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Effect of vermicompost on some morphological, physiological and biochemical traits of bean (*Phaseolus vulgaris* L.) under salinity stress

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ABSTRACT

Vermicompost can play an effective role in plant growth and development and also in reducing harmful effects of various environmental stresses on plants due to its porous structure, high water storage capacity, having hormone-like substances and plant growth regulators and also high levels of macro and micro nutrients. The aim of this study was to investigate the effects of vermicompost and salinity interactions on some morphological and physiological features and concentration of mineral elements of bean (*Phaseolus vulgaris* L. cv. Light Red Kidney) cultivar. A factorial experimental with five different volumetric ratios of vermicompost and sand, including to: 0:100; 10:90; 25:75; 50:50 and 75:25 and four levels of salinity [20, 40, 60 and 80 mmol l^{-1} sodium chloride (NaCl)], and control was conducted base on Randomized Complete Block Design with three replications. Bean seeds were sowed in plastic pots, the seedlings being sampled 42 days old (flowering stage).The results showed that vermicompost had significant effect on all studied traits under stress and non-stress ($p \leq 0.05$).In this experiment, the vermicompost significantly increased the photosynthetic rate and concentrations of potassium (K^{+}) and calcium $(Ca^{2})^{+}$in leaf and root tissues. In salinity levels of 20, 40 and 60 mmol l^{-1}NaCl, all subjected ratios of vermicompost and in 80 mmol l^{-1}NaCl the ratios of 10% and 75% vermicompost, significantly ameliorated negative effects of salinity. In both stress and non-stress conditions, using 10% volume of vermicompost is recommended to improve the growth of bean plants.

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Introduction

Beans as a major source of protein (20–25 percent), carbohydrates (50–60 percent) and also minerals, vitamins and unsaturated fatty acids (Rehman et al., 2001; Reyes-Moreno and Paredes-Lopez 1993) play an important role in human diet, so it is widely cultivated worldwide.

Soil salinity and nutrient deficiency are two important agricultural problems affecting almost 20% of the world's agricultural lands (Flowers and Yeo, 1995). Many of studies confirm the negative effects of salinity on physical and chemical properties of the soil, as well as the activity of soil microorganisms (Lakhdar et al., 2009).The salinity would affect the plant growth and development by creating toxicity in the soil and disrupting nutrient balance in soil solution (Hafsi et al., 2007).

In recent decades the use of organic fertilizer is a common method for improving saline lands (Lakhdar et al., 2009). Vermicomposts are products of nonthermophilic bio-degradation of organic

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materials through interactions between earthworms and microorganisms (Sallaku et al., 2009). This organic composition, is light, odorless and free of weed seeds (Atiyeh et al., 2002a), with abundant pores, high capacity of ventilation, drainage and water storage (Atiyeh et al., 2001), large amounts of macro and micro elements (Atiyeh et al., 2000), large and active microbial biodiversity (Arancon et al., 2004a), plant hormones and growth regulators (Muscolo et al., 1999; Atiyeh et al., 2002b). According to these characteristics, vermicompost can play an effective role in plant growth and development and also in reducing harmful effects of various environmental stresses.

Subler et al. (1998) reported that the replacement of medium volume with 10% and 20% of vermicompost, improved growth and germination of peppers (*Capsicum annum* L.), cabbage (*Brassica oleracea*), and tomato (*Lycopersicum esculentom* L.) .In another study on chickpea (*Cicer arietinum* L.), it was found that taking three thousand kg/ha vermicompost, significantly increases the biological function (Jat and Ahlawat, 2006). Zaller (2007) reported a significant increase in K^+ concentration in tomato fruit treated with vermicompost. In his opinion, the major reasons for increasing K^+ concentration are the improvement of microbial activity, presence of plant growth regulators and increased absorption of minerals, such as potassium. Significant increase in chlorophyll content and photosynthetic rate in presence of vermicompost weight ratios of 10and 20% on pistachio (*Pista ciavera*) seedlings was reported by Golchin et al. (2006).

