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Original Article

Effects of salinity on Na, K and Ca contents of borage (*Borago officinalis* L.) and echium (*Echium amoenum* Fisch. & Mey.)

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Abstract

Soil salinity affects ion concentrations of plant tissues and this may alter the quality of medicinal plants. Experiments were conducted during 2003 at the Isfahan University of Technology Campus, Isfahan, Iran, to assess the effects of five soil salinity levels (3.2, 3.6, 4.5, 5.4 and 7.5 dS m^{-1}) on Na, K, and Ca contents of borage and echium. Each plant species was studied in a separate experiment using a completely randomized design with three replications. The increase in soil salinity increased Na, but decreased K and Ca contents and K/Na ratio of aerial parts of both borage and echium plants. Borage had much higher Na concentration and much lower K/Na ratio than echium. Consequently, it could be implied that the medicinal quality of borage might be more adversely affected by soil salinity than that of echium. Soil salinity should be considered as an important factor in borage production as a medicinal plant.

Keywords: *Borago officinalis*; *Echium amoenum*; Na; K; Ca

INTRODUCTION

Soil salinity alters ionic concentrations in various plant organs (1-5). However, plants differ in their response to salinity. While many salt tolerant plants may accumulate Na in all tissues (1-3,6,7), some plants have effective exclusion mechanism by which restricts the accumulation of potentially toxic levels of Na in the leaves (4,5,8). Aydin et al. (6) reported that Ca content of common bean and spinach was not affected by soil salinity. However, other researches (3-5,7,8) have shown a reduction in concentrations of K and Ca and a lower K/Na ratio due to increase in soil salinity. Concentrations of some ions may increase or decrease the medical value of medicinal plants (9) such as borage. In an experiment (10) in which, borage plants grown in a non-saline soil (EC=1.92 dS m^{-1}), accumulated a large amount of Na (~30 g kg^{-1} dry weight).

The entire stem of borage is usually used to treat inflammation of the urinary tract and heart rheumatic diseases (11). Echium is another medicinal plant that its petals are used as tonic, tranquilizer, diaphoretic, and as a remedy for pneumonia in traditional medicine of Iran (12). High levels of Na and low levels of K and Ca could be contradictious to the medicinal value of borage and echium in hypertensive patients (9). The sensitivity of borage and echium to soil salinity and the effects of soil salinity on Na, Ca, and K ions accumulation and K/Na ratio in borage and echium have not been reported before. These effects are evaluated in the present study.

MATERIALS AND METHODS

Experiments were conducted during 2003 in large pots (50 cm diameter and

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100 cm depth) inserted in the ground at the College of Agriculture Research Field, Isfahan University of Technology Campus (31º32´ N, 51º38´ E, elevation 1610 m). Borage (a genotype with unknown origin) and echium (a local variety) were studied in separate experiments using a completely randomized design with three replications. Five soil samples with different primary salinity (dS m^{-1}) levels (referred to as control=3.2, A=7.2, B=7.5, C=8.0 and D=13.6) were considered in each experiment.

A layer of approximately 35 cm of control treatment soil was laid in all pots. On the top of this soil, about 60 cm of each soil with the above mentioned primary salinity was laid according to the experimental design. Since the reduction in soil salinity during the growing season as the result of watering was expected, six soil samples were taken from 0-30 cm depth of each pot during the growing season and soil EC, Na, K and Ca contents were determined. The mean values were calculated and were considered as the mean soil chemical characteristics (Table 1). Soil EC was determined on saturated extract using EC meter (644 Conductometer, Metrohn, Swiss), Na and K by flame photometry (Flame Photometer 410, Corning, UK) and Ca by atomic absorption (3030 Atomic Absorption Spectrophotometer, Perkin Elmer, USA).

