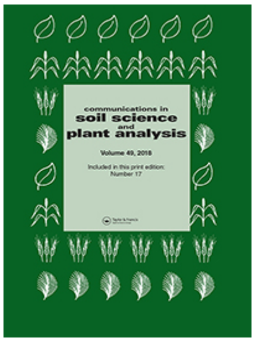

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Alleviation of Salinity Stress by Vermicompost Extract: A Comparative Study on Five Fennel Landraces

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ABSTRACT

In the present study, interaction between salinity (0, 40, 80, 120 mM NaCl) and vermicompost extract (VCE) on five fennel landraces (Urmia, Mashhad, Shiraz, Boushehr, Isfahan) was investigated in a factorial experiment as completely randomized design to find the best salt-tolerant landrace and potential alleviating role of VCE. Results showed that Boushehr and Isfahan were the most tolerant and sensitive landrace to salinity, respectively. Application of VCE improved germination and growth of salt-treated fennels. The amylase activity of fennels was not affected by salinity and not improved by VCE. While sodium (Na^+) content of root and shoot of all salt-treated fennels increased, their potassium (K) content decreased. Under salinity stress, root K content of VCE-amended landraces was more than that of not amended ones. VCE also caused an increase in calcium (Ca) content of root of salt-treated Shiraz and Urmia landraces. In conclusion, VCE can alleviate adverse effects of salinity stress on fennel.

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Compost; fertilizer; salinity; vermicompost

Introduction

Fennel (*Foeniculum vulgare* Mill) from Apiaceae family is a medicinal plant grown in different regions of the world such as Europe, China, India, Pakistan, and Iran. Fennel is a biennial or perennial herb having feathery leaves and golden yellow flowers, with a maximum height of 2 m. Different parts of this plant including seeds, foliage, roots, and even pollen can be used for many pharmaceutical, cosmetic, and food goals (Bahmani et al. 2015), such as perfume industry, spices, and vegetable (Barros, Carvalho, and Ferreira 2010; Edoardo, Curcuruto, and Ruberto 2010).

Salinity is one of the major abiotic stresses in worldwide adversely affecting soil fertility and plant growth and production (Zhang and Shi 2013). The total area of salt-affected soils is estimated to be about one billion hectares (Toth, Montanarella, and Rusco 2008). Salinity can affect plant growth and development due to the nutrient disruption, induction of ion toxicity and/or low water potential (Hafsi et al. 2007; Taiz and Zeiger 2010). The ability of germination and early growth of seedling in saline soil is the most important stage for surviving under such conditions (Rejili et al. 2009). The application of organic composts in recent years has been a common way to improve the farmlands affected by salt stress (Lakhdar et al. 2009).

Vermicompost is an organic compost containing aerobic microorganisms such as acetobacter, and is free from anaerobic bacteria, fungi, and pathogenic microorganisms. It also contains humate, one of the humic substances having the effects similar to plant growth regulators. The improvement of the plant growth by vermicompost containing humic and organic substances is more than that induced by inorganic composts (Atiyeh et al. 2002). Having a high content of macro- (such as nitrogen, phosphorus, potassium, calcium, and magnesium), and micro-nutrients (such as iron, zinc, copper, and manganese),

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compared with other organic composts, is another benefit of vermicompost (Atiyeh et al., 2000). Production and use of VCE have expanded rapidly in recent years (Edwards et al. 2007). VCE has beneficial microbial and chemical properties of its solid form. According to the researches on some plants such as common bean (*Phaseolus vulgaris* L.) and sunflower (*Helianthus annuus* L.), vermicompost can alleviate the adverse effects of salinity (Beykkhormizi et al. 2016; Rafiq and Nusrat 2009).

