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ORIGINAL ARTICLE

Effect of priming on growth, biochemical parameters and mineral composition of different cultivars of coriander (*Coriandrum sativum* L.) under salt stress

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At Higher Institute of Agriculture of Chott Mariem, Sousse, Tunisia, this study was conducted to evaluate the interactive effect of salinity and seed priming on coriander. The experiment was carried out in completely randomized design with three replications consisting of four coriander genotypes (Tunisian cv, Algerian cv, Syrian cv and Egyptian cv) at two seed conditions (seed priming with 4 g/l NaCl for 12h or no seed priming). Results revealed that seed priming and salinity had significantly ($p \leq 0.05$) affected all the parameters under study. On the first hand, salinity stress had adversely affected growth, chlorophyll content, mineral composition (K^+ and Ca^{2+}) of coriander in all genotypes. Also, it activated Na^+ accumulation and synthesis of proline, soluble sugars and proteins. However, seed priming with NaCl had diminished the negative impact of salt stress in all cultivars and primed plants showed better response to salinity compared to unprimed plants. Maximum values were recorded in tolerant cultivar which is Tunisian one whereas minimum values were noted in sensitive cultivar (Algerian cv).

Key words: Coriandrum sativum. L, NaCl, seed priming, growth, chlorophyll, solutes, mineral content

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Key words: Coriandrum sativum. L, NaCl, seed priming, growth, chlorophyll, solutes, mineral content

Salinity is one of the major abiotic stresses that negatively affect crop productivity. It affects more than 10 percent of arable land and salinization is rapidly increasing on a global scale, declining average yield for most major crop plants by more than 50 percent (Bray *et al.,* 2000). Salt stress occurs in areas where soils are naturally high in salt and precipitation is low (Neumann, 1995) and/or where irrigation, hydraulic lifting of salty underground water, or invasion of sea water in coastal areas brings salt to the surface soil that inhabit plants. NaCl is the predominant salt causing salinization (Munns and Tester 2008). The most widely accepted effects of salinity on plant growth include water stress, specific ion toxicity and ion imbalance (Niu *et al.*, 1995). Also, it touched cellular metabolism including photosynthesis (Munns, 2002) and synthesis of compatible solutes called “osmolytes” (Ashraf, 1994) like proline (Ashraf and Foolad, 2007; Amirjani, 2010), sugars (Amirjani, 2011) and proteins (Sen and Alikamanogli, 2011). For this reason, it was evident to focus on a method that could alert and/or attenuate negative impact of this stress and increase the tolerance to salinity in plants. One of the most methods is seed halopriming (Sadeghi *et al.*, 2010) that among different techniques of tolerance to salinity is an easy, low cost and low risk method (Iqbal and Ashraf, 2006). Halopriming is a pre-sowing soaking of seeds in salt solutions (Afzal *et al.,* 2008) proved to be efficient in improvement salt tolerance under adverse environmental conditions by altering plant physiological and biochemical responses to salt stress (Cayuela *et al.,* 1996, Bakht *et al.,* 2011). NaCl is one of the most famous agent used in priming on several crops like wheat (Ashraf *et al.*, 1999), melon (Sivritepe *et al.,* 2003) and coriander (Elouer and Hannachi, 2013).

Coriander (*Coriandrum sativum* L.) is an annual plant, native to Southern Europe and North Africa to South Western Asia (Mouterde, 1986). It belongs to the Umbelliferae (Apiaceae) family and is used as aromatic and medicinal plant as anti-spasmodic, appetite stimulant, stomachic, diuretic, anti inflammatory and anti-diarrheic agent (Mir Heidar, 1992). Coriander is known as a species moderately tolerant to salinity, the salinity effect appears mainly during plant growth (Elouer and Hannachi, 2013). In Tunisia, coriander is grown in all regions and is mainly used as condiment but it suffers like all the crops from high levels of salts in soil.

Hence in the present study, three cultivars of coriander are used to be studied (Egyptian, Syrian and Algerian cvs) and compared to Tunisian cultivar in order to i) investigate the effect of NaCl treatment (0, 2, 4, 6 and 8 g/l) on physiological and biochemical metabolism and select tolerant cultivar, ii) to test the effectiveness NaCl priming of seeds to alleviate the adverse effects of salinity on coriander.

MATERIALS AND METHODS

The study was carried out In Higher Institute of Agronomy, Chott Meriem, Sousse, Tunisia under greenhouse (170 m^2) where temperature ranged between 18 (night) and 25° C (day), relative humidity between 70 and 85% and 16h photoperiod. This greenhouse is covered with plastic film (low density polyethylene) and cemented by its side.

Seeds of four cultivars (Tunisian, Algerian, Egyptian and Syrian cvs) were disinfected with sodium hypochloride (5%) for 3 min and then washed 5 times with distilled water. Then, they were primed in sterile Petri dishes (100x100 mm) with NaCl agent (4 g/l for 12h) at 22°C. After priming, seeds were removed from solutions and rinsed thoroughly with distilled water to remove the external salts, placed on paper towels on the laboratory bench and dried under ambient conditions for 48h. Finally, ten unprimed seeds (used as control) and primed seeds as per treatment were sown on January 10th 2012, at depth of 2 cm, in plastic pot (20 cm diameter and 25 cm height) filled with peat, sand and topsoil (1/3:1/3:1/3).