Sallaku et al. (2009) expressed that the increased in plant growth treated with vermicompost is due to significant increase in soil enzyme activities such as urease, phosphomonoesterase, phosphodiesterase and arylsulfatase, solubilization of nutrients, and production of growth compounds like 1-aminocyclopropane-1-carboxylate (ACC) deaminase .vermicompost also provides higher growth rate of cucumber (*Cucumis sativus* L.) seedlings under salinity stress conditions. Research showed that some plants such as sunflower (*Helianthus annuus* L.),vermicompost can reduce harmful effects of salinity and increase growth and yield production (Rafiq and Nusrat 2009).Several studies have shown that photosynthesis and biomass of the Tamarind plantlets (*Tamarindu sindica*) increases in presence of vermicompost in sodium chloride (NaCl) stress conditions, significantly (Oliva et al., 2008).

Since the bean is a product of economic value playing an important role in nutrition and due to its high sensitivity to salinity, the aim of this study was to investigate the effects of vermicompost and salinity interactions on morphological, physiological and biochemical traits of the bean.

Materials and methods

Plant culture and experimental treatments

This experiment was carried out as factorial experiment based on Randomized Complete Block Design, with three replications at the Research Greenhouse, Faculty of Agriculture, Ferdowsi university of Mashhad, Iran in 2010. In this experiment we studied the effect of five different volumetric ratios of vermicompost and washed sand, including: 0:100; 10:90; 25:75; 50:50 and 75:25 and four levels of salinity including: 20, 40, 60 and 80 mmol L^{-1} sodium chloride (NaCl), and control treatment, in a control condition (temperature: 25–30°C, relative humidity: 70–60%, and natural light). Particle size of sand used in the mixture, was 0.2–2 mm and its pH was neutral. Chemical analysis of the vermicompost used in this experiment is shown in Table 1.

Treatments were prepared by volumetric mixing ratios of vermicompost and sand. Each experimental unit contained a pot with the height of 16 cm and 9 cm in diameter and four seeds were sown in each pot to ensure the emergence of the seedlings, then thinned to two plant in each pot. Hoagland's nutrient solution was used during the growth period of plant in order to supply nutrient requirements.

Table 1. Chemical characteristics of vermicompost.

Sample	Organic mater (%)	pH	C/N	P (%)	Ca (%)	K (%)	Na (%)	Total N (%)
Vermicompost	35–40	8–8.5	16	1.5–2	3.8–4	0.9–1.5	0.6–0.9	1.3–1.6

The two-week-old plants were treated with four levels of salinity. To keep salinity stability, the electrical conductivity of water drainage in pots was measured regularly.

Morphological measurements

The samples were harvested 42 days after planting (flowering stage) and then shoot and root were separated from each other and morphological traits including plant height and dry weight of leaves, stems and roots were measured. Leaf area was determined by Leaf Area Meter. Traits related to the roots of each plant, including total length and root area were measured using a scanner connected to computer after washing and staining with magnesium permanganate. Stems, leaves and roots were oven dried at 70°C for 48 h to determine the dry weight.

Physiological measurements

Fixed carbon dioxide (CO_2) rate (photosynthetic rate) (P_r), transpiration rate (T_r) and CO_2 concentration inside the cell (C_i) of young leaves in flowering stage, were measured using a Leaf Chamber Analyzer (LCA-4, ADC Bio Scientific Ltd., Hoddesdon, UK). Water use efficiency (WUE) was calculated as the ratio of the CO_2 fixation rate to transpiration rate (P_r/T_r) (Ahmedet al., 2002).

