COBISS Code 1.01

DOI: 10.2478/acas-2013-0005

Agrovoc descriptors: coriander, coriandrum sativum, spices, salinity, semiarid zones, pregermination, seed treatment, crop yield, emergence, plant developmental stages, germination, seedlings, growth, biological development stress, osmotic stress, salt tolerance, mineral content, essential oils

Agris category code: F62

Influence of seed priming on emergence and growth of coriander (*Coriandrum sativum* L.) seedlings grown under salt stress

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Received August 21, 2012; accepted January 28, 2013.
Delo je prispelo 21. avgusta 2012, sprejeto 28. januarja 2013.

ABSTRACT

Salinity is one of the biggest limiting factors for agriculture in semi-arid areas of the world. For this reason, an experiment was conducted to study the effect of seed priming with NaCl and $CaCl_2$ on growth and yield responses of Tunisian coriander cultivar exposed to five levels of salinity (0, 2, 4, 6, 8 g l^{-1}). Seeds of coriander were primed with aerated solutions of 0.13 M NaCl and $CaCl_2$ for 24 h. Results indicated that with increasing salinity, emergence traits (total emergence, mean emergence time), growth parameters (plant height, shoot fresh and dry weight) and mineral contents (K^+ and Ca^{2+}) decreased, but to a less degree in primed seeds. In all of the salinity levels, primed seeds possessed higher emergence and growth rate than control. However, further studies are needed to highlight the effect of seed priming on yield and oil content of coriander under salt stress.

Key words: Coriander, salinity, seed priming, emergence, growth, mineral content

IZVLEČEK

VPLIV PRETRETIRANJA SEMEN KORIANDRA (*Coriandrum sativum* L.) S SOLNIMI RAZTOPINAMI NA VZNIK IN RAST V RAZMERAH SOLNEGA STRESA

Slanost je eden izmed največjih omejevalnih dejavnikov kmetijstva v polsušnih območjih sveta. V ta namen je bil izveden poskus za preučevanje učinkov predtretiranja semen z NaCl in $CaCl_2$ sorte tunizijskega koriandra na parametre rasti in pridelka, ki je bila izpostavljena petim stopnjam slanosti (0, 2, 4, 6, 8 g l^{-1}). Semena koriandra so bila tretirana s prezračeno raztopino 0.13 M NaCl in $CaCl_2$ za 24 h. Izsledki so pokazali, da so z naraščajočo slanostjo parametri vznika (totalni vznik, poprečni čas vznika), rasti (višina rastlin, sveža in suha masa poganjkov) in vsebnosti hranil (K^+ in Ca^{2+}) upadli, vendar manj pri predhodno tretiranih semenih. Predhodno tretirana semena so imela pri vseh stopnjah slanosti boljši vznik in večjo rast kot kontrola. Za preučitev učinka predtretiranja s solmi na pridelek in vsebnost olj koriandra v razmerah solnega stresa so potrebne še nadaljne raziskave.

Ključne besede: koriander, slanost, predtretiranje semen, vznik, rast, vsebnost hranil

1 INTRODUCTION

Salt stress is certainly one of the most serious environmental factors limiting the productivity of crop plants (Ashraf, 1999). This is due to the fact that salinity affects most aspects of plant physiology, growth and development (Borsani et al. 2003). It is expected that salinity will affect 50% of arable land in the middle of the 21st century (Wang et al. 2003). In this respect, the need to develop crops with high tolerance to salinity has increased dramatically in the last decade. Beside genetic adaptation plants can, to a certain level, acclimated to salt stress. Salt tolerance of plants can be increased by seed treatment with different osmotic solutions

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(inorganic salts, sugars, growth regulators and polyethylene glycol) known as seed priming. Seed priming is a pre-sowing treatment that involves exposure of seeds to low external water potential that limits hydration. This hydration is sufficient to permit pre-germinative metabolic events but insufficient to allow radicle protrusion through the seed coat. This technique has become a common seed treatment that can increase emergence, growth, yield and salt tolerance mainly under unfavorable environmental conditions. Seeds with rapid germination under salt stress are expected to have a high percentage of germination and early establishment of culture and a better yield (Rogers et al. 1995). In general, coriander is known as a species moderately tolerant to salinity, the salinity effect appears mainly during germination and plant growth. In this context, the objective of this work is to improve the germination, growth and mineral contents of coriander using NaCl and $CaCl_2$ as osmotic solutions under salt stress.