Pots were left in greenhouse on bricks. After complete emergence, five plants per pot were maintained on which the trial continues. The pots were irrigated every 3 days with NaCl at five concentrations (0, 2, 4, 6 and 8 g/l). During culture, plants were fertilized with Nitrogen (33%) to enhance vegetation and treated with Talastar (80 cc/hl) curatively against aphids using a Knapsack sprayer. Plants were harvested 60 days after sowing and impact of priming on improvement the plant growth against salinity stress was studied by measuring number of leaves, shoot and root lengths, fresh and dry weights of shoot and root, chlorophyll content (a and b), solutes (proline, sugars and proteins) content in leaves and mineral composition of roots. Dry weight was determined after drying in an oven at 80°C for 48h. Chlorophylls and solutes and contents were estimated by UV spectrophotometer (PG T60 U). Chlorophylls amount was determined by Arnon method (1949) at 663 nm and 645 nm. Proline content was calculated in leaves by Bates *et al.* (1973) method at 520 nm. Total soluble Sugars were extracted from the leaves according to Dubois *et al.* (1956) at 625 nm. Total soluble proteins content was measured at 595 nm according to Bradford (1976) using bovine serum albumin (BSA) as a protein standard. For ion determination, extraction was done in nitric acid (0.1 N) for 48 h and content of K^+, Na^+ and Ca^{2+} were estimated with a flame emission spectrophotometer (JENWAY PFP7). Pots were disturbed in completely randomized design with three replications and data analysis was done using “SPSS software 13.00”. Duncan’s Multiple Range test was used to compare between means and determine significance between variables ($P < 0.05$).

RESULTS

Growth

Salinity affected significantly ($P<0.01$) the growth parameters such as shoot and root length, number of leaves and fresh and dry matters. In control condition (plants derived from unstressed seeds), shoot length was affected by salinity and at 8 g/l it was severely reduced (Table 1): it decreased from 35.48 to 12.12 cm in Tunisian cv, from 19.15 to 4.02 cm in Algerian cv, from 32.02 to 6.19 cm in Egyptian cv and from 25.72 to 4.02 cm in Syrian cv. Application of NaCl priming stimulated growth of shoot in all the cultivars even in control and salinity stress conditions.

The length of root was also drastically affected by salinity in all coriander cultivars (Table 1). In control plant, increasing NaCl concentration from 0 to 8 g/l was accompanied by a reduction in root length of 82.3, 80.37, 94.8 and 79 % respectively in Tunisian, Egyptian, Algerian and Syrian cvs. By priming treatment, this decrease was less pronounced and root length increased in all coriander cultivars as compared to unprimed treatment.

Similarly, leaves number per plant was affected by salinity (Table 1) but higher number was recorded by plants derived from primed seeds in all the cultivars. As compared to unstressed condition, treated plants decreased the synthesis of leaves at 8g/l from 30.08 to 7.12 leaves, from 27.10 to 6.19 leaves, from 20.02 to 2 leaves and from 28 to 6 leaves respectively in Tunisian, Egyptian, Algerian and Syrian cvs. In all treatments, maximum number was belonged to Tunisian cultivar.

Results for fresh and dry weights (Table 2) showed that salinity exerted a significant ($P<0.05$) impact on biomass of the four coriander cultivars studied. Thus, where plants are not stressed, root fresh weight varied from 7.15 (Algerian cv) to 10.12 g (Tunisian cv) and shoot fresh weight was comprised between 21.11 (Algerian cv cv) and 47.32 g (Tunisian cv). When NaCl is added, fresh weights in both root and shoot decreased by increasing salt stress level and at the highest concentration (8 g/l), we observed the most significant decline corresponding to 81(Tunisian cv), 89 (Syrian cv), 90 (Egyptian cv) and 95 % (Algerian cv) in shoot and 88 (Tunisian cv), 89 (Egyptian cv), 93 (Syrian cv) and 98 % (Algerian cv) in root.

The same trend was observed in primed plants but values were higher than unprimed plants. Thus, at 8 g/l, root fresh weight was enhanced with priming treatment by 3.6, 2, 3.3 and 3 times respectively in Tunisian, Algerian, Egyptian and Syrian cvs. Also, fresh matter of shoot was enhanced at the same level of salinity by 1.9, 1.14, 1.84 and 1.47 times respectively in Tunisian, Algerian, Egyptian and Syrian cvs. The same result was observed for dry matters which decreased in shoot and root with increasing salinity level (Table 2) as in unprimed and primed plants but seed priming ameliorated data. For example, in Tunisian cv, for unprimed plants, the increase in salinity up to 8 g/l caused a 85 and 96 % reduction respectively in shoot and root dry weight compared to control (0 g/l) whereas this reduction was 80 (shoot) and 83% (root) or for primed plants.

Chlorophylls synthesis

Salt stress affected negatively chlorophylls amounts in leaves of coriander of all cultivars in study (Table 3) and this reduction was more in chlorophyll b than in chlorophyll a. Indeed, in control (0 g/l), leaves contained about 2.36 (Algerian cv) to 3.10 (Syrian cv) mg/g FW for chlorophyll a (Table 3) and about 1.66 (Syrian cv) to 1.95 mg/g FW (Tunisian cv) for chlorophyll b. Increasing NaCl concentration was accompanied by a decline of chlorophyll synthesis among the four cultivars of coriander especially at higher level (8 g/l) where chlorophyll a and b contents did not exceed respectively 0.11 and 0.21 mg/g FW in Algerian cv. Seed priming treatment improved the chlorophylls content of coriander leaves in all the cultivars under normal and saline conditions (Table 3). So, at 6 g/l, chlorophyll a content increased d by 40. 9, 19 and 21% and chlorophyll b content was amplified by 34, 25, 55 and 31 % respectively in Tunisian, Algerian, Egyptian and Syrian cvs. The same results showed that Tunisian cv maintained maximum values for chlorophyll a and Egyptian cv maintained highest amounts for chlorophyll b.