Besides an increased demand for fennel due to its many beneficial uses, since it has been reported that fennel is a moderately sensitive plant to salinity (Semiz et al. 2012), it is necessary to identify the landraces with high yield and more tolerant to salinity. It also needs to find a way to help this plant to tolerate salt condition. On the other hand, since Iran is one of the main producers of fennel (Bahmani et al. 2015) and its most plant habitats and agricultural lands is saline soil (Akhani 2004), this study was conducted to investigate: 1- The response of some fennel landraces to different level of salinity, and 2- Alleviating role of VCE in such conditions.

Materials and methods

Culture and treatment condition

For investigating the interaction between salinity stress and vermicompost extract (VCE) on growth of five landraces of fennel (Urmia, Mashhad, Shiraz, Boushehr, and Isfahan), a factorial experiment with four salinity levels (0, 40, 80, 120 mM sodium chloride (NaCl)) and two VCEs (0 and 10 percent) was conducted as completely randomized design with three replicates. For preparing VCE, it was mixed with distilled water in the ratio of 1:4 (Greytak, Edwards, and Arancon 2006). After shaking for 24 h, the resulting mixture was filtered with a cleaning cloth and then 10 percent extract was prepared with adding distilled water. Chemical analysis of the vermicompost used for preparing extract is shown in Table 1. VCE (or distilled water for control) was used to prepare different concentrations of NaCl, accounting for experimental treatments.

Each experimental unit was a Petri dish with a filter paper placed on its floor, containing 5 ml of corresponding treatment, and 50 seeds placed on filter paper. Before placing in Petri dishes, seeds of different landraces were sterilized with 1% sodium hypochlorite for 3 min, and washed with distilled water. Petri dishes were sealed with Parafilm and placed in a germinator at 25°C under dark condition. The number of germinated seeds was recorded each day. After one week, amylase activity of 20 germinated seeds was measured according to Freehold (1972) and then Petri dishes containing the remaining seeds were again sealed with Parafilm and placed in the same condition.

Two weeks after culturing, the growth traits of the seedlings were investigated. For determining dry weight, seedlings root and shoot were oven-dried at 70°C for 48 h. Sodium (Na), calcium (Ca), and potassium (K) contents of root and shoot were measured with a flame photometer (Chapman and Pratt 1982). Germination rate and percentage were calculated according to the following equations (Piper et al. 1996):

$$\text{GR}(\text{Germination rate}) = \frac{\sum \text{Gi}}{\sum \text{Gi Ni}}$$

$$\text{GP}(\text{Germination percentage}) = \frac{\sum \text{ni}}{\sum \text{N}} \times 100$$

where: Gi = number of germinated seeds in day of i; Ni = number of day; ni = number of germinated seeds after 14 days; N = total number of seeds.

Table 1. Chemical characteristics of vermicompost.

Properties	Mn	Cu	Zn	Fe	Na	Mg	Ca	K_2O	P_2O_5	N
content	488 ppm	31.2 ppm	127 ppm	1.52%	0.42%	1.89%	5.2%	1.59%	2.22%	1.54%

Statistical analysis

Data were analyzed with MSTAT-C software (MSTAT, Eastl Lansing MI). All data were recorded as mean± standard deviation (SD). Significant differences were determined at $p \leq 0.05$. Duncan's multiple range test was used for means comparison.

Results

GP and GR

Results showed that GP of Mashhad, Shiraz, and Boushehr landraces was not significantly affected under 40 and 80 mM sodium chloride (NaCl), compared to the controls. However, it was significantly increased in Boushehr seeds under 40 mM, and decreased in Isfahan landrace under 40 and 80 mM, and Urmia landrace under 80 mM. Under 120 mM NaCl, GP of all landraces was significantly decreased, except for Boushehr (Table 2).

The results of GR under different levels of salinity, compared to the control, was similar to those of GP, except that in Mashhad and Shiraz landraces it was significantly decreased under 80 mM NaCl. Overall, under salinity stress, seeds of Boushehr landrace had the highest GR compared to other landraces (Table 2).

