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Full Length Research

The effect of salinity priming on germination and growth stage of Cumin (*Cuminum cyminum* L.)

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Salinity stress is one of the most important environmental stresses limiting economic gains from land to produce plants and crops. In this regard, an experiment was conducted to study salinity priming as an interesting strategy for increasing the salt tolerance and its effect on seed germination and growth of Cumin (*Cuminumcyminum*). This study was carried out using a Factorial experiment based on RCD design with 3 replications to determine the influence of priming (0, 0.5, 1 M NaCl solution for 24 hours at room temperature and control with distilled water) and osmotic potentials (0, -2, -4, -6, -8, -10 bar) on germination of Cumin plants. These researches were conducted in two separate experiments both in laboratory and greenhouse. The results indicated that seed priming treatments significantly increased germination percentage, seedling weight, germination rate, root length and plumule length. The results also showed that K^+, Mg^{2+} andCa^{2+} concentration significantly increased in P2, P3 (0.5, 1 M NaCl) with increasing salinity levels and Na^+ concentration decreased in seedling in primed seeds. To determine the influence of Salinity priming (0, 0.5, 1 M NaCl solution for 24 hours at room temperature and control with distilled water) and different salinity stress (0, 3, 6, 9, 12 ds/m) on cumin growth stages, an experiment was carried out in greenhouse condition. The results also indicated that seed priming treatments were significantly increased dry matter accumulation and relative growth rate (RGR). Furthermore the results indicated that K^+, Ca^{2+} and Mg^{2+} concentration significantly increased in P3 (1M NaCl) and Na^+ concentration decreased in seedling in primed seeds compared with non-primed seeds. These results suggest that the use of NaCl pre-treatments could be a useful strategy to increase the salt tolerance of cumin plants in the long-term and to permit the establishment of cumin crop by direct sowing in a saline medium.

Key words: Dry matter, Relative growth rate, Germinationpercentage.

INTRODUCTION

According to the studies of Ben-Salah et al. (2011) 7% of the world lands is saline and 3% is high saline. Because of low precipitation, high evaporation and irrigation by saline waters, soil salinity is growing getting increased (Teimouri *et al*., 2009). Salinity is regarded as one of the major and increasing problems in agricultural system in Iran. Soil salinity is among environmental tensional factors that make problems for plants in terms of nutrition and metabolic processes further to disordering and decreasing water absorption by roots (Alebrahim *et al*. 2004). The most important problems facing the economic crops production in arid regions are high concentration of ions especially NaCl that is present either in soil or water (Moeinrad, 2008). The adverse effects of high concentration of salts on plants are due to the osmotic retention of water and the specific ionic effects on the

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protoplasm. Water is osmotically held in salt solutions, so as the concentration of salt increased water becomes less and less accessible to the plant. Poor germination and seedling establishment are the results of soil salinity (Akramghaderi *et al*., 2002). It is a major problem adversely affecting growth and development of crop plants and results in to low agricultural production (Gargand Gupta, 1997). Salt and osmotic stresses are responsible for either inhibition or delayed seed germination and seedling establishment (Almansouri *et al*., 2001). Under these stresses circumstances there is a decrease in water uptake during imbibition. Furthermore salt stress may cause excessive uptake of ions (Murillo-Amador *et al*., 2002). Recently, medicinal and aromatic plants have received much attention in several fields such as agro alimentary, perfumes, pharmaceutical industries and natural cosmetic products (OlfaBaatour *et al*., 2009). Numbers of medicinal plants in arid and semi arid regions of the country are produced. Cumin is one of the most important medicinal plants of the apiaceae family and one of the commercial products in Iran for exports (Kafi, 2002). Considering the specific ecological conditions required for the cultivation of this plant some of its important features and characteristics have made it necessary and economical to cultivate. Among them, the followings worth mentioning here: short growing season of 120-100 days, little water requirement, no interference with the growth of other crops grown in the growing season (Kafi, 2002). It contains 7% tannin, 13% oil, and 2.5 to 4% resin and essence (Zargary, 2001). Researches have shown that germination of plant will, either in tissue culture or cultivation, decrease with the increase of salinity. Hassanzadehdelouei *et al*. (2013) studied the effect of salt stress in different stages of growth on qualitative and quantitative characteristics of cumin. The results showed that the salinity had significant impact on fresh weight, dry weight, height, percentage of essence, seed and biological yield. With the increase in salinity from 2 to 11ds/m, all vegetative and reproductive characteristics were decreased significantly. The most sensitive growth stages of plant to salt stress, during vegetative and reproductive period were the stage of establishment and flowering, respectively. There was no interactionbetween the growth stage of plant and salinity rate, except for seed yield and harvest index. Roodbari *et al*. (2013) studied the effect of salinity stress on germination and seedling growth of cumin. Results showed that salt stress decreased biomass of primary shoots, roots and germination percentage and other physiological factors in the stage germination. There was no significant difference in treatments regarding means variation of fresh weight and root length. However, different salinity levels had an effect on dry weight, shoot length, root/shoot ratio with $P<0.05$. Tatari and Abbasi (2004) having applied different levels of salinity and using different periods of irrigation, studied the growth and production of cumin in Mashhad, and concluded that growth and biologic indices of cumin decrease with the increase of salinity rate. Seed priming has successfully demonstrated to improve germination and emergence in seeds of many crops, particularly seeds of vegetables and small seeded grasses (Bradford, 1986; Demir Kaya *et al*., 2006; Murungu *et al*., 2003). Seed priming was defined as pre-sowing treatments in water or in an osmotic solution that allows seed to imbibe water to proceed to the first stage of germination, but prevents radicle protrusion through the seed coat (McDonald, 1999). Various reports indicated that priming increases of speed and uniformity of germination and seedling emergence (Murungu *et al*., 2003; Demir and Vande venter, 1999; Demir Kaya *et al*., 2006; Ashraf and Rauf, 2001). It is also reported that these techniques increase seed germination in the range of stress conditions, such as salinity, drought and temperature (Fuji Kara *et al*., 1993; Wall *et al*., 2003; DemirKaya *et al*., 2006; Ashraf and Foolad, 2005). The most important priming treatments are halopriming. Halopriming is a pre-sowing soaking of seeds in salt solutions, which enhances germination and seedling emergence uniformly under adverse environmental conditions. Previous work (Afzal *et al*., 2005; Ashraf and Rauf, 2001; Basra *et al.,* 2006; Roy and Srivastava, 2000) suggested that the adverse and depressive effects of salinity stress on germination can be alleviated by various seed priming treatments.It has also been demonstrated that this technique improves performance by plants (Harris *et al*., 2001). Hus and Sung (1997) and Bailey (1997) reported that priming increased enzymatic antioxidants such as glutathione and ascorbate. The seed of the enzyme activity reduce lipid peroxidation during germination and increased germination. There are numerous reports regarding the effect of priming on germination and emergence at the different plants (Murungu *et al*., 2003; DemirKaya *et al*., 2006; Ashraf and Rauf, 2001). Soybean seed priming increased the number of seeds in plants and reduced seed loss but no any effect on grain weight (Eleiwa 1989).Cotton seed soaking in a solution of superphosphate increased the number of open boll. Similarly in wheat seed treated with a mixture of soluble saltswith different concentrations of salinity significantly increased total chlorophyll, chlorophyll a and b, and the ratio of chlorophyll b; a comparison with untreated plants obtained from seeds showed (Roy and Srivastava, 2000). Although the effects of priming treatments on germination of some seed crops have been studied, but relatively little information is available on the invigorating of cumin seed under salt stress. The aim of this study is to evaluate whether priming with salt solution (NaCl) results in enhancement of seed vigour, germination, growth parameters and yield in cumin (*Cuminum cyminum*) under a range of osmotic potentials due to NaCl. Further to realize whether responsible factors for failure of Cumin seed germination under saline condition is an osmotic blockade or is due to toxic effects of NaCl.