2 MATERIALS AND METHODS

The experiment was carried in the experimental field research of High Institute of Agriculture, Chott Mariem, Tunisia. Coriander (*Coriandrum sativum* 'Sandra') seeds were primed with 0.13 M aerated solutions of NaCl and $CaCl_2$ for 24 hours, at 22 °C. After priming, primed and non-primed seeds (control seeds) were sown directly in the soil in March 2011 in the field experiment of High Institute of Agronomy, Chott-Mariem, Tunisia. The climate of the region is described as semi-arid, with an average annual precipitation of 230 mm and an approximate daily evaporation of 6 mm day^{-1}. In winter, the average minimum temperature is 6 °C and the average maximum is 18 °C, while in summer average minimum is 23 °C and average maximum is 38 °C. The soil is sandy clay with an organic matter of 1%. Throughout their vegetative cycles, plants from primed and control seeds were irrigated with saline water at five levels of NaCl concentrations (0, 2, 4, 6 and 8 g l^{-1}). The experiment was arranged factorial in a completely randomized design with two factors which are priming treatment (NaCl primed seeds, $CaCl_2$ primed seeds and control seeds) and salinity levels (0, 2, 4, 6 and 8 g l^{-1} NaCl) with three replications and 20 plants per replicate.

Plants were harvested at the flowering stage for both salt treated and non-treated plants. Data on total emergence (%), mean emergence time (days), plant height (cm), shoot fresh and dry weight (g plant^{-1}). Coriander shoot mineral contents (Na^+, K^+, Ca^{2+}, Na^+/K^+ and Na^+/Ca^{2+}) was determined according to the method of Taleisnik and Grunberg (1994). Dried matters of leaves and stems of coriander were digested with nitric acid 0.1 N. Cations concentrations in the extracts such as Na^+, K^+ and Ca^{2+} were determined by flame spectrophotometer.

Emergence, growth and mineral parameters of coriander were evaluated with analysis of variance (ANOVA) and Duncan multiple range test ($p < 0.05$) using SPSS software version (13.0). Differences were considered significant at the 5% level (means followed by different letters).

3 RESULTS

3.1 Total emergence and mean emergence time

Total emergence of coriander seedlings from both primed (P) and non-primed seeds (NP) decreased significantly with increasing NaCl salinity. However, this reduction in total emergence was higher for NP seeds, compared to P seeds. NaCl primed seeds have the highest total emergence. At 4 g l^{-1} NaCl, it was about 3% and 18% higher, in comparison with $CaCl_2$ and control seeds, respectively. This difference becomes more pronounced with increasing NaCl level.

Mean emergence time (MET) increased with rising of salinity levels in both primed and un-primed seeds (Table 1). Rising salinity increases MET from 7.3 days at 0 g L^{-1} to 20.3 days at 8 g L^{-1} for control seeds. Meanwhile, MET in primed seeds in all salinity levels was less than that of un-primed seeds. In fact, at 4 g l^{-1}, MET is about 16.5 days for control seeds, 14.3 days for $CaCl_2$ primed seeds and 12.6 days for NaCl primed seeds.

3.2 Plant height

Salinity levels and seed priming had a significant ($p < 0.05$) effect on plant height. Its reduction by salinity was more severe in control seeds when compared with primed seeds. Similarly, the effect of seed priming was more profound on plant height at high salinity level (8 g l^{-1}). Plant height decreased significantly ($p < 0.05$) with increasing salinity for both plants derived from primed and control seeds; however, this decrease was less pronounced in plants originated from primed seeds. Increasing salinity from 0 g l^{-1} to 8 g l^{-1} drastically decreases coriander plant height of about 80% in plant derived from control seeds; nevertheless, this decrease was less marked in plants derived from NaCl primed seeds (62%) and plants derived from CaCl2 primed seeds (65%).

3.3 Plant fresh and dry weight

Fresh and dry weight of coriander plant significantly decreased due to an increase in NaCl salinity in both primed and control seed (Table 1). Under saline conditions, plants of primed group had a higher fresh weight than non primed group. At 6 g l^{-1} NaCl, plant fresh weight of NaCl and $CaCl_2$ primed group is 32% and 12% higher, respectively, than of control group. In general, increased NaCl salinity significantly decreased plant dry weight in both primed and control groups. However, dry weight in plant of primed group was significantly higher in each salinity level than in the non primed group. In fact, at 4 g l^{-1} NaCl, dry weight of primed group (NaCl and $CaCl_2$ seed priming) is 1.02 and 0.82 g $plant^{-1}$ respectively and 0.73 g $plant^{-1}$ for plants derived from control seeds.

