Salinity and salt composition effects on seed germination and root length of four sugarbeet cultivars

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Abstract Salinization is one of the most important factors affecting agricultural land in the world. Salinization occurs naturally in arid and semiarid regions where evaporation is higher than rainfall. Sugar beet yield declines with an increase in salinity, but the sensitivity to salts varies with salt composition in water and sugar beet growth stage. The aim of this study was to determine the effect of water salinity levels and salt composition on germination and seedling root length of four sugar beet cultivars (PP22, IC2, PP36, and 7233). The experiments were undertaken with irrigation water with two salt compositions (NaCl alone and mixture of $MgSO_4$ + NaCl + Na_2SO_4 + $CaCl_2$) in three replicates. Thirteen salinity levels with electrical conductivity (EC) of the irrigation water ranging from 0 to 30 dS/m were applied to each cultivar in both experiments. Seed germination percentage and seedling root length growth were determined in 13 days. Statistical analysis revealed that germination and root length were significantly affected by salt composition, cultivars and salinity levels. Regardless of salt composition, seed germination and seedling root length were significantly affected by the irrigation water with EC up to 8 dS/m and 4 dS/m, respectively. Except for cultivar PP22, the adverse effect of salinity of the irrigation water on seed germination and seedling root length was higher for NaCl alone than for the salt mixture, which refers to lower salt stress in field conditions with natural salt composition.

Key words: *salinity, salt composition, sugar beet, germination, root length*

Introduction

Land affected by salinization in arid and semiarid regions of South Asia is about 42 million hectares (FAO, 1994). Approximately 33 M ha are in I.R. of Iran, where about 55% of all agriculture lands are shown as being affected. Therefore salinity can be hazardous to plant growth in nearly every irrigated area of Iran, which is affected by salt accumulation. Salt accumulation in the root zone is a serious problem in crop fields in semi-arid regions, which are affected by dynamics of water and ion transport in the soil-plant-atmosphere continuum (Volkmar et al., 1998). Although water and ion transport in crop fields is driven through physical and physiological processes, the transport phenomena in the root zone have been studied mainly through physical processes because of the difficulties in quantitative analysis of root physiological functions (Hillel, 1998).

The results of the monitoring of saline soil development prove that the main source of salts in soil is the salinity of shallow groundwater (El Lateef et al., 2006). In areas with an evaporation water regime of the soil, such as the many part of Iran dissolved salts are transported from a groundwater level to the soil profile by means of vertical flow. Moreover, using such groundwater for irrigation also leads to the accumulation of salts in the soil profile. In both processes groundwater is drawn by evapotranspiration, and soluble salts coagulate on the surface of soil particles and sodium ions are adsorbed into the soil colloidal system. Irrigation with secondary treated wastewater can also be the source of salts in soil (El Lateef et al., 2006).

The suitability of water depends on how it can be used under specific conditions. These conditions include the tolerance of crops to salts (Burger, Čelková, 2001) various physical and chemical properties of soil, management of irrigation methods, and climatic conditions in the given region.

The term salinity relates to the total concentration of the main dissolved inorganic ions, i.e. Na^+, Ca^{2+}, Mg^{2+}, K^+, HCO^{3-}, SO_4^{2-} and Cl^- in groundwater, channel waters and drainage waters (Epstein, Rains, 1987). In some saline soils the predominant anion often is SO_4, not Cl, and Mg concentration may exceed those of Ca by large factors. Magnesium and Ca combined may exceed the concentration of Na (Epstein, Rains, 1987). The particular concentrations of these cations and anions can be expressed by means of chemical equivalents (mmolc/l) or on a mass basis (mg/l). The total concentration of salts (i.e. the salinity) is then expressed as the sum of the individual cations and anions in mmolc/l, or in mg/l. For the reasons of analytical simplification, the real salinity indicator is the electrical conductivity of water (EC) expressed in dS/m, or in mS/m or μS/cm. Electrical conductivity is always expressed at a standard temperature of 25°C in order to allow for the comparison of electrical conductivity in various climatic conditions (Rhoades et al., 1992).

The sugar beet (*Beta vulgaris* L.) crop is cultivated successfully in a wide range of climates on many different soils. Most is grown at latitudes between 30° to 60° N, as a winter or summer crop in Mediterranean and semiarid condition (Draycott, 1972). In addition to this, nearly 200000 ha of soils in different provinces of Iran (e.g. West and East Azarbaidjan, Ardebil, Khorasan) are under sugar beet cultivation, and the effect of salinity in different stages is one of the problems in these regions. Therefore, the objective of the study was to examine the effect of salt levels on sugar beet germination and root length, and to compare the effect of different salt composition and cultivars.

Materials and methods

Four sugar beet cultivars (PP22, IC2, PP36, and 7233) that are mostly grown in East and West Azarbaidjan, Ardebil, Khorasan, etc of Iran were used. Thirteen different salt concentrations of irrigation water ranging from 0 to 30 dS/m (0, 2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 25, and 30 dS/m) were applied to each cultivar and replicated three times. The treatment solutions were made using distilled water and different amount of either NaCl or a mixture of NaCl, $MgSO_4$, Na_2SO_4 and $CaCl_2$, because they are relevant salt compositions of cultivated areas in Iran (e.g. to achieve the electrical conductivity to EC = 1 dS/m, 512 mg/l of NaCl or the mixture of 91.176 mg/l of $MgSO_4$, 187.184 mg/l of Na_2SO_4, 163.658 mg/l of $CaCl_2$, and 169.334 mg/l of NaCl were added) (Aliasgharzad, 2001). The control solution was distilled water with EC = 3 μS/cm (~0 dS/m). Two layers of sterile filter paper were placed in each Petri dish and enough solution was pipetted into each dish. Seeds were surface sterilized with 0.5% NaOCl (Jafarzadeh, Aliasgharzad, 2001). The Petri dishes were placed in incubator kept at a constant temperature of 18°C. Germinated seeds were counted and root length were measured every day for 13 days straight in each experiment between 1998 to 2001. Analysis of variance and Duncan's multiple range test were used to determine statistically significant differences of cultivars and salt composition using MSTATC software.