Solutes content

Salt application enhanced significantly ($p<0.01$) synthesis of proline in leaf in all cultivars of coriander with the increase of salt concentration in irrigation water (Table 4). At 8 g/l NaCl level, the four cultivars presented highest values: 70.41 (Tunisian cv), 55.12 (Algerian cv), 68.74 (Egyptian cv) and 69.75 µg/g FW (Syrian cv) which corresponded respectively to 1.44, 1.31, 1.52 and 1.55 times to the level found in controlled plants. As response to priming, proline content rose more even by application of salinity. Thus, minimum amount of proline was recorded in control leaves of primed plants especially in Algerian cv whereas the highest value was related to saline-treated 8 g/l in Tunisian cv.

Table 4 revealed results about soluble sugars amount in leaves of the coriander cultivars studied. Data showed significant ($p \leq 0.01$) effect of salinity, seed priming and genotypes on this parameter. Salinity caused an increase in accumulation of soluble sugars in leaves of the four cultivars of coriander (Table 4). Maximum content was recorded under higher salinity level (8 g/l): 1304 (Tunisian cv), 1202 (Algerian cv), 1297 (Egyptian cv) and 1263 (Syria cv) µg/g FW which presented 1.22, 1.17, 1.23 and 1.19 times the level measured on non stressed plants. Seed priming increased more soluble sugars content when compared with unprimed seed. The highest value was obtained in primed leaves of Tunisian cv (1328 µg/g FW at 8 g/l NaCl) while lowest value was maintained by unprimed Algerian cv (1202 µg/g FW at 0 g/l NaCl).

Similarly, measurement of soluble proteins content in leaves of coriander showed that salinity stress induced a significant ($p<0.01$) increase in soluble proteins content as NaCl concentration increased in all cultivars studied (Table 4). This increase was more important after priming treatment. Therefore, the leaves of plants from the salt-primed seeds had highest total soluble sugars contents which were 52.84, 37.11, 45.62 and 41.02 mg/g FW respectively in Tunisian, Algerian, Egyptian and Syrian cvs.

Mineral analysis

Mineral composition in roots was significantly ($p<0.05$) affected by salt stress, priming and genotypes. On the first hand, results illustrated that content of sodium (Na^+), potassium (K^+) and calcium (Ca^{2+}) were not affected as the same way: increasing salinity stress increased accumulation of Na+ but decreased K^+ and Ca^{2+} content in root of coriander (Table 5). On the second hand, the same essay showed that after priming treatment, content of Na^+ and Cl^- decreased in primed seeds than unprimed ones whereas the content of K^+ and Ca^{2+} increased. Consequently, plants derived from unprimed seeds presented more Na^+ and less K^+ and Ca^{2+} amounts than plants derived from primed seeds. On the last hand, mean values of the data revealed significant ($p<0.05$) decreased in Na^+/K^+ ratios in roots with increasing salinity in both primed and non-primed seeds (Table 5). Highest root Na^+/K^+ ratio was recorded at 8 g/l in primed plants of Tunisian cv followed by Egyptian cv, Syrian cv and Algerian cv with respectively a ratio of 0.37, 0.32, 0.22 and 0.16.

Table 1. Root length, shoot length and number of leaves of coriander cultivars (C) as affected by seed priming (P) and salinity (S).

Cultivar	NaCl (g/l)	Priming (NaCl: g/l)	Root length (cm)	Shoot length (cm)	Number of leaves
Tunisian cv	0	0	12.35 a	35.48 a	30.08 a
	2		10.85 b	24.85 b	22.14 bc
	4		8.94 c	21.75 c	19.25 c
	6		4.97 d	15.85 d	12.14 d
	8		2.18 e	12.12 e	7.12 e
	0	4	15.65 a	41.13 a	36.00 a
	2		13.76 ab	30.22 b	27.00 b
	4		10.31 b	24.63 c	21.22 c
	6		7.13 c	18.14 d	15.00 d
	8		4.42 d	13. 82 e	10.00 e
Algerian cv	0	0	9.05 a	19.15 a	20.00 a
	2		7.25 b	16. 84 b	16.00 b
	4		3.94 c	9.24 c	12.22 c
	6		2.43 d	7.59 d	5.74 d
	8		0.47 e	4.02 e	2.09 e
	0	4	10.18 ab	21.72 a	22.00 a
	2		9.75 b	18. 19 b	17.00 b
	4		4.63 c	10.32 c	15.00 c
	6		3.14 d	8.12 d	6.12 d
	8		1.17 e	5.00 e	4.33 e
Egyptian cv	0	0	11.31 a	32.01 a	27.10 ab
	2		10.25 b	20.15 b	24.08 b
	4		7.84 c	14.38 c	13.25 c
	6		5.61 d	9.22 d	10.57 d
	8		2.22 e	6.19 e	6.19 e
	0	4	13.88 a	34.42 a	30.33 a
	2		11.01 b	23.12 b	26.33 b
	4		9.24 c	17.68 c	17.00 c
	6		7.61 d	13.57 d	12.00 d
	8		3.02 e	8.42 e	8.00 e
Syrian cv	0	0	10.72 a	25.72 a	25.11 a
	2		7.35 b	16.22 b	20.14 b
	4		5.94 cd	10.44 c	15.03 c
	6		4.97 d	7.59 d	8.22 d
	8		2.18 e	4.02 e	4.19 e
	0	4	13.07 a	27.33 a	28.00 a
	2		8.15 b	20.13 b	23.00 b
	4		6.88 c	14.58 c	18.33 c
	6		5.13 d	8.11 d	10.33d
	8		2.62 e	6.34 e	6.00 e
Interactions	**Significance level**				
C*S			s	s	s
C*P			s	s	s
S*P			s	s	s
C*S*P			s	s	s

Means at the same colon and same treatment followed by the same letter are not significantly different at 5% level according to Duncan test

Table 2. Effect of seed priming (P) and salinity (S) on biomass of four coriander cultivars (C).