Results of interaction between VCE and salinity showed that GR and GP of fennel seeds under such condition were higher than those treated with the same levels of salt stress but not amended with VCE, except for Isfahan landrace. Here, the most affected landrace was Shiraz (Table 2).

Length and dry weight of the root and shoot

According to the results of the length and dry weight of the root and shoot, Boushehr was the most tolerant landrace to salinity stress, whereas Isfahan was the most sensitive one. Results showed that those traits of Boushehr were not significantly decreased under any levels of salt stress, instead, those were significantly increased under 40 mM NaCl. In contrast, in Isfahan, they were decreased under all salinity levels that were significant in most cases (Table 2).

Length and dry weight of the root and shoot of Shiraz, Urmia, Mashhad, and Boushehr landraces grown under salt-treated mediums amended with VCE were proportionally higher than those of seedling grown under the same mediums but not amended with VCE. This was especially prominent in Shiraz landrace. However, later traits of Isfahan landrace treated with salinity stress were not improved by VCE (Table 2).

Amylase activity

Results showed that amylase activity of fennel landraces was not significantly affected by different levels of salinity stress, except for Urmia and Shiraz landraces under 80 and 120 mM NaCl. Moreover, VCE did not significantly affect amylase activity of salt-treated fennel landraces, compared to those not amended with that, except for Boushehr landrace under 120 mM NaCl (Table 2).

Na^+, K^+, and ca^{2+} content of root and shoot

Results showed that Na^+ content of root and shoot of all fennel landraces was significantly increased under all salinity levels. VCE induced a more accumulation of Na in seedlings of salt-treated fennel landraces, especially in root, that was significant in some cases (Table 3).

According to the results, K content of shoot was decreased in salt-treated fennels, that was significant in Isfahan landrace under all salinity levels, Boushehr under 80 and 120 mM, and Mashhad and Shiraz under 120 mM NaCl, while it was not significant in Urmia landrace. In all landraces, the salinity levels of 80 and 120 mM NaCl significantly induced a decrease in K content of

Table 2. Effects of salinity stress and VCE on some traits of fennel landraces.