MATERIALS AND METHODS

Seeds of Cumin were used for this study. Seed pre-treatments consisted of P1: distilled water (untreated seeds), P2: 0.5 M , P3: 1 M solution of NaCl for 24 h. Priming treatments were conducted at 25±1°C in the dark separately and re-dried up to original weight with forced air under shade following Basra et al. (2006) procedure. Germination and early seedling growth were studied using distilled water (control) and under osmotic potentials of 0, -2, -4, -6, -8, -10 bar by NaCl. Referred osmotic potential of NaCl solution (-2, - 4, -6,-8 and -10 bar) were prepared by using of 2.62, 5.25, 7.87, 10.5 and 13.12 g/l. NaCl concentrations had the electrical conductivity (EC) values of 0, 3, 6, 9 and 12 ds/m. After priming stage, the numbers of 25 seeds were sown in Petri dish. Petri dish used in the experiments was thoroughly washed and sterilized (autoclave-sterilized: 121^0C, 15 min, at 103 kpa) (Erowid, 2007). After priming stage, 10ml of each salinity solution was added to each Petri dish. The dish, then, transferred to germinator in appropriate conditions, for cumin, temperature 20±1ºC and photoperiod 16h light and 8h dark (Kafi2002). A seed scored germinated when radicle length reached 2mm or more. Germinating seed were counted daily, and terminated when no further germination occurred.

Germination percentage (GP) was calculated using the following formula:

GP= [Total seeds germinated (when no further germination occurred)/Total number of seeds] × 100

Mean germination time (MGT) which expressed as speed of germination was calculated using the following modified formula:

$$MGT=\sum NiTi / \sum Ni$$

Where *Ti* is the number of days after sowing, *Ni* is the number of seeds germinated on *i* the day.

Mean shoot and root lengths at the end of germination were measured per replication. Dry weights of seedlings were taken with the help of an electric balance after drying each replication at 70°C in the oven to get the constant weight (Afzal *et al*., 2005). The experimental design was two factors factorial (3×6) based on completely randomized design (CRD) with three replications. First factor was priming (NaCl), the second factor was osmotic potential levels (0, -2, -4, -6, -8, -10 bar). Data collected were subjected to analysis of variance (ANOVA) and the significant means were separated with the Duncan's multiple range tests using SAS (2005).In greenhouse, the experiment was performed for 67 days. The Hoagland's solution (Hoagland, 1948) used in this study. The cumin seeds planted in pots filled with sterilized perlite. These pots placed under a controlled environment greenhouse with day/night temperatures of 30–25 8C, 30–35% relative humidity and a 16h photoperiod. All the experimental seedlings received Hoagland's nutrient solution (macro- and micronutrients). In this experiment in order to study the effect of priming in yield and quality characteristics of cumin, the amount of dry matter was harvested in 5 stages and K, Na, Mg, Ca concentration, relative growth rate in 4 stages.

RESULTS

Laboratory results

Root length

In this study, the effect of salinity, priming salinity and interaction between them on root length was statistically significant at 1% level (Table 1). The comparison of means by Duncan's method showed that the root length decreased by increasing in osmotic potential. The highest level of priming treatments on root length was P2, the salinity was T2and their interactions were P2T2 (Table 2).