Cultivar	NaCl (g/l)	Priming (NaCl: g/l)	Root fresh weight (g)	Shoot fresh weight (g)	Root dry weight (mg)	Shoot dry weight (mg)
Tunisian cv	0	0	10.12 a	47.32 a	7.94 a	12.77 a
	2		7.18 b	37.34 b	4.22 b	8.33 b
	4		4.22 c	28.56 c	2.17 c	5.22 c
	6		2.88 d	18.06 d	1.46 d	3.25 cd
	8		1.18 e	9.06 e	0.32 e	1.84 d
	0	4	14.45 a	51.84 a	10.28 a	16.00 a
	2		10.47 b	45.11 b	7.24 b	11.30 b
	4		7.12 c	34.33 c	5.08 c	7.22 c
	6		5.59 d	24.41 d	3. 33 d	6.11 cd
	8		4.27 e	17.24 e	1.75 e	3.15 d
Algerian cv	0	0	7.15 a	21.11 a	4.33 a	8.33a
	2		4.00 b	13.33 b	2.04 b	4.46 b
	4		2.86 c	7.58 c	0.88 c	2.00 c
	6		0.68 d	3.02 d	0.31 d	1.22 cd
	8		0. 18 e	0.97 e	0.07 e	0.67 d
	0	4	9.11a	27.02 a	7.13 a	14.15 a
	2		5.33 b	19.31 b	3.25 b	11.03 b
	4		4.00 c	10.00 c	2.18 c	7.56 c
	6		1.87 d	5.35 d	1.01 d	5.00 cd
	8		0.36 e	1.11 e	0.67 e	2.10 d
Egyptian cv	0	0	9.33 a	39.11 a	7.22 a	11.37 a
	2		6.24 b	22.48 b	3.10 b	7.64 b
	4		3.00 c	15.94 c	2.16 c	4.67 c
	6		2.03 d	6.33 d	0.86 d	3.00 cd
	8		1. 00 e	3.86 e	0.22 e	2.07 d
	0	4	12.55 a	44.25 a	11. 00 a	23.75 a
	2		9.33 b	31.71 b	7.00 b	18.00 b
	4		7.04 c	19.84 c	4.43 c	15.33 c
	6		5.18 d	15.00 d	2. 62 d	10.30 cd
	8		3.27 e	7.21 e	1.35 e	5.76 d
Syrian cv	0	0	9.00 a	28.10 a	6.86 a	9.42 a
	2		5.33 b	17.58 b	4.12 b	5.14 b
	4		3.15 c	9.25 c	1.76 c	2.68 c
	6		1.00 d	4.22 d	0.56 d	1.92 cd
	8		0. 58 e	2.86 e	0.14 e	0.87 d
	0	4	11.25a	32.00 a	10. 14 a	16.75 a
	2		7.00 b	27.71 b	6.48 b	10.13 b
	4		5.86 c	16.33 c	3.66 c	8.16 c
	6		3.66 d	9.81 d	1. 75 d	5.331 cd
	8		1.76 e	4.21 e	0.35 e	3.00 d
Interactions	**Significance level**					
C*S			s	s	s	s
C*P			s	s	s	s
S*P			s	s	s	s
C*S*P			s	s	s	s

Means at the same colon and same treatment followed by the same letter are not significantly different at 5% level according to Duncan test

Table 3. Effect of seed priming and salinity on chlorophyll content in coriander cultivars.

Cultivar	NaCl (g/l)	Priming (NaCl: g/L)	Chlorophyll a content (mg g^{-1} FW)	Chlorophyll b content (mg g^{-1} FW)
Tunisian cv	0	0	2.65 a	1.95 a
	2		2.31 ab	1.33 b
	4		1.84 b	0.89 c
	6		1.32 c	0.65 d
	8		0.78 d	0.21 e
	0	4	2.95 a	2.15 a
	2		2.75 ab	1.84 b
	4		2.09 b	1.24 c
	6		1. 84 c	0.87 d
	8		1.02 d	0.47 e
Algerian cv	0	0	2.36 a	1.85 a
	2		2.31 b	1.62 b
	4		1.57c	0.75 c
	6		1.08 d	0.43 d
	8		0.21 e	0.11 e
	0	4	2.43 a	1.94 ab
	2		2.21 b	1.77 b
	4		1.12 c	1.00 c
	6		1.18 d	0.54 d
	8		0.45 e	0.18 e
Egyptian cv	0	0	2.85 a	1.75 a
	2		2.45 ab	1.21 b
	4		2.01 b	0.76 c
	6		1.62 c	0.42 d
	8		0.88 d	0.11e
	0	4	3.05 a	2.00 a
	2		2.89 ab	1.66 b
	4		2.66 b	1.12 c
	6		1. 94 c	0.65 d
	8		1.12d	0.28 e
Syrian cv	0	0	3.11 a	1.66 a
	2		2.84 ab	1.13 b
	4		2.11 b	0.56 c
	6		1.44 c	0.32 d
	8		0.48 d	0.15 e
	0	4	3.15 a	1.84 a
	2		2.99 ab	1.24 b
	4		2.69 b	0.89 c
	6		1. 74 c	0.42d
	8		0.68 d	0.25 e
Interactions	**Significance level**			
C*S			s	s
C*P			s	s
S*P			s	s
C*S*P			s	s

Means at the same colon and same treatment followed by the same letter are not significantly different at 5% level according to Duncan test

Table 4. Proline, soluble sugars and soluble proteins contents in leaves of coriander genotypes as affected by seed priming and salinity.