Membrane stability index (MSI) was determined according to the method of Sairam et al. (2001) (Equation 1). 0.1 grams of the second leaf per plant were weighed and placed in the two series of test tubes containing 10 ml distilled water. A series of tubes were left in 40°C water bath for 30 min and then the electrical conductivity (EC) of samples were measured by EC meter (C_1) and another series of tubes were placed in 100°C water bath for 10 min and the electrical conductivity was recorded (C_2). The MSI was calculated as:

$$MSI = 1 - (C1 / C2) \times 100 \quad (1)$$

To determine the leaf relative water content (RWC), some amounts of the second leaf of each plant were immersed for 48 h in distilled water after being weighed. Then the leaves were extracted from water and their surface was dried with paper napkins and weighed. Leaves were oven dried at 70°C for 48 h and the dry weight was determined. RWC was determined according to the equation 2 (Bian and Jiang, 2008) where FW is leaf fresh weight, DW is the dry weight of leaves and TW is the turgid weight of leaves after soaking in water.

$$RWC = [(FW - DW) / (TW - DW)] \times 100 \quad (2)$$

Measurement of mineral elements

Concentrations of sodium (Na^+), calcium (Ca^{2+}) and potassium (K^+) in leaves and roots were determined using the method of Rafiq and Nusrat (2009). Wet ash was prepared with Nitric acid and the amount of cations was calculated as g/100 g dry weight with flame photometry.

Statistical analysis

The means were compared using the Duncans Multiple Range Test. All the statistical tests were performed at $p \leq 0.05$, using the software MSTAT-C (MSTAT-C, Michigan State University, East Lansing, MI, USA).

Table 2. Means comparison of different salinity levels on characteristics related to bean root and shoot morphological features.

Salinity levels (mmol l^{-1}NaCl)	Plant height (cm)	Leaf area (mm^2)	Stem dry weight (g)	Leaf dry weight (g)	Total root length (mm)	Total root area (mm^2)	Root dry weight (g)
0	15.73 a	2436 a	0.3145 a	0.4112 a	55840 a	46890 a	0.5785 a
20	15.33 a	2300 a	0.2620 b	0.2713 b	56200 a	48430 a	0.5463ab
40	13.67 b	1956 b	0.2488 b	0.3189 b	60100 a	46050 a	0.5310 b
60	12.03 c	1384 c	0.1535 c	0.1334 c	42540 b	28700 b	0.3054 c
80	11.00 d	1163 d	0.1305 d	0.1150 c	36960 c	23130 c	0.2903 c

Means, in each column, followed by at least one letter in common are not significantly different statistically, using Duncan's Multiple Range Test ($p \leq 0.05$). The data is across all vermicompost levels.

Results and discussion

Salinity effects: Shoots and roots

Plant height and leaf area were significantly decreased by salinity levels of 40 mmol$l^{-1}$and above, whereas stem and leaf dry weights were reduced by all salinity levels.In this experiment, the lowest amount of shoot growth parameters were observed in 80 mmol l^{-1}NaCl.Root length and Total root area were not adversely affected by salinity levels up to 40 mmol L-1, but were reduced by 60 and 80 mmoll^{-1}. Root dry weight was slightly reduced by 40 mmol Ll-1 and greatly reduced by increasing the salinity level to 60 and 80 mmol l-1 (Table 2).

Romero-Aranda et al. (2001) reported that in salinity stress, photosynthetic product declined due to accumulation of Na^+ and chloride (Cl^-) ions in leaves, stomatal closure and reduced chlorophyll content. Other studies have mentioned about dry weight loss under salinity stress as a resultof combined effects of osmotic stress, ion toxicity and change in nutrient concentration (Hasegawa et al., 2000; Munns, 2002).

Vermicompost effects: Shoots and roots

All treatments of vermicompost significantly increased plant height, leaf area and shoot dry weight compared to the control. All traits mentioned above were significantly increased and decreased, in ratios of 75 and 50% vermicompost, respectively. In 75% of vermicompost, plant height was increased by about 30% and leaf area by about 40% compared to the control. A significant reduction in dry weight, total length and area of roots were observed in all subjected ratios of vermicompost. These root traits increased from 50 to 75% vermicompost (Table 3).