Fennel Landrace	VCE	Salinity level (mM NaCl)	Germination percentage	Germination rate (d^{-1})	Root length (cm)	Shoot length (cm)	Root dry weight (g)	Shoot dry weight (g)	amylase activity (unit/mg protein)
Urmia	0	0	88.89 b-e	0.1287 ab	8.127 b-d	0.8107 b-g	0.0173 j-m	0.0097 e-g	101.7 d-h
		40	92.22 a-d	0.1267 a-c	10.92 a	0.6852 d-i	0.0230 g-i	0.0103 c-f	79.87 h-n
		80	83.33 d-h	0.1127 d-g	3.421 l-n	0.6660 d-i	0.0150 mn	0.0093 e-h	60.65 m-t
		120	53.33 m-o	0.0843 m-o	1.366 p-r	0.1840 o-t	0.0090 p-r	0.0073 hi	44.89 r-v
	10%	0	100.0 a	0.1290 ab	8.783 b	0.6799 d-i	0.0247 e-g	0.0120 b-d	103.7 d-g
		40	92.22 a-d	0.1280 ab	10.94 a	0.9787 ab	0.0260 d-g	0.0107 c-e	83.76 f-l
		80	87.77 b-e	0.1247 a-d	8.449 bc	0.9253 a-c	0.0230 g-i	0.0120 b-d	62.71 k-s
		120	62.22 k-m	0.1090 e-h	2.860 m-o	0.3420 l-q	0.0123 no	0.0103 c-f	53.92 p-v
Shiraz	0	0	84.44 c-g	0.1303 ab	7.844 b-e	0.8143 b-g	2.333 gh	0.0103 c-f	153.1 a
		40	86.66 c-f	0.1240 a-d	6.732 e-h	0.7920 b-g	0.0267 c-f	0.0120 b-d	141.3 ab
		80	75.55 g-i	0.09533 i-n	2.652 no	0.4130 j-o	0.0106 o-q	0.0093 e-h	131.2 bc
		120	44.44 o-q	0.08600 l-o	0.8047 rs	0.1493 q-t	0.0090 p-r	0.0070 ij	128.4 bc
	10%	0	93.33 a-c	0.1363 a	8.833 b	1.093 a	0.0290 b-d	0.0130 b	155.2 a
		40	92.22 a-d	0.1373 a	9.077 b	0.9553 ab	0.03100 ab	0.0160 a	153.8 a
		80	90.00 b-d	0.1240 a-d	7.999 b-d	0.8830 a-e	0.02733 c-e	0.0123 bc	146.8 ab
		120	84.44 c-g	0.09933 g-l	5.777 hi	0.7107 c-i	0.0203 h-j	0.0113 b-e	139.4 ab
Boushehr	0	0	77.78 f-i	0.1287 ab	5.891 g-i	0.6667 d-i	0.0190 j-l	0.0100 d-g	97.59 d-i
		40	87.77 b-e	0.1283 ab	7.883 b-e	0.8700 a-f	0.0250 e-g	0.0103 c-f	97.51 d-i
		80	74.44 hi	0.1247 a-d	5.700 h-j	0.6653 d-i	0.0196 i-l	0.0100 d-g	89.08 d-j
		120	71.11 i-k	0.1183 b-e	5.655 h-j	0.5840 g-k	0.0200 i-k	0.0100 d-g	77.51 i-o
	10%	0	80.00 e-i	0.1297 ab	6.366 f-h	0.9020 a-d	0.0193 j-l	0.0107 c-e	107.3 de
		40	93.33 a-c	0.1290 ab	9.083 b	0.8933 a-e	0.0236 fg	0.0130 b	110.5 cd
		80	84.44 c-g	0.1280 ab	7.036 d-g	0.8430 b-f	0.0166 k-m	0.0123 bc	107.2 de
		120	72.22 ij	0.1190 b-e	5.916 g-i	0.6410 f-j	0.01567 m	0.0107 c-e	105.5 d-f
Mashhad	0	0	85.55 c-f	0.1300 ab	5.468 h-j	0.5377 h-l	0.0230 g-i	0.0103 c-f	78.35 i-o
		40	86.66 c-f	0.1180 b-e	4.978 i-k	0.6610 e-i	0.0230 g-i	0.0110 b-e	83.05 f-m
		80	86.66 c-f	0.09333 j-o	2.658 no	0.3763 k-q	0.0196 i-l	0.0100 d-g	60.81 l-t
		120	50.00 n-p	0.09000 j-o	0.9497 q-s	0.1687 p-t	0.0063 rs	0.0050 jk	56.00 o-v
	10%	0	92.22 a-d	0.1343 a	6.333 f-h	0.7987 b-g	0.0266 c-f	0.0120 b-d	77.18 i-o
		40	96.66 ab	0.1290 ab	7.322 c-f	0.9667 ab	0.0323 a	0.0130 b	84.73 e-k
		80	88.88 b-e	0.1080 e-i	7.121 d-g	0.7717 b-h	0.0293 a-c	0.0107 c-e	62.12 k-s
		120	55.55 l-n	0.09200 j-o	1.203 q-s	0.3663 k-q	0.0080 qr	0.0073 hi	58.54 n-u
Isfahan	0	0	57.78 mn	0.1037 f-j	3.989 k-m	0.3920 k-p	0.0193 j-l	0.0083 f-i	72.31 j-q
		40	42.22 p-r	0.1017 f-k	2.540 n-p	0.2863 m-r	0.0163 lm	0.0066 ij	74.21 j-p
		80	36.66 q-s	0.08200 no	1.643 o-r	0.1993 n-t	0.0100 o-q	0.0050 jk	70.58 j-q
		120	28.89 st	0.0813 o	1.224 q-s	0.09877 r-t	0.0060 rs	0.0040 kl	67.36 j-r
	10%	0	63.33 j-l	0.1197 b-e	4.533 j-l	0.4907 i-m	0.0200 i-k	0.0100 d-g	82.64 g-m
		40	43.33 pq	0.1030 f-j	3.633 l-n	0.4230 j-n	0.0170 j-m	0.0080 g-i	77.59 i-o
		80	37.77 q-s	0.09500 i-o	2.128 o-q	0.2753 m-s	0.0120 n-p	0.0066 ij	73.08 j-p
		120	33.33 rs	0.08800 k-o	1.382 p-r	0.1657 p-t	0.0063 rs	0.0050 jk	69.95 j-q