Shoot length

The results showed that primed and salinity levels were highly significant, but no significant interaction between prime and salinity was observed for shoot length (Table 1). Maximum shoot length at different levels of primed and salinity were observed in P2 and T2, respectively (Table 2). The results suggested that pretreatment of salt 0.5 M NaCl can greatly reduce the negative effects of salinity on shoot and root length. Results also showed that the interaction effect of priming seeds before planting the decreased sensitivity to salinity stress is the root and shoot length. Research in this field (Tatari and Abbasi, 2004; Roodbari *et al*., 2013; Hassanzadehdelouei *et al*., 2013) in wheat, canola and cumin showed that with the increasing salinity, root length and shoot length decreases. However, it is concluded that the sensitivity to salinity in root length is higher than shoot length. It can be interpreted that the sodium chloride affects ion-induced osmotic stress and tension, and ions may pass through the membrane and this is how it may affect root growth (Baalbaki *et al*. 1999; Fujikura *et al*., 1993).

Seedlings weight

Analysis of variance and mean comparison showed that the prime levels, salinity and their interactions were statistically significant at 1% level (Table 1). Maximum weight per seedling was recorded in P2, T2 and P2T2, respectively (Tables 2 and 3). As germination, root and shoot length, seedling weight was significant in P2 than

Table 1. Factorial analysis of the seed priming effect and salinity on germination and growth of cumin (under different levels of osmotic potential induced by NaCl.

Source of variance	Degree of freedom	Root length seedling	Shoot length seedling	Seedling weight	Germination percentage	Mean Time Germination	K	Na	Ca	Mg
Priming (a)	2	0.814**	2.82**	1052.45**	408.65**	15.18**	5.24**	4.71**	1.0001**	0.019**
salinity (b)	5	6.05**	14.64**	2128.41**	8966.46**	19.49**	4.09**	8.99**	0.00006**	0.006 ^{ns}
Interaction a × b	10	0.26*	0.11 ^{ns}	46.19**	55.1**	0.24 ^{ns}	0.42**	0.63*	0.00002**	0.002 ^{ns}
Error	36	0.29	0.41	1.39	3.88	0.367	0.18	0.52	0.001	0.024
c.v. %	-	15.59	14.11	3.97	7.52	11.73	10.77	27.95	7.6	24.78

*P < 0.05; **P < 0.01; Ns: not significant

Table 2. Comparison of treatments on cumin seedling growth parameters.

	Treatment	Root length Seedling (cm)	Shoot length Seedling (cm)	Seedling Weight (gr)	Germination percentage	Mean Time Germination	K	Na	Ca	Mg
Priming	P1	1.68b	2.64b	29.55c	47.5c	4.1a	1.1b	2.04a	0.01c	0.06b
	P2	2.09a	3.39a	43.82a	56.81a	2.28c	2.01a	1.28b	0.016a	0.116a
	P3	1.79b	2.79b	31.92b	50.5b	2.3b	2.06a	2.26a	0.014b	0.118a
salinity	T1	2.38b	3.72b	49.34b	93.33a	1.23f	1.61c	0.6d	0.009e	0.04b
	T2	2.9a	4.37a	54.51a	82.66b	1.7e	2.68a	1.16c	0.011d	0.1a
	T3	2.33b	3.84b	38.42c	57c	2.88d	2.08b	1.28c	0.015b	0.11a
	T4	1.61c	2.66c	31.88d	37.33d	3.61c	2.03b	2.18b	0.013c	0.11a
	T5	1.22d	2.03d	20.62e	20.77e	4.35b	1.05d	2.91a	0.015b	0.093a
	T6	0.71e	1.008e	15.81f	18.55e	4.97a	0.91d	3.03a	0.016a	0.108a

Priming	P1	1.68b	2.64b	29.55c	47.5c	4.1a	1.1b	2.04a	0.01c	0.06b
	P2	2.09a	3.39a	43.82a	56.81a	2.28c	2.01a	1.28b	0.016a	0.116a
	P3	1.79b	2.79b	31.92b	50.5b	2.3b	2.06a	2.26a	0.014b	0.118a
salinity	T1	2.38b	3.72b	49.34b	93.33a	1.23f	1.61c	0.6d	0.009e	0.04b
	T2	2.9a	4.37a	54.51a	82.66b	1.7e	2.68a	1.16c	0.011d	0.1a
	T3	2.33b	3.84b	38.42c	57c	2.88d	2.08b	1.28c	0.015b	0.11a
	T4	1.61c	2.66c	31.88d	37.33d	3.61c	2.03b	2.18b	0.013c	0.11a
	T5	1.22d	2.03d	20.62e	20.77e	4.35b	1.05d	2.91a	0.015b	0.093a
	T6	0.71e	1.008e	15.81f	18.55e	4.97a	0.91d	3.03a	0.016a	0.108a

Table 2. Contd.

	Treatment	Root length	Shoot length	Seedling weight(gr)	Germination percentage	Mean Time Germination	K	Na	Ca	Mg
Priming * salinity	P1T1	1.95ef	3.33g	41.22f	93ab	1.77h	1.22def	3.29c	0.009hi	0.031j
	P1T2	2.48bcd	3.91ed	52.3c	77d	2.66g	2.6ab	1.76b	0.011fg	0.033ij
	P1T3	2.2de	3.68ef	30.91h	51f	4.02cde	1.23def	1.73b	0.011fg	0.062ghij
	P1T4	1.55fg	2.41i	22.84j	33hi	4.4c	0.99f	1.88b	0.01gh	0.084efgh
	P1T5	1.25gh	1.61k	17.17l	15j	5.53b	0.36g	3.58a	0.01gh	0.077fgh
	P1T6	0.7i	0.92l	12.88n	16j	6.23a	0.23g	3.01a	0.008i	0.073fghi
	P2T2	3.48a	5.01a	67.3a	84c	0.87j	2.61ab	0.57c	0.012ef	0.123bcde
	P2T1	2.91b	4.42b	59.23b	94a	0.82j	1.4d	0.28c	0.011fg	0.055ghij
	P2T3	2.77bc	4.14cd	46.66d	63e	1.73h	2.76a	0.34c	0.015d	0.13abcd
	P2T4	1.68fg	2.94h	41.28f	41g	2.76g	2.45bc	1.7b	0.018b	0.13abcd
	P2T5	1hi	2.41i	27.82i	27i	3.46ef	1.48d	1.87b	0.017bc	0.11cdef
	P2T5	0.75i	1.41k	20.64k	32hi	4.12cd	1.4d	2.94a	0.023a	0.14abc
	P3T1	2.29cde	3.42fg	47.56d	93ab	1.09ij	2.22c	1.23bc	0.008i	0.04hij
	P3T2	2.74bc	4.19bc	43.93e	87bc	1.67hi	2.84a	1.15bc	0.0118efg	0.17a
	P3T3	2.03def	3.72e	37.69g	57ef	2.91fg	2.27c	1.77b	0.019b	0.16ab
	P3T4	1.6fg	2.64i	31.53h	38gh	3.66de	2.65ab	2.97a	0.013e	0.12abcd
	P3T5	1.41gh	2.07g	16.68l	13.67j	4.08cde	1.31de	3.29a	0.017c	0.09defg
	P3T6	0.7i	0.69l	13.93m	14.33j	4.57c	1.09ef	3.14a	0.019b	0.1cdef