Positive effect of vermicompost on increasing the height of *Cicer* and *Pisum palant* (Sinha et al., 2010) and also dry weight of soybean (*Glycine max* L.) and oat (*Avena ludoviciana*) (Atiyeh et al., 2001) is shown in a medium containing vermicompost. Muscolo et al. (1999) stated that increased plant height is due to the stimulation of auxin-like substances produced during vermicompost consumption. Humic and fulvic acids and other organic acids found in vermicompost (Arancon et al., 2007), as well as frequency of nutrients especially nitrogen (Samiran et al., 2010) can stimulate plant growth. Arancon et al. (2004b) reported that leaf area increase in vermicompost treated strawberry

Table 3. Means comparison of different vermicompost ratios on characteristics related to bean root and shoot morphological features.

Vermicompost ratio(V/V)	Plant height (cm)	Leaf area (mm^2)	Stem dry weight (g)	Leaf dry weight (g)	Total root length (mm)	Total root area (mm^2)	Root dry weigh (g)
0	10.67 d	1387 d	0.1453 d	0.0921 c	74010 a	55600 a	0.6193 a
10	14.03 b	1967 b	0.2348 b	0.2701 ab	48190 c	31810 cd	0.4358 c
25	14.43 b	1961 b	0.2298 b	0.2561 b	39770 d	35360 c	0.3589 d
50	13.23 c	1642 c	0.2024 c	0.2618 ab	34630 e	28550 d	0.3393 d
75	15.40 a	2282 a	0.2970 a	0.3262 a	55060 b	41880 b	0.4981 b

Means, in each column, followed by at least one letter in common are not significantly different statistically, using Duncan's Multiple Range Test ($p \leq 0.05$). The data is across all salinity levels.

(*Fragaria ananassa* Duch.) is due to an increase in microbial population in vermicompost. Tolerance of seedlings grown in vermicompost, is probably due to the organic material in vermicompost, capable of inhibiting substances such as heavy metals (Oliva et al., 2008). Matos and Arruda (2003) believe that humic materials in vermicompost have a high absorption capacity of metals due to the presence of negatively charged functional groups.

Samiran et al. (2010) reported that the root length of bean plants was increased in the presence of vermicompost but root length of maize (*Zea mays* L.) showed no particular trend. They stated that the different patterns of mineral absorption in many plants, is probably the main reason for various responses in plants to different ratios of vermicompost. Reduced root growth in the presence of vermicompost is due to the high concentrations of auxin that inhibiting the root growth either directly or indirectly by induction of ethylene biosynthesis (Taiz and Zeiger, 2002). Auxin and other plant growth hormones are present in the vermicompost. In general, it seems that the use of vermicompost, has provided better conditions for water and nutrient absorption and plants have therefore spent less energy for root growth.

Interactions of salinity and vermicompost: Shoots and roots

The observations indicated that the interactions of salinity and vermicompost significantly affected characteristics related to bean root and shoot morphological traits. Plant height was increased in all combinations of vermicompost and salinity in comparison with control (no vermicompost) and this increase in 20, 40 and 60 mmol l^{-1}NaCl was significant. In 80 mmol l^{-1}NaCl, plant height was significantly increased at 10 and 75% vermicompost, (Figure 1A). The overall results of this study indicated