Means in each column followed by at least one letter in common are not significantly different statistically, according to Duncans Multiple Range Test ($p \le 0.05$).

Table 3. Effects of salinity stress and VCE on Na, K, and Ca concentration in root and shoot seedlings of fennel landraces.

Fennel Landrace	VCE	Salinity level (mM NaCl)	Na content of root (g/100g dw)	Na content of shoot (g/100g dw)	K content of root (g/100g dw)	K content of shoot (g/100g dw)	Ca content of root (g/100g dw)	Ca content of shoot (g/100g dw)
Urmia	0	0	24.31 w	19.19 w	59.83 k-p	23.73 m-o	12.39 d-g	1.380 de
		40	152.0 i-k	34.18 st	69.88 f-k	23.39 no	14.82 c-e	1.347 de
		80	172.0 d-h	44.78 j-q	58.43 l-q	23.39 no	10.76 f-i	1.314 de
		120	195.8 bc	61.96 ab	40.62 t-w	22.38 o	9.142 g-j	1.281 e
	10%	0	45.35 v	20.29 w	89.63 cd	25.75 k-o	22.12 a	1.380 de
		40	180.9 c-f	48.80 e-n	93.05 bc	27.09 h-o	15.63 cd	1.380 de
		80	180.4 d-f	49.17 e-m	69.19 g-l	28.10 h-n	18.88 b	1.380 de
		120	218.7 a	54.28 c-f	41.28 s-v	31.81 e-h	17.25 bc	1.380 de
Shiraz	0	0	45.97 v	18.10 w	93.22 bc	25.75 k-o	12.39 d-g	1.380 de
		40	159.5 h-k	36.37 rs	91.37 bc	24.74 l-o	14.01 c-f	1.380 de
		80	160.2 h-k	38.57 q-s	73.22 f-i	24.06 l-o	10.76 f-i	1.314 de
		120	164.6 g-j	39.66 p-s	54.78 m-r	15.98 p	7.520 i-k	1.281 e
	10%	0	63.14 s-u	18.83 w	101.8 b	28.10 h-n	22.21 a	1.380 de
		40	163.9 g-j	41.86 n-r	92.71 bc	26.08 j-o	18.88 b	1.380 de
		80	181.5 c-e	44.41k-q	76.92 e-g	24.74 l-o	15.63 cd	1.380 de
		120	198.9 b	47.34 f-o	80.62 d-f	24.40 l-o	14.01 c-f	1.314 de
Boushehr	0	0	63.14 s-u	22.12 u-w	69.19 g-l	30.12 f-k	10.76 f-i	1.347 de
		40	87.55 pq	48.80 e-n	63.14 i-n	28.78 g-l	11.57 e-h	1.314 de
		80	152.6 i-k	59.03 a-d	60.79m j-o	24.40 l-o	7.520 i-k	1.314 de
		120	185.5 b-d	61.81 ab	47.34 q-v	23.39 no	6.709 j-l	1.314 de
	10%	0	64.65 s-u	22.48 u-w	76.92 e-g	31.13 e-i	13.20 d-f	1.380 de
		40	148.1 kl	50.26 e-l	71.88 f-j	30.12 f-k	12.39 d-g	1.380 de
		80	176.7 d-g	59.34 a-c	64.32 i-n	27.77 h-n	8.331 h-k	1.380 de
		120	187.3 b-d	64.88 a	60.45 k-o	24.06 l-o	7.520 i-k	1.380 de
Mashhad	0	0	69.47 r-t	19.19 w	73.89 f-i	33.15 d-g	7.520 i-k	1.347 de
		40	126.4 mn	49.53 e-l	63.47 i-n	34.16 d-f	6.709 j-l	1.314 de
		80	158.6 h-k	52.09 d-i	36.25 vw	28.47 g-m	5.898 j-l	1.281 e
		120	180.0 d-f	55.38 b-e	29.87 w	26.76 i-o	5.087 kl	1.248 e
	10%	0	75.35 q-s	21.02 vw	78.60 e-g	37.53 d	9.142 g-j	1.380 de
		40	149.6 j-l	50.99 e-k	75.57 e-h	35.51 de	8.331 h-k	1.347 de
		80	165.7 f-i	53.19 c-i	48.69 p-u	28.78 g-l	7.520 i-k	1.314 de
		120	186.7 b-d	51.72 e-j	38.27 u-w	28.10 h-n	5.898 j-l	1.314 de
Isfahan	0	0	58.75 t-v	28.33 tu	63.47 i-n	36.86 d	6.709 j-l	1.380 de
		40	91.20 p	35.64 rs	51.38 o-t	30.80 e-j	5.898 j-l	1.347 de
		80	110.0 o	40.39 o-s	44.99 r-v	28.78 g-l	5.087 kl	1.314 de
		120	125.1 mn	46.97 g-o	38.27 u-w	27.09 h-o	3.391 l	1.281 e
	10%	0	63.15 s-u	27.24 uv	77.59 e-g	37.87 d	7.520 i-k	1.380 de
		40	115.3 no	48.43 e-n	65.49 h-m	34.84 d-f	6.709 j-l	1.380 de
		80	121.9 no	46.24 i-p	51.71 o-s	31.81 e-h	6.709 j-l	1.380 de
		120	137.3 lm	46.61 h-p	56.42 m-q	28.10 h-n	5.087 kl	1.347 de