Cultivar	NaCl (g/l)	Priming (NaCl: g/l)	Proline content (µg g^{-1} FW)	Soluble sugars content (µg g^{-1} FW)	Soluble proteins content (mg g^{-1} FW)
	0	0	48.90 e	1075 e	24.12 e
	2		52.47d	1133 d	27.33 d
	4		62.38c	1194 cd	34.78 c
	6		66.98 bc	1272 b	40.25 bc
Tunisian cv	8		70.41 a	1313 a	47.09 a
	0	0	53.21 e	1124 e	27.35 d
	2		56.41d	1175 d	30.74 cd
	4		66.17 c	1213 cd	38.41 c
	6		68.62 bc	1294 b	42.33 b
	8		75.25 a	1328 a	52.84 a
	0		42.02 e	1022 e	23.95 e
	2	0	45.35 d	1033 d	24.28 d
	4		48.75 c	1100 cd	26.22 c
	6		52.14 bc	1184 b	27.14 b
Algerian cv	8		55.12 a	1202 a	32.62 a
	0	4	45.12 e	1047 e	24.12c
	2		47.52 d	1084 d	25.16 c
	4		50.22 c	1116 cd	30.44 b
	6		55.33 bc	1217 b	33.33 b
	8		60.11 a	1241 a	37.11 ab
	0	0	45.12 e	1053 e	23.75 d
	2		48.32 d	1096 d	26.63 c
	4		56.33 c	1172 cd	30.22 b
	6		62.11 bc	1242 b	35.66 b
Egyptian cv	8		68.74 a	1297 a	44.11 a
	0	4	50.10e	1108 e	25.22 e
	2		55.21 d	1125 d	28.41 d
	4		63.62 c	1199 cd	32.87 c
	6		65.00 bc	1274 b	39.26 b
	8		71.33 a	1300 a	45.62 a
	0	0	45.00 e	1037 e	23.77 c
	2		48.12 d	1076 d	25.73 c
	4		50.10 c	1141 cd	28.54 b
	6		58.87 bc	1200 b	30.62 b
Syrian cv	8		61.12 a	1244 a	37.19 a
	0	4	48.54 e	1094 e	25.41 e
	2		50.07 d	1102 d	28.74 de
	4		56.72 c	1176 cd	32.94 c
	6		63.08 bc	1261 b	35.69 b
	8		69.75 a	1294 a	41.02 a
Interactions	**Significance level**				
C*S			s	s	s
C*P			s	s	s
S*P			s	s	s
C*S*P			s	s	s

Means at the same colon and same treatment followed by the same letter are not significantly different at 5% level according to Duncan test

Table 5. Impact of salinity and seed priming on sodium, potassium, calcium uptake and Na⁻/K⁺ ratio in roots of coriander cultivars.

Cultivar	NaCl (g/l)	Priming (NaCl: g/l)	Na^+ content (mg g^{-1} DW)	K^+ content (mg g^{-1} DW)	Ca^{2+} amount (mg g^{-1} DW)	Na^+/K^+ ratio
Tunisian cv	0	0	0,35 e	1,35 ab	0.95 a	0.84 a
	2		1,73 d	1,30 b	0.75 b	0.67 b
	4		2,22 c	0,88 c	0.52 c	0.52 c
	6		3,12 b	0,44 de	0.34 d	0.46 d
	8		4,16 a	0,32 e	0.21 e	0.26 e
	0	4	0,15 e	1,74 a	1.12 a	0.92 a
	2		1,34 d	1,52 b	0.93 b	0.75 b
	4		2,01 c	1,05 c	0.72 c	0.61 b
	6		2,75 b	0,84 d	0.57 d	0.53 c
	8		3,22 a	0,62 e	0.36 e	0.37 d
Algerian cv	0	0	0,44 e	0,86 ab	0.42 a	0.62 a
	2		1,23 d	0,77 b	0.37 b	0.42 b
	4		2,75 c	0,38 c	0.27 c	0.31 c
	6		3,86 b	0,24 d	0.17 d	0.24 d
	8		5,00 a	0,16 e	0.09 e	0.08 e
	0	4	0,22 e	1,21 a	0.68 a	0.72 a
	2		0,75d	0.89 b	0.44 b	0.51 b
	4		2,03 c	0,54 c	0.37 c	0.39 c
	6		2,99 b	0,38 d	0.20 d	0.30 c
	8		3,66 a	0,21 e	0.14 e	0.16 d
Egyptian cv	0	0	0,65 e	1,04 a	0.88 a	0.76 a
	2		1,43 d	1,17 bc	0.62 b	0.65 b
	4		2,86 c	0,57 c	0.47 c	0.49 c
	6		3,73 b	0,36 de	0.30 d	0.38 d
	8		4,75 a	0,21 e	0.19 e	0.22 e
	0	4	0,15 e	1,64 a	0.98 a	0.84 a
	2		1,11 d	1,44 ab	0.75 b	0.75 b
	4		1,33 c	1,03 b	0.57 c	0.52 c
	6		2,05 b	0,72 c	0.32 d	0.46 d
	8		3,15 a	0,47 c	0.27 e	0.32 e
Syrian cv	0	0	0,55 e	1,05 a	0.63 a	0.75 a
	2		1,63 d	1,35 a	0.51 b	0.51 b
	4		2,76 c	0,63 b	0.34 c	0.44 c
	6		3,41 b	0,42 c	0.25 d	0.31 d
	8		4,15 a	0,29 d	0.17 e	0.16 e
	0	4	0,21 e	1,54 a	0.88 a	0.80 a
	2		1,44 d	1,33 a	0.61 b	0.65 b
	4		2,33 c	0,86 b	0.46 c	0.49 c
	6		3,05 b	0,61 c	0.29 d	0.34 d
	8		3,82 a	0,37 d	0.20 e	0.22 e
Interactions	**Significance level**					
C*S			s	s	s	s
C*P			s	s	s	s
S*P			s	s	s	s
C*S*P			s	s	s	s