Before planting, 2 g ammonium phosphate (46% P_2O_5 and 18% N) was applied to each pot. Three seeds were planted at each corner of a square (20 × 20 cm) on March 15, 2003. Plants were thinned to one plant per spot (four plants per pot) at two-leaf stage. About 30 days after planting, 2 g Urea (46% N) was added to each pot. Pots were watered (~10 liter per pot) to wet the top 60 cm soil at 6-8 days interval according to the weather conditions. No leachate was allowed to drain from the pots.

The inflorescences of borage were harvested at 50% flowering and petals of echium were clipped after flowering. During June, July and August, one borage plant was harvested from each pot, and during October, four echium plants were harvested from each pot. The plant samples harvested from each pot were thoroughly mixed and dried at 65 ºC to constant weight and grounded. One gram of each plant sample was converted to ash and dissolved in distilled water. The water volume was adjusted to 100 ml. Na, K and Ca were determined by the same procedures used for soil samples. Data were subjected to an analysis of variance and mean values were compared by duncan's multiple range test at 5% probability level using SAS software, 6.12 version (SAS Institute, Inc., Cary, NC, USA).

Table 1. Texture, salinity (dS m^{-1}), and Na, Ca and Kcontent (me 100 g^{-1}) of soil samples.

Soil texture	Salinity	Na	Ca	K
Silty clay loam	3.2	125	25	45
Silty clay loam	3.6	138	23	42
Loam	4.5	145	20	38
Silty clay loam	5.4	158	18	32
Clay	7.5	189	15	28

RESULTS

Soil samples

Na content of soil samples increased and Ca and K contents of them decreased as soil salinity increased (Table 1). Thus, increase in Na absorption and decrease in Ca and K absorption is expected as a result of soil salinity increase (3-5).

Boarge

Na, Ca, and K contents and K/Na ratio of inflorescence and leaves plus stems ofborage were significantly ($P<0.01$) affected by soil salinity. The means are presented in Table 2. Na content of borage

Table 2. Effects of soil salinity (dS m^{-1}) on Na, Ca and K contents (mg kg^{-1}), and K/Na ratio of borage plants[a]

Soil salinity	Inflorescences				Leaves and stems			
	Na	Ca	K	K/Na ratio	Na	Ca	K	K/Na ratio
3.2	10538d	15259a	54242a	5.14a	20122d	20863a	48233a	2.41a
3.6	11044d	15125a	46978b	4.25b	22734cd	16165b	46533ab	2.07ab
4.5	11740bc	12414ab	43806b	3.73c	24500c	13997c	42633b	1.74b
5.4	12403b	11970b	41889b	3.38c	31411b	12606d	36167c	1.15c
7.5	18103a	8454c	35258c	1.95d	43400a	11330c	30100d	0.69d

[a]Mean values within the same column followed by the same letter do not differ significantly (0.05 level) according to the Duncan's multiple range test.

Table 3. Effects of soil salinity (dS m^{-1}) on Na, Ca and K contents (mg kg^{-1}), and K/Na ratio of echium plants[a]

Soil Salinity	Flowers				Leaves and stems			
	Na	Ca	K	K/Na ratio	Na	Ca	K	K/Na ratio
3.2	2767d	11320a	27896a	10.14a	5089d	17193a	35675a	7.02a
3.6	2979cd	11173a	26845ab	9.04ab	5673c	16534a	31175b	5.51b
4.5	3276c	10373a	25854ab	7.89b	6258b	14899ab	29072bc	4.65c
5.4	4043b	9008b	24797ab	6.13c	6628b	13053bc	26638cd	4.03d
7.5	5031a	7813b	23807b	4.74c	7813a	11775c	25868d	3.31e

[a]Mean values within the same column followed by the same letter do not differ significantly (0.05 level) according to the Duncan's multiple range test.