Means, in each column, followed by at least one letter in common are not significantly different statistically, according to Duncans Multiple Range Test ($p \leq 0.05$).

root (except for Urmia landrace under 80 mM) compared to their corresponding controls. Although VCE did not significantly affect shoot K content of salt-treated fennels (except for Shiraz and Urmia landraces under 120 mM NaCl), it induced an increase in the root K content of all salt-treated landraces, compared to those not amended with VCE (Table 3).

Ca content of root and shoot of fennel landraces was not significantly affected by salinity stress, except for that of root of Shiraz and Boushehr landraces treated with 120 mM NaCl. VCE did not significantly change shoot Ca content of salt-treated fennel landraces. It, however, caused a significant increase in root Ca content of Shiraz and Urmia landraces treated with salinity, compared to root Ca content of those grown under salt-medium not amended with VCE (Table 3).

Discussion

It has been known for many years that salinity stress can inhibit seed germination or reduce its rate that has been reported in many researches (Delgado Fernández et al. 2016; Khadhri, Neffati, and Smiti 2011; Nedjimi 2013). Salt stress can induce low-water-potential condition resulted in limiting water absorption by seed (Dodd and Donovan 1999). In such condition, metabolic activities of seedling are also retarded and thus the rate of germination is declined, and in extreme condition, seed germination may be halted (De and Kar 1994).

In the present study, germination rate and percentage of fennel seeds were increased by VCE. Like our results, it has been reported that 1: 10 and 1: 15 dilutions of vermiwash (an extract obtained during vermicomposting organic matters) induced germination of cow pea and paddy, while its higher concentrations (1: 0 and 1: 1) had phytotoxic effect on germination (Gopal et al. 2010). In contrast to our study, Warman and AngLopez (2010) reported that VCE suppressed germination of radish and marigold. These different results can be attributed to using a variety of different organic matter for preparing vermicompost, different methods for extracting, and different dilutions of VCE.