Mean separation by Duncan's Multiple Range Test at P = 0.05. The same letters within a column are not significantly different.

the other treatments. It showed positive effect of salinity priming on germination, vigour and strength of cumin. Researches in this field (Tatari and Abbasi, 2004; Roodbari *et al*., 2013; Hassanzadehdelouei *et al*., 2013) in cumin showed that with the increasing salinity, seedling weight decreases. Abbasdokht (2011) in wheat showed that hydroprimed seeds achieved maximum germination seedling dry weight, especially during the higher osmotic potentials. Minimum germination was recorded at untreated seeds (control).

Mean time germination

The priming effect of salinity and priming salinity on mean time germination was statistically significant at 1%level (Table 1). The highest mean germination time in the primed and salinity related to P1and T6 respectively. There was no significant difference in the interaction between them (Table 2). Salinity priming did not have positive impact on germination speed at different levels of salinity. Similar observations were also made by Abbasdokht (2011) and Toselli and Casenave (2003).

Germinationpercentage

The salinity priming effect, salinity and interactions between them on germination percentage was statistically significant at 1%level (Table 1). The comparison showed that the highest percentage of germination in different levels primed, salinity and interaction between them was P2, T1 and P2T1, respectively (Table 2). These results

Table 3. Factorial analysis of the seed priming effect and salinity on growth stage in greenhouse

Source of variance	Degree of freedom	DM1	DM2	DM3	DM4	DM5	K	Na	Ca	Mg	RGR1	RGR2	RGR3	RGR4
Priming (a)	2	0.00002 ^{ns}	0.000009**	0.00021**	0.0004**	0.00003 ^{ns}	0.026*	1.06**	0.077**	0.078**	0.0001**	0.00005**	0.00001**	0.0003**
salinity (b)	4	0.000009 ^{ns}	0.00069**	0.0035**	0.0092**	0.013**	0.129**	3.92**	0.043**	0.083**	0.0025**	0.002**	0.001**	0.0002**
Interaction a × b	8	0.00004**	0.00003 ^{ns}	0.00006 ^{ns}	0.00016**	0.0001 ^{ns}	0.011 ^{ns}	0.38*	0.0018 ^{ns}	0.0019 ^{ns}	0.00008**	0.00004**	0.00003**	0.0001**
Error	45	0.002	0.0041	0.0055	0.0068	0.008	0.076	0.39	0.039	0.058	0	0	0	0
c.**v**. %	-	8.66	8.93	9.28	9.33	9.61	26.29	42.25	18.32	28.53	0.000001	0	0	0

*P < 0.05; **P < 0.01; Ns: not significant

correspond with the results achieved by Nabizadeh *et al*. (2004), Tawfik and Noga (2001) and Davazdah Emami and Mazaheri (2009) about cumin. Haigh (1988) in the experiments on tomato reported that priming resulting absorption of water faster, development of cell wall root and loosening of the endosperm and thus increase the percentage of germination. Seed priming with inorganic salts may cause significant changes in the activity of enzymes involved in seed germination. For example, melon seeds that were soaked in a solution of KNO_3 increased dehydrogenase and alpha-amylase activity under low temperature conditions (Singh *et al*., 1999).

The concentration of elements

Analysis of variance of the effects of primed, salinity and the interaction between primed and salinity in different values of K^+, Na^+, Mg^{2+} and Ca^{2+} was significant. K and Ca were significant at 1% for the effects of primed, salinity and the interaction between them. But Na was significant at 5% for the interaction between primed and salinity. Mg was significant at 1% for the effects of primed (Table 1). Duncan comparison showed that the highest amount of potassium in the prime, at different levels of salinity and the interaction between them were level (P2 and P3), level (P2), and (P2T3, P3T2), respectively (Table 2). The highest concentration of Sodium of the prime and salinity was Levels 3 and 6 (Table 2). The highest amount of magnesium in prime and salinity was levels 2 and 3, respectively (Table 2). The highest amount of calcium in the prime was level 2, the lowest was level 1. The highest and the lowest amount of calcium in salinity treatments was Level 6 and 1 (distilled water), respectively. The highest amount of calcium in interaction effects of salinity and primed was P2T6 (Table 2). In embryos of wheat under salt stress small quantities of K^+ (Patel *et al*., 1991) has been found. In addition, there are reports that Ca^{2+}, Mg^{2+} and K in seed plants have been grown under the salt stress (Ashraf and Rauf, 2001; Kent and Lauchli, 1985). Thus, increasing the concentration of Ca^{2+}, Mg^{2+} and K^+ in the primed seeds of cumin by salt can be one of the reasons for sprouting the seeds. In contrast, the pea seed priming with salts of Ca and Na salts did not improve the germination of treated seeds compared with distilled water (Guerrier 1988).