inflorescence rose linearly by less than 18% as salinity increased from 3.2 to 5.4 dS m^{-1}. Further increase in soil salinity (from 5.4 to 7.5 dS m^{-1}) caused drastic rise (about 50%) of Na in borage inflorescence. However, Na in leaves plus stems of borage did not respond appreciably to soil salinities lower than 5.4 dS m^{-1}, but increased approximately 77% when soil salinity rose from 4.5 to 7.5 dS m^{-1}. Ca content of borage inflorescence decreased almost linearly (44%) when soil salinity increased from 3.6 to 7.5 dS m^{-1}. The increase in soil salinity from 3.2 to 3.6 dS m^{-1}, decreased (22.5%) Ca content of leaves plus stems in borage, but increase in soil salinity from 3.6 to 7.5 dS m^{-1}, decreased (30%) Ca content. Reduction in K in borage inflorescence was almost linear (35%) when soil salinity increased from 3.2 to 7.5 dS m^{-1}. A more drastic reduction in K was observed in leaves plus stems of borage (30%) when soil salinity increased from 4.5 to 7.5 dS m^{-1}. Ratio of K/Na in borage inflorescence decreased as soil salinity increased, and the highest decrease was when soil salinity increased from 5.4 to 7.5 dS m^{-1}. A linear decrease in K/Na ratio in leaves plus stems of borage was observed with the soil salinity increase.

Echium

Na, Ca and K contents and K/Na ratio of flower and leaves plus stem of echium were significantly ($P<0.01$) affected by soil salinity. The means are presented in Table 3. Na of flowers and leaves plus stem increased linearly as soil salinity rose from 3.2 to 7.5 dS m^{-1}. The increase of Na in flower was higher (~82%) than that in leaves plus stem (~54%). Ca content of flowers and leaves plus stem, on the other hand, decreased linearly (~31%) as soil salinity increased from 3.2 to 7.5 dS m^{-1}. K content of flowers and leaves plus stem decreased linearly as soil salinity rose from 3.2 to 7.5 dS m^{-1}. However, the decrease in flowers was less severe (~15%) than in leaves plus stem (~27.5%). K/Na ratio in flowers and leaves plus stem of echium reduced with the same intensity (~53%) when soil salinity rose from 3.2 to 7.5 dS m^{-1}.

DISCUSSION

Accumulation of Na in plant tissues without considerable loss in biomass/yield is a tolerance mechanism to salinity (1-3). Mean sodium content in borage plant organs was 3.5 times higher than that of echium in control, and 4.9 times in the highest salinity treatment. This may indicate that borage is more salt tolerant than echium. All plant parts of borage (11) and petals of echium (12) are used as a medicine in hypertensive patients, who should avoid high levels of Na intake (9). Consequently, the organs harvested from these medicinal plants, cultivated in saline soils, especially from borage, might be undesirable for the hypertensive patients.

Ca may reduce Na damage to plants thus plants with higher Ca might be more resistant to soil salinity (1,2) and higher Ca in borage may indicate its tolerance to soil salinity. This conclusion is consistent with the results of Aydin et al. (6) working with spinach (a salinity resistant plant) and common bean (a salinity sensitive plant). Although lower Ca content may improve the plant quality as a medicine for the treatment of high blood pressure (9), but negative association between Ca and Na may obscure this advantage.

K content and its rate of reduction were higher in borage than that of echium. This is consistent with the results of Aydin et al. (6) on spinach and bean. Other investigators (2-5,7,8) also have shown a reduction in K content in plants by salinity. Although high K content might be considered as an advantage of borage over echium as a salinity tolerance mechanism (1,2), but K/Na ratio of echium was 2 to 2.4 times higher than that of borage. Thus, the medical merits of borage might be more severely reduced than that in echium by soil salinity. Other investigators (5,7,8) also have shown a reduction in K/Na ratio in plants due to salinity.

As a result of this study, Na, Ca, and K contents and K/Na ratio of echium flower is less affected by soil salinity than that of borage plant. Use of soils with very low salinity might be recommended for borage production as a medicinal plant.

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