Results and discussion

It was found that seed germination was significantly affected by salinity levels, cultivars, interaction of salt composition with cultivars ($P<0.001$), and salt composition ($P<0.01$). Interactions of salinity levels with salt composition and salinity levels with cultivars had no significant effect on seed germination (Table 1). The effects of treatments on root length had the same trend as on seed germination, except for the interaction of salinity levels with cultivars, which significantly ($P<0.05$) affected root length (Table 1).

Both seed germination and seedling root length were enhanced by low salinity level (2 dS/m) in comparsion with control (~0 dS/m). Regarding 2 dS/m as baseline for the highest germination and root length, it could be pointed out that the germination is significantly reduced at 8 dS/m and that of root length occurred at 4 dS/m suggesting which the root length growth of all sugar beet cultivars are more sensitive to increasing salinity levels than their seed germination (Table 2).

Among four cultivars tested for salinity tolerance, the cultivars 7233 and IC2 had the highest and lowest germination percentage respectively. Cultivar PP36 had the lowest root length (Table 3). It seems that the variation in seed germination percentage between cultivars is more than root length variation.

Seed germination of cultivars IC2, PP36 and 7233 were significantly higher in the solution with salt mixture than NaCl alone. On the other hand, seed germination of the cultivar PP22 was significantly higher in the solution with NaCl than the salt mixture. The root length growth showed the same trend as seed germination except for the cultivar 7233, root lengths of which had no significant difference in two salt compositions (Table 4). Our findings on higher reduction of both germination and root length of sugar beet by NaCl in comparison with the salt mixture are in agreement with the Stewart (1898) findings for NaCl and Na_2SO_4. Bonilla et al. (2004) showed that the increasing concentrations of Ca in moderate salinity level (75 mM NaCl) enhances the proportion of germinated pea seeds and prevents the delay on germination.

Table 1 Analysis of variance of the effects of salinity levels, salt composition, and cultivars on seed germination and seedling root length of sugar beet.

Source of variation	df	Mean square	
		Germination	Root length
Salinity levels (SL)	12	4131.5***	577.9***
Salt composition (SC)	1	1850.8**	483.2***
Cultivars (C)	3	2366.1***	284.0***
SL x SC	12	294.3 ns	59.8 ns
SL x C	36	280.5 ns	55.8*
SC x C	3	2382.8***	699.6***
SL x SC x C	36	2684 ns	60.3*

*, **, *** significant at P levels of 0.05, 0.01, and 0.001; respectively. ns, non-significant.

Table 2 Effects of salinity levels on seed germination and seedling root length of sugar beet cultivars

Salinity levels (dS/m)	Germination (%)	Root length (cm)
0	26.67c	11.93b
2	41.25a	18.25a
4	37.50ab	13.69b
6	32.92abc	12.94b
8	22.92cd	10.82bc
10	29.58cd	13.72b
12	26.67c	12.81b
14	26.25c	10.02bcd
16	15.84de	7.814cd
18	11.25ef	7.515cd
20	6.672efg	6.369de
25	2.924fg	2.910ef
30	0.4263g	0.09292f

Means in each column followed by the same letter are not significantly different ($P<0.05$)

Table 3 Seed germination and seedling root length for four sugar beet cultivars.

Cultivars	Germination (%)	Root length (cm)
PP22	20.64b	10.41a
IC2	14.87c	10.23a
PP36	22.69b	7.243b
7233	28.21a	11.77a

Means in each column followed by the same letter are not significantly different ($P<0.05$)

Table 4 The effects of salt composition and cultivars on seed germination and seedling root length.

Cultivar	Germination (%)		Root length(cm)	
	Salt mixture	NaCl	Salt mixture	NaCl
PP22	16.67cd	24.62bc	8.329b	12.49a
IC2	15.64d	14.11c	12.96a	7.505b
PP36	26.41b	18.98bcd	11.85a	2.634c
7233	27.44a	18.98bcd	11.49a	12.05a

Means in each column followed by the same letter are not significantly different ($P<0.05$)

The above-mentioned results support findings from Wannamaker, Pike (1987) and Jafarzadeh and Aliasgharzad (2001) about the effect of salinity on onion germination up to 10 dS/m, and effect of salinity on sugar beet germination up to 12 dS/m (Mohammadian, 1995). These findings also give a new idea about the sensitivity of sugar beet on salinity, when germination was affected at lower EC than root length.

Since saline field soils contain a mixture of salts rather than single salt, it seems that plants in field condition are more salt tolerant in comparison with NaCl salinity. It may be related to the presence of Ca, Mg and SO_4 ions that reduce the Na- and Cl-deleterious effects on plants (Volkmar et al., 1998). Other researchers (Harris, Pitman, 1918, 1919; Epstein, Rains, 1987) show high, moderate and low toxicity effect of chloride, carbonate and sulfate salts on germination, respectively. It seems that research works about salinity effect on seed germination and seedling growth should be concerned in two different aspects of NaCl and salt composition effects, which obtained results confirming this idea.

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