Greenhouse results

Dry matter harvested at different stages

Table of the Results of analysis of variance showed that the interaction between prime and salinity on dry matter harvested in the first stage (DM1) is quite significant and the maximum rate belonged to P2T1 (Prime 0M and salinity 9ds/m). Dry matter harvested in the second, third and fourth (DM2, DM3 and DM4)(Figure 1) and the prime levels and levels of salinity showed significant differences at 1%. But the interaction effect was highly significant only in the fifth stage DM5 (Table 3 and Figure 2). Highest dry matter harvested in the second, third and fourth levels of priming was (P2) and the highest mean in salinity treatments was at T1 and T2 (distilled water andsalinity 3ds/m) and minimum mean harvest was the treatment of T5 (salinity 12ds/m). Interactions found that the highest dry matter harvested was related to the fourth stage P2T1 and P2T2 and the lowest dry matter harvested at

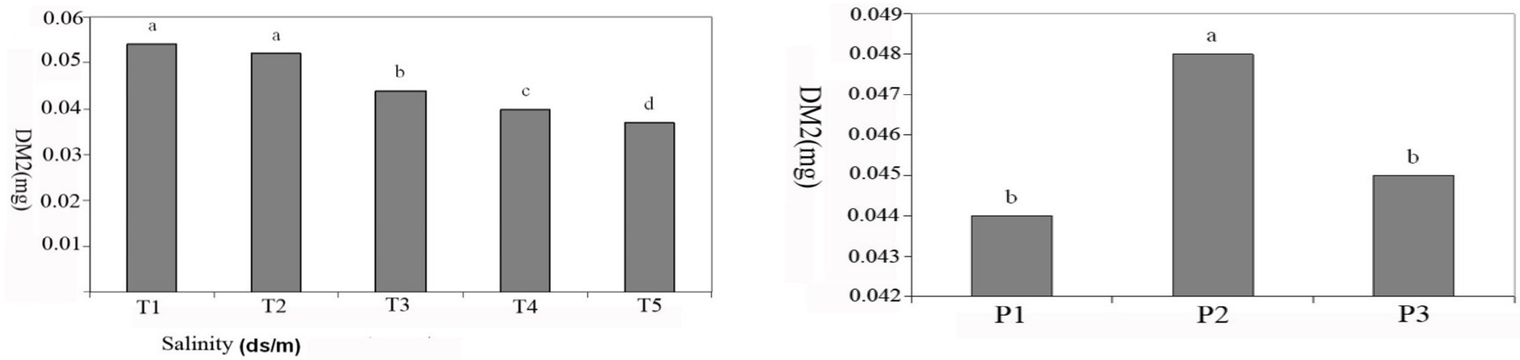

Figure 1. The effect of salinity (NaCl) and priming in dry matter of the second stage of harvest (DM2) in cumin.
Figures not sharing same letters differ significantly at P=0.05, (DM2at each osmotic potential is average of all seed treatments).

Table 4. Comparison of treatments in growth stage in greenhouse on cumin seedling.

	Treatment	DM1	DM2	DM3	DM4	DM5	RGR1	RGR2	RGR3	RGR4	K	Na	Ca	Mg
Priming	P1	0.034ab	20044b	0.57b	0.07b	0.081a	0.024c	0.022c	0.018b	0.012b	0.25b	1.18a	0.15c	0.14c
	P2	0.035a	0.048a	0.063a	0.079a	0.083a	0.029a	0.024b	0.0186a	0.005c	0.32a	0.91b	0.27a	0.26a
	P3	0.033b	0.045b	0.059b	0.071b	0.083a	0.0294a	0.025a	0.0168c	0.013a	0.3a	0.72b	0.23b	0.20b
salinity	T1	0.035a	0.054a	0.08a	0.104a	0.12a	0.042a	0.037a	0.026b	0.014a	0.37a	0.17d	0.29a	0.31a
	T2	0.034a	0.052a	0.075a	0.1a	0.11a	0.041b	0.036b	0.028a	0.133b	0.4a	0.62c	0.26a	0.26a
	T3	0.034a	0.044b	0.056b	0.067b	0.77b	0.026c	0.024c	0.017c	0.013c	0.29b	0.97b	0.21b	0.19b
	T4	0.033a	0.04c	0.048c	0.053c	0.057c	0.018d	0.016d	0.011d	0006d	0.22c	1.27b	0.17c	0.14bc
	T5	0.033a	0.037d	0.04d	0.042d	0.044d	0.009e	0.007e	0.006e	0.004e	0.16c	1.65a	0.14c	0.11c

Mean separation by Duncan's Multiple Range Test at P = 0.05. The same letters within a column are not significantly different.

this stage related to P2T5 and P3T5 (Tables 3 and Figure 3). Dry matter content at harvest in fifth stage (DM5), between the salinity levels was significant at 1% level (Table 3) The mean comparison also showed that the highest amount of dry matter harvested in the fifth stage was related to the distilled water and salinity 3 ds/m and the lowest dry matter harvested at this stage related to T5 (salinity 12ds/m) (Table 4).