Means at the same colon and same treatment followed by the same letter are not significantly different at 5% level according to Duncan test

DISCUSSION

The present study investigated the response of four cultivars of coriander to salinity induced by NaCl (0, 2, 4, 6 and 8 g/l) and seed priming (NaCl at 4g/l for 12h) with regard to vegetative growth, chlorophylls and solutes synthesis and ion balance.

Data showed that salinity had significantly affected vegetative growth as well as stress level increased resulting in severe reduce on the corresponding parameters in study. Similar results were reported in barley (Naseer, 2001) and wheat (Kumar *et al.,* 1981, Sharma and Grag, 1985) for root length, in basil (Ghanbari *et al.,* 2013) for shoot length and in groundnut (Mensah *et al*., 2006) and sunflower (Afkari, 2010) for number of leaves. Also, salinity severely touched biomass of the plant: fresh and dry weights of the root and root were inhibited progressively with the rise of NaCl concentration compared with control especially for Algerian cv whereas Tunisian cv showed resistance to this effect usually up to the highest value. These results are comparable to those reported for different crops such as maize (Cicek and Cakirlar, 2002), soyebean (Farhoudi and Tafti, 2011), sprout (Al Thabet *et al.,* 2004), wheat (Khan *et al.,* 2009), savory (Keshavarzi, 2011), carthamus (Abbaspour, 2010), pistachio (Banakar and Ranjbar, 2010) and pepper (Zhani *et al*., 2012a).

The deleterious effect of salinity was suggested as a result of water stress, ion toxicities, ion imbalance (Greenway and Munns, 1980) or combination of all these factors (Kurth *et al.,* 1986). Some researchers thought that the growth reduction is the consequences of ion accumulation through the changing of membrane permeability (Cramer *et al.,* 1985, Grieve and Fujiyama, 1987). Bandeoglu *et al.* (2004) indicated also that this retarded growth is due to inhibition of cell elongation due to higher concentration of Na+ which causes membrane disorganization, inhibition of cell division and expansion (Deivanai *et al.,* 2011). Researches of Rahimi and Biglarifard (2011) showed that accumulation of ions in plant growth environment causes osmotic and pseudo-drought stress leading to decrease of water absorption by plant tissues making roots cells unable to obtain the required water from the medium. Thus, decrease of tissue water content resulted in reduction of cellular growth and development (Marschner, 1995). According to Cuartero *et al*. (2006), the reduce in leaves number is due to the interference of salinity stress on the phytohormones biosynthesis and action. Furthermore, Mauromicale and Cavallaro (1997) attributed growth inhibition at high levels of salinity to the retard of leaf primordial initiation.

Studying the effect of seed priming on coriander growth, results demonstrated that this treatment limited the negative impact of salinity because plants raised from primed seeds recorded better growth than plants derived from unprimed seeds where they showed significant amelioration when exposed to different salinity levels. These results agree with the finding of many researchers on different crops e.g wheat (Mehta *et al*., 1979)*, Sorghum bicolor* (Kadiri and Hussaini, 1999), *Vicia faba* (Salam, 1999), maize (Bakht *et al*., 2011), canola (Mohammadi, 2009), watermelon (Demir and Van Deventer, 1999; Armin *et* *al*., 2010), tomato (Liu *et al.* ,1996; Mirabi and Hasanabadi, 2012), melon (Sivritepe et *al*. 2003), safflower (Elouer et *al.* 2012) and *Ziziphus Spina-Christi* (Takhti and Shekafandeh, 2012).

According to Anwar *et al.* (2011a), the increase in root length in primed seeds as compared to control might be the result of embryo cell wall extensibility. Also, Sakhabutdinova *et al*. (2003) suggested that priming increased the level of cell division within the apical meristem of seedling roots which caused an increase in plant growth. In other point of view, to offset the action of free radicals and increase the activity of membrane bound enzyme, seed priming seems to act by increasing the free radical scavenging enzymes (peroxidase, catalase and superoxide dismutase) to improve plant viability and vitality under salinity stress (Chang and Sung, 1998; Shafi *et al*., 2009). Working on cucumber, muskmelon and Amaranth, Passam and Kakouritis (1994), Nascimento and West (1999), and Omami (2005) believed that seed priming improved seedling growth due to reducing of seed coat viscosity especially in adverse conditions (Desai *et al*., 1997). This improvement is induced by enhancing protein and DNA synthesis that may be effective in increasing cell membrane stability in embryo. Also, phospholipids in cell membrane of embryo can increase the resistance and permeability of cell membrane (Bradford, 1995).