Decreased biomass under salt stress is due to the integrated adverse effects of ion toxicity and nutritional disorders in soil solution (Hasegawa et al. 2000; Munns 2002). Like present study, Archana et al. (2009) reported a VCE-induced increase in length and dry weight of Pak choi that they attributed it to the existence of the essential minerals, especially nitrogen, in VCE. Aquatic VCEs have also a large amount of indole acetic acid, and lower concentrations of other hormones (Edwards 2004) that may have a role in inducing plant growth. Beneficial microorganisms and growth regulators such as hormones, and humic and fulvic acids were accounted for increasing growth of tomatoes amended with VCE (Greytak, Edwards, and Arancon 2006).

Results of the present study showed that K content of seedlings was decreased in NaCl-treated fennels. Since the uptake of K^+ and Na^+ is carried out through the same transporter, a high concentration of Na^+ can suppress uptake of K^+ by root (Taiz and Zeiger 2010) that may be one of the reasons for the deleterious effects of salinity stress on growth, because of the important physiological role of K^+ in the plant. Some studies have also reported a decreased content of Ca of leaf in response to salt stress (Navarro, Martinez, and Carvajal 2000).

Vermicompost have a large amount of essential macronutrients such as N, phosphorus (P), K, Ca, and Mg, and also micronutrients such as iron (Fe), zinc (Zn), copper (Cu), and manganese (Mn) (Atiyeh et al., 2000) that can be absorbed by plant, resulting in an increase in growth, provided that do not induce toxicity (Taiz and Zeiger 2010). According to Lakhdar et al. (2009), after application of Vermicompost in saline conditions, some elements such as Ca and Mg can substitute for Na. It has also been reported that improved bacterial activity, existence of plant growth regulators, and an increased absorption of mineral nutrients such as K led to a high concentration of K in fruits of tomato treated with vermicompost (Zaller 2007). It is expected that vermicompost could also increase soil porosity and improve its structure led to an improvement of water relationship and uptake of minerals such as K and Ca.

If seeds are provided with water, hormones involved in germinations are increased and seed reserves are broken down by a variety of hydrolytic enzymes such as amylases, proteases, and lipases to provide soluble products for growing embryo (Taiz and Zeiger 2010). However, in the present study amylase activity of most fennel landraces was not significantly affected by salinity stress and VCE, indicating that other enzymes may be affected by them.

Vermicompost can improve soil quality and plant growth due to the good physical and chemical properties (Zuo et al. 2018). The alleviation of salinity stress by vermicompost has also been reported in potato (Pérez-Gómez et al. 2017), pomegranate (Bidabadi, Dehghanipoodeh, and Wright 2017), and tomato (Benazzouk, Djazouli, and Lutts 2018). In a study carried out on tamarind to find vermicompost role against NaCl stress, it was found that tamarind seedlings could tolerate salt stress in the presence of vermicompost, attributed to its organic compounds (Oliva et al. 2008). It has been reported that gibberellins and ethylene from vermicompost may have a role in alleviating stress induced by salinity (Wilson et al. 2014). Beside plant hormones, Ca ions of vermicompost can also have a role in tolerating saline condition (Zehra et al. 2012).

Conclusions

After comparing the response of five fennel landraces widely cultured in Iran, including Urmia, Mashhad, Shiraz, Boushehr, and Isfahan to the salt stress induced by NaCl, it can be concluded that Boushehr landrace was the most tolerant one to salinity, whereas Isfahan landrace was the most sensitive one. Since adverse effects of NaCl stress on the germination and seedling growth of fennel landraces were alleviated by VCE to some extent, the present study suggests VCE as a beneficial matter for ameliorating damages and toxicity of saline conditions.

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