3.4 The content of minerals

Mineral elements (sodium (Na^+), potassium (K^+), calcium (Ca^{2+}), Na^+/K^+ and Na^+/Ca^{2+} ratios), were significantly affected by increasing salinity level (Table 2). Na^+, K^+ and Ca^{2+} concentrations of coriander shoot were significantly ($p < 0.05$) affected by increasing salinity levels and seed priming treatments. Increasing salinity levels increased the accumulation of Na^+ and decreased K^+ and Ca^{2+} content of coriander shoot. Plants derived from control seeds accumulated more Na^+ and less K^+ and Ca^{2+} than plants derived from primed seeds when exposed to different salinity levels. Plants from NaCl primed seeds accumulated 35% less Na^+, 32% more K^+ and 28% more Ca^{2+} at 6 g l^{-1} when compared with non-primed treatment. Na^+/K^+ and Na^+/Ca^{2+} ratios significantly increased with increasing salinity in both primed and non-primed seeds.

Table 1: Effect of seed priming and salinity on growth characteristics of coriander under NaCl stress. Means ± standard errors are presented. Means followed by the same letter are not significantly different at 5% level according to Duncan test.

Treatments		Total Emergence (%)	Mean Emergence Time (days)	Plant Height (cm)	Shoot Fresh Weight (g plant^{-1})	Shoot dry weight (g plant^{-1})
NaCl (g l^{-1})	**Seed priming**					
0	NaCl priming	98.6 ± 2.01^{a}	7.3 ± 0.12^{g}	51.2 ± 1.33^{a}	4.21 ± 0.12^{a}	1.62 ± 0.06^{a}
	$CaCl_2$ priming	98.4 ± 1.89^{a}	10.2 ± 0.18^{f}	48.2 ± 1.35^{b}	3.42 ± 0.16^{b}	1.45 ± 0.05^{b}
	Control seed	97.8 ± 1.96^{a}	12.4 ± 0.16^{e}	45.3 ± 1.31^{c}	3.18 ± 0.17^{b}	1.31 ± 0.02^{c}
2	NaCl priming	86.7 ± 1.65^{b}	9.4 ± 0.11^{f}	40.8 ± 1.22^{d}	2.84 ± 0.09^{c}	1.18 ± 0.03^{d}
	CaCl2 priming	81.8± 1.54^{c}	12.8 ± 0.17^{e}	37.2 ± 1.18^{e}	2.44 ± 0.08^{c}	1.06 ± 0.02^{de}
	Control seed	78.3± 1.43^{cd}	14.6 ± 0.19^{d}	31.6 ± 1.19^{f}	2.12 ± 0.07^{d}	0.91 ± 0.01^{e}
4	NaCl priming	77.4 ± 1.45^{cd}	12.6 ± 0.21^{e}	32.6 ± 1.11^{f}	2.58 ± 0.09^{c}	1.02 ± 0.02^{de}
	CaCl2 priming	75.1 ± 1.44^{d}	14.3 ± 0.22^{d}	29.3 ± 1.08^{g}	1.76 ± 0.04^{e}	0.82 ± 0.01^{ef}
	Control seed	63.7 ± 1.38^{e}	16.5 ± 0.26^{c}	20.8 ± 1.02^{h}	1.55 ± 0.02^{f}	0.73 ± 0.02^{f}
6	NaCl priming	56.4 ± 1.23^{f}	14.1 ± 0.31^{d}	28.2 ± 1.19^{g}	2.09 ± 0.06^{d}	0.89 ± 0.01^{ef}
	CaCl2 priming	51.8 ± 1.21^{g}	16.7 ± 0.29^{c}	26.4 ± 1.21^{g}	1.66 ± 0.02^{ef}	0.72 ± 0.02^{f}
	Control seed	37.1 ± 1.11^{h}	18.4 ± 0.28^{b}	17.8 ± 0.93^{i}	1.41 ± 0.01^{g}	0.61 ± 0.01^{g}
8	NaCl priming	38.1 ± 1.02^{h}	16.8 ± 0.28^{c}	19.2 ± 0.82^{h}	1.91 ± 0.03^{de}	0.76 ± 0.02^{f}
	CaCl2 priming	31.2 ± 0.92^{i}	18.3 ± 0.25^{b}	17.3 ± 0.91^{i}	1.49 ± 0.02^{fg}	0.65 ± 0.01^{g}
	Control seed	16.8 ± 0.86^{j}	20.3 ± 0.35^{a}	9.4 ± 0.12^{j}	1.27 ± 0.01^{h}	0.52 ± 0.03^{h}