Salinity made also disorders in metabolism of coriander resulted in inhibition of chlorophyll synthesis especially in Algerian cv at highest NaCl level. This result is in agreement with those of Beinsan *et al.,* (2003) in bean, Iqbal *et al.,* (2006) in wheat, Molazem *et al.* (2010) in corn, Malik *et al.* (2010) in cucumber, El Iklik *et al.* (2011) in tomato and Zhani *et al.* (2012b) in pepper. Decrease in chlorophyll content in response to salt stress is a general phenomenon which led to disordering synthesizing chlorophyll and appearing chlorosis in plant (Parida and Das, 2005). According to Rao and Rao (1981), NaCl stress decrease total chlorophyll content of the plant by increasing the activity of the chlorophyll degrading enzyme: cholorophyllase, inducing the destruction of the chloroplast structure (Blumenthal-Goldschmidt and Poljakoff-Mayber, 1968) and the instability of pigment protein complexes (Dubey, 1997). In another study, Ali *et al.* (2004) attributed this reduction in chlorophyll concentration by NaCl to the inhibitory effect of the accumulated ions of various salts on the biosynthesis of the different chlorophyll fractions. Farahbakhsh and Shamsaddin Saiid (2011) cited that lessening of the thylakoid thickness and granna swelling are other reasons for chlorophyll reduction under salt stress. As for vegetative parameters, results confirmed that priming seeds affected chlorophyll synthesis: plants derived from primed seeds were able to resist more to salinity by an amelioration of synthesis of chlorophyll pigment as compared to non primed plants. Farahbakhsh and Shamsaddin Saiid (2011) found also that seed priming of fenugreek and maize improved all fractions of photosynthetic pigments under salt stress.

As a response to salt stress, leaves of coriander plants accumulated more proline, a common phenomena observed in all organisms ranging from bacteria to higher plants to survive both water deficit and high salinity (Ahmad and Jhon, 2005). Thus, proline content increased significantly in leaves of all coriander cultivars in study as salt concentration increased. Our result is supporting findings in barley (Sadeghi, 2009), mulberry (Kumar *et al*., 2003), *Morus alba* (Ahmad *et al.,* 2007), wheat (Karmous *et al*., 2013), rapessed (Farhoudi, 2011) and pepper (Chookhampaeng, 2011) where salt stress resulted in extensive proline accumulation. In fact, proline is an organic solute known to be involved in osmoregulation which reduces the cell osmotic potential to a level to provide high turgor potential for maintaining growth (De Lacerda *et al*., 2005). Also, apart protection of macromolecules from denaturation and carbon and nitrogen reserve for stress relief, proline has several other functions during stress: e.g. osmoprotection (Kavi Kishor *et al.* 2005) and antioxidant activity (Sharma and Dietz, 2006). Finaly, proline is considered as an index for determining salt tolerance potentials between cultivars in many species (Petrusa and Winicov, 1997; Ramanjula and Sudhakar, 2001). In our study, a similar behavior in the seedling of coriander was also observed: proline accumulation in the salt tolerant coriander (Tunisian cv) was significantly higher than that in the salt sensitive one (Algerian cv). The synthesis of proline was more significant with priming treatment in all cultivars of coriander like it was cited by Ma *et al.* (2010) on sorghum, Farahmandfar *et al.* (2013) on fenugreek.

Like proline, accumulation of total soluble sugars is suggested to be a common phenomenon under stress condition (Murakeozy *et al*., 2003). It has an important role in osmoregulation (Mohanty *et al*., 2002) and maintaining growth (Ashraf and Harris, 2004). Singh (2004) proved then that a greater accumulation of sugars lowers the osmotic potential of cells and reduces loss of turgidity in tolerant genotypes. This trend is confirmed in our results which proved greater increase in soluble sugars content in leaves of coriander with the increase of NaCl concentration. Our finding agrees with researchers done on rice (Siringam *et al.,* 2011), sorghum (Gill *et al.,* 2003), sugar beet (Khavari- Nejad *et al*., 2008), potato (Farhad *et al.,* 2011) and pistachio (Abbaspour *et al*., 2012). Sugar content in leaves was the highest in Tunisian cv (1304 µg/g FW) and the lowest in sensitive one; Algerian cv (1202 µg/g FW) like it was found in rice (Dubey and Singh, 1999) and citrus (Balal *et al.,* 2011) cultivars. By priming seeds, leaves synthesized more soluble sugars and plants from primed seeds have more soluble sugars content in their leaves than plants from derived from non-primed seeds. This same benefic effect was found on tomato (Cayuela *et al*., 1996) wheat (Afzal *et al*., 2008) and barley (Anwar *et al*., 2011b) due probably to an increase of α-amylase activity (Lee and Kim, 2000).