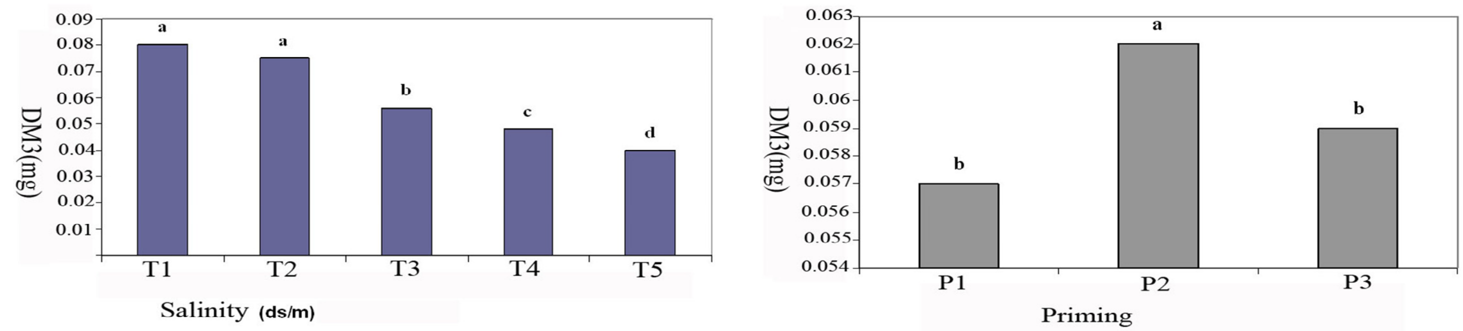

Figure 2. The effect of salinity (NaCl) and priming in dry matter of the third stage of harvest (DM3) in cumin.
Figures not sharing same letters differ significantly at P=0.05, (DM3at each osmotic potential is average of all seed treatments).

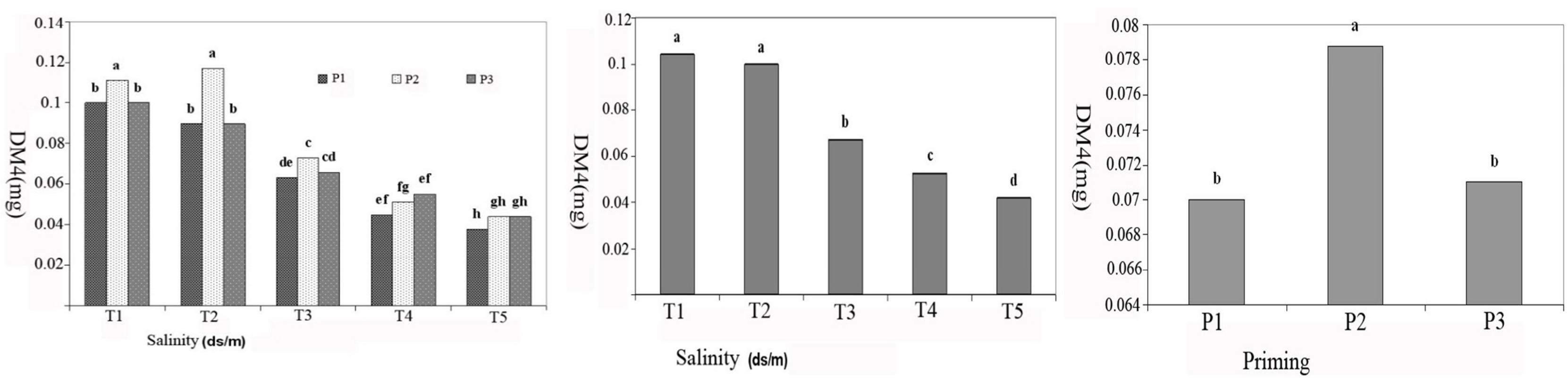

Figure 3. The effect of salinity (NaCl) , priming and interaction between them in dry matter of the fourth stage of harvest (DM4) in cumin.
Figures not sharing same letters differ significantly at P=0.05, (DM4 at each osmotic potential is average of all seed treatments).

The concentrations of elements

Results of the study showed that Na^{+}, Ca^{2+} and Mg^{2+} in different primed and salinity treatments were significant at 1%, but the element K in primed treatments was significant at 5% level and salinity levels at 1% (Table 3). Duncan mean comparison method showed that the greatest and the lowest amount of Sodium were P1 (distilled water) and P3 (Prime 1M), respectively. Also in T5 (salinity 12 ds/m), Sodium content was the highest and T1 (sterile water), Sodium content was the lowest (Table 4 and Figure 4). The maximum amount of potassium based on a comparison of means by Duncan's method related to priming P2 and P3 (Prime 0.5, 1 M), whereas different levels of salinity, the maximum amount related to T1 and T2 (salinity 0 and 3 ds/m) (Table 4 and Figure 5). In greenhouse experiments, changes of magnesium and calcium, in priming, different levels of salinity and their interactions remained

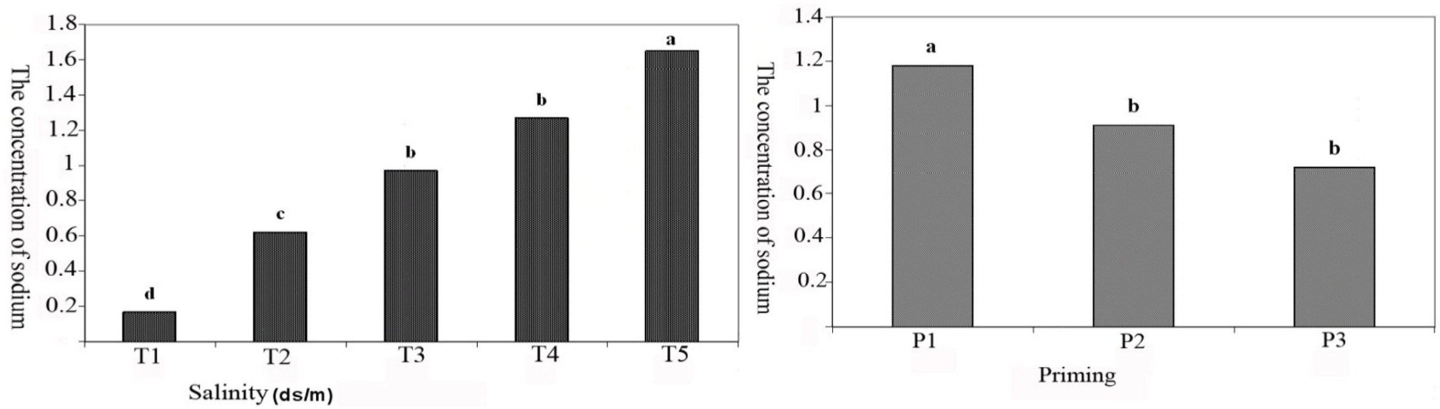

Figure 4. The effect of salinity (NaCl) and priming in the concentration of sodium (Na+) in cumin.
Figures not sharing same letters differ significantly at P=0.05, (Na+at each osmotic potential is average of all seed treatments).