Table 2: Effect of seed priming and salinity on growth characteristics of coriander under NaCl stress. Means ± standard errors are presented. Means followed by the same letter are not significantly different at 5% level according to Duncan test.

Treatments		Na^+ (meq mg^{-1} dw)	K^+ (meq mg^{-1} dw)	Ca^{2+} (meq mg^{-1} dw)	Na^+/K^+	Na^+/Ca^{2+}
NaCl (g l^{-1})	Seed priming					
0	NaCl priming	0.61± 0.01^{j}	0.63 ± 0.01^{a}	0.71 ± 0.04^{a}	0.96 ± 0.06^{j}	0.85 ± 0.04^{g}
	$CaCl_2$ priming	0.69 ± 0.01^{ij}	0.51 ± 0.02^{b}	0.59 ± 0.03^{b}	1.35 ± 0.08^{i}	1.16 ± 0.09^{fg}
	Control seed	0.82 ± 0.02^{h}	0.42 ± 0.03^{d}	0.51 ± 0.02^{c}	1.95 ± 0.09^{g}	1.57 ± 0.11^{f}
2	NaCl priming	0.72 ± 0.03^{i}	0.53 ± 0.02^{b}	0.58 ± 0.02^{b}	1.35 ± 0.08^{i}	1.24 ± 0.06^{fg}
	CaCl2 priming	0.78 ± 0.02^{h}	0.47 ± 0.02^{c}	0.52 ± 0.03^{c}	1.65 ± 0.06^{h}	1.51 ± 0.05^{f}
	Control seed	1.15 ± 0.03^{g}	0.36 ± 0.01^{e}	0.43 ± 0.01^{e}	3.19 ± 0.15^{e}	2.67 ± 0.08^{e}
4	NaCl priming	1.14 ± 0.04^{g}	0.46 ± 0.02^{c}	0.51 ± 0.03^{c}	2.47 ± 0.23^{f}	2.23 ± 0.07^{ef}
	CaCl2 priming	1.24 ± 0.05^{fg}	0.41 ± 0.01^{d}	0.46 ± 0.04^{d}	3.02 ± 0.21^{e}	2.69 ± 0.09^{e}
	Control seed	1.41 ± 0.06^{de}	0.31 ± 0.02^{f}	0.36 ± 0.02^{f}	4.53 ± 0.27^{d}	3.91 ± 0.11^{d}
6	NaCl priming	1.27 ± 0.05^{f}	0.39 ± 0.04^{d}	0.46 ± 0.02^{d}	3.25 ± 0.26^{e}	2.76 ± 0.08^{e}
	CaCl2 priming	1.34 ± 0.07^{e}	0.30 ± 0.03^{f}	0.38 ± 0.02^{f}	4.46 ± 0.31^{d}	3.52 ± 0.09^{d}
	Control seed	1.72 ± 0.09^{b}	0.22 ± 0.01^{g}	0.29 ± 0.01^{h}	7.81 ± 0.42^{b}	5.93 ± 0.17^{b}
8	NaCl priming	1.48 ± 0.05^{d}	0.28 ± 0.01^{fg}	0.34 ± 0.02^{g}	5.28 ± 0.36^{c}	4.35 ± 0.12^{c}
	CaCl2 priming	1.58 ± 0.07^{c}	0.14 ± 0.02^{h}	0.27 ± 0.03^{h}	13.36 ± 0.34^{ab}	5.85 ± 0.13^{b}
	Control seed	1.88 ± 0.10^{a}	0.10 ± 0.01^{i}	0.21 ± 0.01^{i}	15.42 ± 0.53^{a}	8.95 ± 0.21^{a}

