weight and seedling vigor index than cv. Letin. Also, they have found that the all investigated parameters, except phytotoxicity of root and shoot, significantly decrease with increasing osmotic stress. Phytotoxicity of root and shoot significantly increase with increasing osmotic stress.

Table 4. The effects of cultivar and osmotic stress on germination energy (GE), germination (G), root length (RL), shoot length (ShL), root fresh weight (RFW), shoot fresh weight (ShFW), root dry weight (RDW) and shoot dry weight (ShDW).

Factor	GE %	G %	RL cm	ShL cm	RFW mg	ShFW mg	RDW mg	ShDW mg
	Cultivar (A)							
Kosmaj	55.4^a	92.1^b	5.6^b	5.6^a	49.6^b	79.3^a	6.3^b	7.9^a
Letin	27.8^b	98.6^a	10.3^a	2.2^b	90.2^a	57.5^b	13.2^a	6.7^b
F test	**	**	**	**	**	**	**	*
	Osmotic stress, MPa (B)							
0	89.2^a	98.9^a	11.2^a	9.0^a	100.2^a	136.9^a	13.6^a	13.6^a
-0.3	70.4^a	98.1^a	9.6^b	5.4^b	93.1^a	112.9^b	13.2^a	11.4^b
-0.6	45.6^b	98.0^a	9.2^b	3.6^c	75.7^b	71.3^c	10.8^b	8.1^c
-0.9	37.5^b	96.8^a	7.4^c	3.3^c	63.6^c	54.6^c	7.2^c	6.0^d
-1.2	5.6^c	92.9^b	5.3^d	1.5^d	44.6^d	23.8^d	7.0^c	3.1^e
-1.5	1.2^c	87.5^c	5.0^d	0.7^d	42.1^d	10.9^d	6.8^c	1.6^e
F test	**	**	**	**	**	**	**	**
A × B	**	**	**	**	*	ns	**	**

Means followed by the same letter within a row are not significantly different by Duncan's Multiple Range Test at the 5% level; ** - significant at 1% level of probability, * - significant at 5% level of probability and ns - not significant

Table 5. The effects of cultivar and osmotic stress on seedling vigor index (SVI), relative seedling water content (RSWC), phytotoxicity of root (PhR), phytotoxicity of shoot (PhSh) and dry matter stress tolerance index (DMSI) of field pea

Factor	SVI	RSWC %	PhR %	PhSh %	DMSI %
	Cultivar (A)				
Kosmaj	1068.1^{b}	87.8^{a}	44.6^{a}	58.0	61.7
Letin	238.0^{a}	86.1^{b}	15.3^{b}	51.7	63.8
F test	**	**	**	ns	ns
	Osmotic stress, MPa (B)				
0	1991.8^{a}	88.6^{a}	0^{a}	0^{a}	100.0^{a}
-0.3	1474.8^{b}	88.0^{a}	15.7^{b}	29.8^{b}	90.4^{b}
-0.6	1256.4^{c}	87.2^{a}	18.2^{c}	55.5^{c}	68.9^{c}
-0.9	1036.1^{d}	88.8^{a}	34.7^{c}	66.3^{c}	50.4^{d}
-1.2	637.5^{e}	85.4^{b}	54.1^{d}	85.6^{d}	37.1^{e}
-1.5	521.6^{e}	83.7^{b}	57.0^{d}	91.9^{d}	30.0^{e}
F test	**	**	**	**	**
A × B	**	*	**	*	**

Means followed by the same letter within a row are not significantly different by Duncan's Multiple Range Test at the 5% level; ** - significant at 1% level of probability, * - significant at 5% level of probability and ns - not significant

Conclusions

Salt stress causes huge losses in crop production worldwide. The high salt concentration in the solutions had effect on germination and seedling parameters in the crops studied. Significant differences were found in germination of seeds and seedling parameters between genotypes of crops. The choice of crops and genotypes can be a way for their cultivation on salinity soil environments in a sustainable and productive way. It is therefore necessary to start with identification and selection of varieties for cultivation on saline soils during the seedling stage.

Uticaj sonog stresa na klijanje i rast klijanaca nekih useva

Violeta Mandić, Zorica Bijelić, Vesna Krnjaja, Maja Petričević, Aleksandar Stanojković, Marija Gogić, Aleksandar Simić

Rezime

Zaslanjivanje zemljišta je jedan od najvažnijih faktora koji ograničava produktivnost useva. Poznato je da površina poljoprivrednog zemljišta sa visokom

koncentracijom soli raste iz dana u dan. Iz tog razloga, neophodno je pratiti toleranciju useva i genotipova na stres soli jer imaju različitu graničnu osetljivost. Generalno, viši nivoi saliniteta u medijuma negativno utiču na klijavost semena i rast klijanaca većine useva. Klijavost, brzina klijanja i rast klijanaca značajno se smanjuju sa povećanjem koncentracije soli u medijumu. U suštini, salinitet i kiselost negativno utiču na klijanje, što dovodi do lošeg (proređenog) sklopa. Stoga bi razvoj genotipova tolerantnih na soli sa obećavajućim prinosima bilo idealno rešenje za gajenje biljaka na takvim zemljištima, kao i za održivu proizvodnju hrane.

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