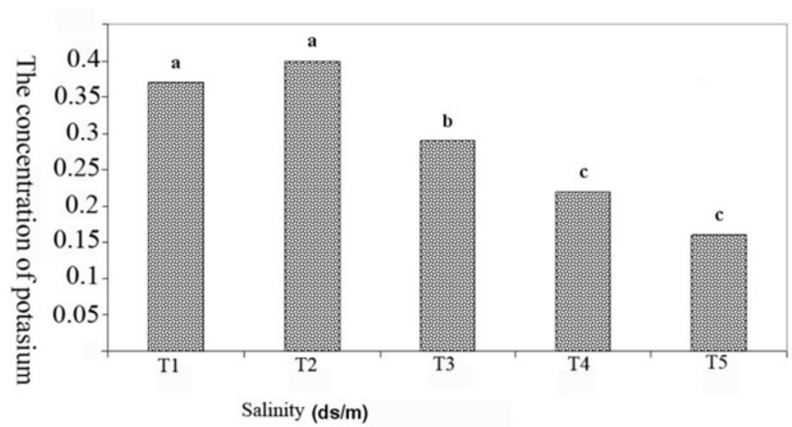

Figure 5. The effect of salinity (NaCl) in the concentration of potassium (K+) in cumin.
Figures not sharing same letters differ significantly at P=0.05, (K+ at each osmotic potential is average of all seed treatments).

almost the same. Maximum amount of priming was P2 (Prime 0.5M) and the salinity was T1 and T2 (distilled water and salinity 3 ds/m) (Tables 3

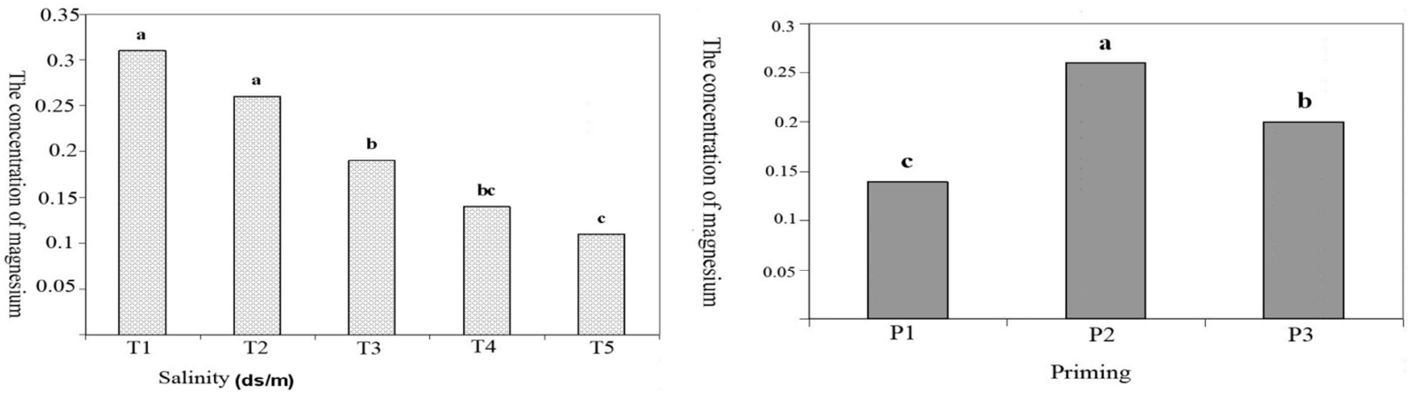

Figure 6. The effect of salinity (NaCl) and priming in the concentration of magnesium (Mg2+) in cumin.
Figures not sharing same letters differ significantly at P=0.05, (Mg2+ at each osmotic potential is average of all seed treatments).

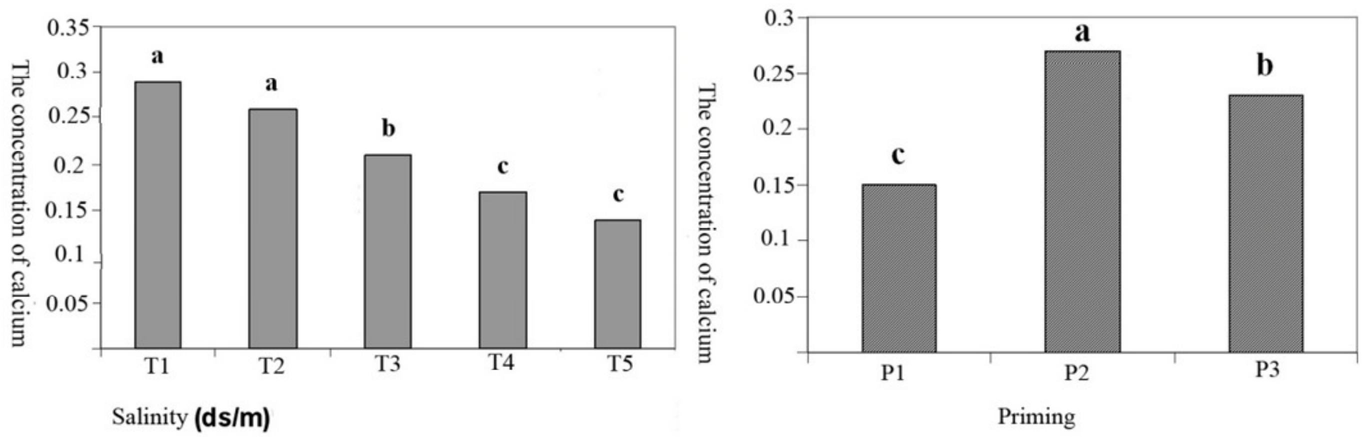

Figure 7. The effect of salinity (NaCl) and priming in the concentration of calcium (Ca2+) in cumin.
Figures not sharing same letters differ significantly at P=0.05, (Ca2+ at each osmotic potential is average of all seed treatments).