Similarly, soluble proteins content in leaves was also touched by salinity stress and priming treatment. Indeed, in all the cultivars studied, biosynthesis of soluble proteins is enhanced as NaCl concentration increases. Similar results were reported in rice (Raja babu and Ramesh, 2007), wheat (Zerrad *et al*., 2008), cotton (Jiang *et al*., 2005), tomato (Amini and Ehsanpour, 2005), sesame (Hukam Gehlot *et al.,* 2005), mulberry (Ahmad and Sharma, 2010), lentil (Abd El- Monem Sharaf, 2008) and pepper (Zhani *et* *al.,* 2013). Also, after priming, the protein amounts in leaves increased more proving the benefit impact of this method like it was observed on *sorghum* by Bosco de Oliveira *et al*. (2011) and lettuce by Nasri *et al*. (2011). In our study, the highest content of soluble proteins is observed in Tunisian cv and this proves that it's the tolerant accession like it was observed by Hurkman *et al*. (1989) and Lutts *et al*. (1996) on respectively salt tolerant cultivars of barley and rice.

Salinity and priming had moreover significant impact on mineral balance in coriander. Results for ion content showed that there was a competition between Na^+ and K^+ regarding their uptake and as a result increasing NaCl stress was accompanied by an increase in Na^+ concentration in the four cultivars and a decrease at the same time of K^+ uptake. The present result is in agreement with the work of Molazem *et al.* (2010) in corn, Ben Dkhil and Denden (2010) in okra and Akibarimoghaddam *et al.* (2011) in wheat. El-Samad and Shaddad (1997) reported that one of the primary plant responses to salinity is the decrease in K+ concentration in plant tissues and thus the substitution of K^+ by Na^+ may lead to nutritional imbalances. Both of these ions might compete for entry into plant root cells and the antagonistic effect between these elements was confirmed by Greenway and Munns (1980). According to the results, in Tunisian cv, Na^+ accumulation was lower but higher for K^+ ion in the roots contrary to Algerian cv which demonstrates the highest Na^+ content and the lowest K^+ concentration. It is concluded then that Tunisian cv is the most salt stress tolerant due to its less Na^+ absorption and more Na^+ accumulation in roots compared with the three others studied cultivars and that Algerian cv is the most sensitive. Similar results were reported with different cultivars of green bean (Yasar *et al*., 2006) and canola (Bandeh-Hagh *et al.,* 2008). The results for this tolerant accession can be explained in the light of the findings of many scientists that reported that salt tolerant mesophytes generally exclude either Na^+ (Lauchli *et al.,* 1994; Saqib *et al*., 2005) because Na^+ is the primary cause of ion specific damage, resulting of disorders in enzyme activation and protein synthesis (Tester and Davenport, 2003). Therefore, exclusion of Na^+ and maintenance of high K^+ level are vital for the plants to grow under saline conditions (Munns *et al*., 2000). Also, it was reported that potassium has a prevalent action in plants and is involved in maintenance of ionic balance in cell and bounds ironically to enzyme pyruvate kinase which is essential in respiration and carbohydrate metabolism (Aisha *et al.,* 2007). As a consequence, the ration Na^+/K^+ is reduced by salt stress and this result is the same with which found in soybean (Farhoudi and Tafti, 2011) and rapeseed (Farhoudi, 2011). Tunisian cv maintained also considerably high ratio (0.26) contrary to Algerian cv (0.08). Such result explaines more the advantage of this cultivar to present its well responding to salt stress during vegetative growth (Morant-Manceau *et al.,* 2004).

Measurement of Ca^{2+} content demonstrated that it is also affected by salinity and that there is a positive correlation in the accumulation of Ca^{2+} and K^+. The same result was observed in pigeon), in rice (Nemati *et al.,* 2011) and in canola (Tuncturk *et al.,* 2011). In fact, calcium has been shown to play an important role in regulating ion transfer into plant cells growing in saline medium (Ashraf and Naqvi, 1992; Soussi *et al.*, 2001) and in amelioration of the adverse effects of salinity on plants (Amador *et al.*, 2007) by affecting membrane stability (Rengel, 1992) and ion translocations (Cramer, 1992; Unno *et al.*, 2002). Davenport *et al.* (1997) reported that in wheat, extracellular Ca^{2+} inhibits unidirectional Na^+ influx and also inhibits Na^+ influx through a non selective cation channel, isolated in planar lipid bilayers, suggesting that the effect of Ca^{2+} on Na^+ influx might be direct and cytosolic signaling for modification of ion channel activity is not required. In primed plants of coriander, the changes observed in mineral balance ware not the same. Primed plants was proved to have less Na^+ amounts in their roots and more K^+, Na^+/K^+ ratio and Ca^{2+} amounts than plants derived from unprimed seeds. Our finding is supporting those of Massoudi *et al.* (2010) on grasses, Demirkaya (2014) on tomato.

CONCLUSION

From the present study, it is concluded that effects of salinity and seed priming on all the measured traits were significant. Increasing NaCl concentration up to 8g/l negatively influenced growth and photosynthetic metabolism of coriander and obliged the plant to synthesis more solutes. Mineral balance was also touched and as a consequence an increase of amounts of Na^+ and decrease in K^+ and Ca^{2+} were observed. Seed priming alleviated the inhibitory effect of salt stress of four cultivars and all of them positively responded to seed priming. In primed and unprimed treatment, Tunisian cv of coriander is classified as the salt tolerant genotype whereas Algerian cv as susceptible genotype based on various parameters studied especially the maintaining of the highest values of K^+ and Ca^{2+} content, K^+/Na^+ ratio in roots and osmotica (proline, sugars and proteins) in leaves.

Based on these results, seed priming with NaCl associated to the introduction of Egyptian cultivar in framers tradition may be considered as a reliable procedure to increase the coriander salinity tolerance and win more biomass which can probably have an important impact on seed yield. Therefore, it is important to continue the study by testing priming effect on seed yield, essential oil content and its composition.

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