4 DISCUSSION

Primed seeds had better emergence percentage in salt stress in comparison with un-primed seeds. It is obvious that metabolic activities in primed seeds during germination process commenced much earlier than radicle and plumule appearance, so primed seeds emerged earlier than non-primed ones (Hopper et al., 1979). Like emergence percentage, primed seeds had lower mean emergence time (MET) compared with un-primed seeds. These positive effects are probably due to the stimulatory effects of priming on the early stages of germination process by mediation of cell division in germinating seeds (Szabolcs, 1994; Sivriteps et al., 2003). There are several reports that seed priming can homogenize seed germination in a short period of time (Zhu, 2002; Khajeh-Hosseini et al., 2003). The present study also demonstrated that plant height recorded in plants derived from primed seeds were significantly different from plants derived from non-primed treatments when exposed to different salinity levels. Similar results are also reported by Sivritepe et al (2003) in melon. It was observed that boosting levels of salinity has gradually decreased plant height which might be due to decreased physiological activities resulting from water and nutrients stress occurring under salinity stress. The adverse effect of salinity on plants may lead to disturbances in plant metabolism, which consequently led to reduction of plant growth and productivity (Shafi. et al. 2009). Seed priming and salinity levels extensively affected shoot fresh and dry weight (g $plant^{-1}$) of coriander. Shoot weight decreased progressively with the rise of stress level compared with control. Fortmeier and Schubert (1995) also reported similar results in barley.

The toxic effect of sodium at high salt levels and physical damage to roots decreased their ability to absorb water and nutrient which caused marked reduction in photosynthesis, enzymatic process and protein synthesis (Tester and Davenport, 2003), which resulted in stunted growth and poor leaf area development. The decrease in the rate of photosynthesis due to leaf area might be responsible to decrease shoot fresh and in turn dry weight. It is evident from results that primed seeds in comparison with control seeds resulted in more crop growth rate (Basra et al., 2003). Therefore, it is concluded that seed priming improve coriander growth under salt stress. These results agree with the finding of Harris et al. (2001) and Basra et al. (2003). They reported greater plant weight following seed priming.

Similarly, the effect of priming with $CaCl_2$ improved the quantity and quality of germination. These results are consistent with those found by Iqbal et al. (2006); Ashraf and Rauf, (2001) working on wheat (*Triticum aestivum* L.).

NaCl salinity affects ion transport processes in plants, which may change the nutritional status and ion balance (Läuchli and Epstein, 1990). Under salt stress, plants have evolved complex mechanisms allowing for adaptation to osmotic and ionic stress caused by high salinity. These mechanisms include the lowering of the toxic ions concentration in the cytoplasm by restriction of Na^+ influx or its sequestration into the vacuole and/or its extrusion (Hajibagheri et al. 1987). The results of the present study showed that NaCl treatments caused an increase in Na^+ concentration and Na^+/K^+; Na^+/Ca^{2+} ratios, and a decrease in K^+ and Ca^{2+} concentrations of coriander shoot derived from both primed and non-primed seeds (Table 2). Previous studies showed similar effects of salinity in melon (Botia et al. 1998) as well as in celery (Pardossi et al. 1999), pepper (Chartzoulakis and Klapaki, 2000) and tomato (Romero et al. 2001). However, seed priming induced avoidance of coriander shoot from toxic and nutrient deficiency effects of salinity on growth because of less Na^+ but more K^+ and especially Ca^{2+} accumulation. In fact, numerous studies indicated that an increase in the concentration of Ca^{2+} in plants challenged with salinity stress could ameliorate the inhibitory effects on growth (Navarro et al. 2000; Kaya et al. 2002). Na^+/K^+ and Na^+/Ca^{2+} balances of seedlings derived from the primed seeds were significantly lower than those of the non-primed seeds under similar salinity levels. These results suggested that seed priming of coriander seeds increased salt tolerance by promoting K^+ and Ca^{2+} accumulation.

5 CONCLUSIONS

The results of this experiment showed that NaCl and $CaCl_2$ seed priming improves emergence, growth and mineral parameters of coriander. This method is simple, cheap and it does not require any special equipment, so farmers can use it to increase percent and homogeneity of emergence of plants under environmental stresses. Further, this study needs to investigate the effects of seed priming on later growth and yield stages of this plant. In addition, coriander is appreciated for its essential oils biochemical analysis of different plant organs (stems, roots, seeds) would be recommended to evaluate the effect of seed priming on qualitative and quantitative parameters of these oils.

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