and 4 and Figures 6 and 7).

Relative growth rate

Analysis of variance table in relative growth rate (Table 3) showed that all parameters in the primed treatments, salinity and their interactions were significant at 1% level. The maximum amount of relative growth rate (RGR1, RGR2 and RGR4) based on a comparison of means by Duncan's method related to P3 and about RGR3 related to P2. For Salinity treatment the highest value was observed RGR1, RGR2 and RGR4 in T1 and RGR3 in T2. The interaction between salinity treatments and primed, the highest value was observed at RGR1 and RGR2 in P3T1 and P2T2 RGR3 and RGR4 in the P1T1 (Table 4 and Figures 8, 9, and 10). Similar observations were also reported by Abbasdokht (2011) and Toselli and Casenave (2003).

DISCUSSION

Overall, this study found that different levels of salinity have an impact on seed germination, root and coleoptile length, root and shoot dry weight and total dry weight and reduce them. Based on these results, it was found that root growth is more sensitive to salinity.This has been confirmed in other studies on other plants (Baalbaki*et al.* 1999 Toselli and Casenave 2003), too. Thus seed germination and root length may be the best indicator of stress tolerant in plants (Olfa Baatour *et al.*, 2009). The findings of present study are in agreement with the results of Demir Kaya *et al.* (2006) and Basra *et al.* (2006) who reported the primed seeds of sunflower and wheat could germinate faster and produced longer seedling under salinity stress, compared with untreated seeds. Several earlier studies reported that priming can contribute to improve germination rate and seedling emergence in different plant species by increasing the

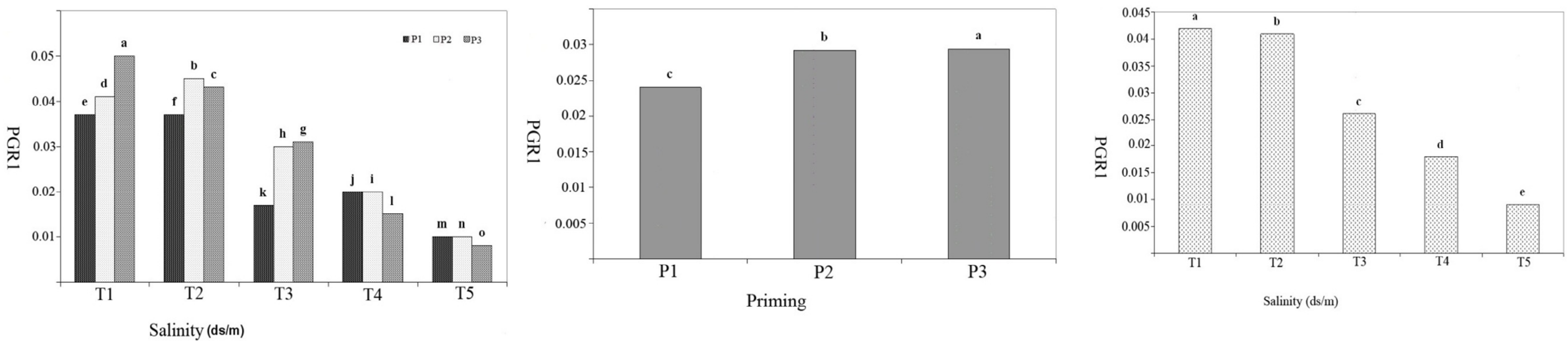

Figure 8. The effect of salinity (NaCl), priming and interaction between them on relative growth rate (RPG) in the first growth phase of cumin. Figures not sharing same letters differ significantly at P=0.05, (PGR1 at each osmotic potential is average of all seed treatments)

expression of aquaporins (Gao *et al*., 1999; Fu *et al*., 1988; Ashraf and Foolad, 2005). In general it can be said in Cumin, salinity priming had a positive effect on germination and root and shoot dry weight, root and shoot length and speed of germination. Salt pretreatment not only increases germination percentage and speed, but also can cause increasing dry matter and growth rate plant. Salinity priming also increased the ability to absorb K^{+}, Mg^{2+} and Ca^{2+} in cumin and reduced Na uptake. In another experiment, it was reported that bean seed priming had a significant increase in major components such as the concentration of sucrose, sugars, carbohydrates, ribonucleic acid, and the K in the stem (Sallam, 1999). The other experiment results showed that the mineral treatment before sowing effect on seed germination affect the metabolic and subsequent growth of plants, and usually increases the performance of plant (Eleiwa, 1989; Sallam, 1999; Metha *et al*., 1979). In general we can say that priming treatments require time and extensive testing. Treatment effectiveness and cost-effectiveness for commercial use must also be considered. Our results suggest that priming could be as suitable, cheap and easy seed invigoration treatment for cumin, especially when germination is affected by salinity. The results of priming among species, varieties, and seed have been variable (Heydecker, 1977). Because of this variability in response, Bradford (1986) has suggested that treatment conditions must be optimized for each seed.

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