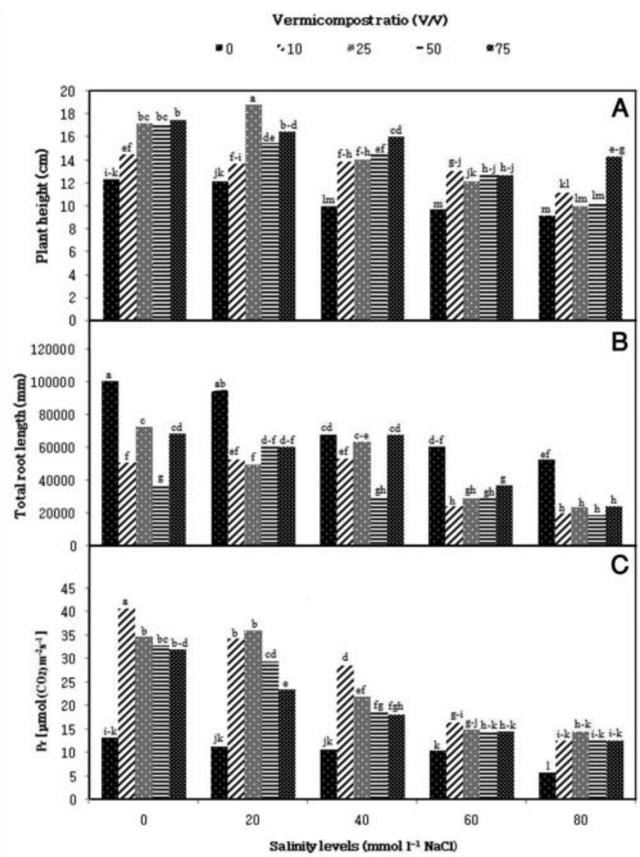

Figure 1. Effect of vermicompost and salinity interaction on A) plant height, B) total root length and C) photosynthetic rate (P_r). Columns with the same letter(s) are not significantly different at $p \leq 0.05$ probability.

that in low salinity, most ratios of vermicompost and in higher salinity (80mmol l^{-1}NaCl), ratios of 10 and 75%, ameliorate the negative effects of salinity on shoot (data not shown).

Total length of roots were significantly reduced in all studied salinity levels and in the all subjected ratios of vermicompost, compared to the control (without vermicompost), except for 40 mmol l^{-1}NaCl and the ratio of 25% and 75% vermicompost, (Figure 1B). A decreased total area and the dry weight of roots were observed in all studied salinity levels in the presence of all vermicompost treatments, compared to the control (without vermicompost) (data not shown).

As shown in Table 1, vermicompost contains various elements such as potassium, calcium and sodium. Therefore vermicompost itself can act as a salinity and salinity boosts by increasing its ratios. This is why the plant height, leaf area and shoot dry weight declined in 50% compared to 25% of vermicompost. On the other hand, probably in high ratios (75%), beneficial effects of vermicompost (such as microorganisms and mineral elements) are more than its negative effects and therefore the outcome is oriented towards positive. Thus in this ratio of vermicompost the characteristics mentioned above increased. The similar explanation is accurate for root traits so that via adding vermicompost to 50% of total length, surface and root dry weight decreased and increased from 50 to 75%.

Biological factors such as mycorrhizal fungi may be involved in the mechanism of salt tolerance in plants. Mycorrhiza fungi uses plant carbohydrates for their metabolism and therefore it may probably increased stress tolerance due to carbohydrates osmolotic effects (Oliva et al., 2008).

Photosynthesis

The P_r and the T_r were significantly decreased, by increasing salinity so that the lowest P_r and T_r was observed in 80 mmol L^{-1}NaCl. C_i in all levels of salinity and WUE in 60 and 80 mmol L^{-1}NaCl were significantly decreased (Table 4). Increase P_r was observed in 10 and 25% vermicompost. T_r in all of vermicompost ratios subjected except in 10% and other traits such as WUE and C_i in all studied ratios were significantly increased. WUE in the presence of 10 and 25% vermicompost was more than to other ratios, that which is related to the increase of P_r in such ratios (Table 5). The results showed that, the P_r were significantly elevated in all treatments of vermicompost in all salinity levels in ours experiment(Except 60 mmol L^{-1}NaCl, in the treatment of 50% and 75% vermicompost) (Figure 1C). Interactions of salinity and vermicompost showed that T_r was increased significantly only in 25% of vermicompost and 20 mmol l^{-1}NaCl, compared to the control. In studied salinity levels, WUE was elevated in all subjected vermicompost treatments. In ours experiment C_i in 60 and 80 mmol l^{-1}NaCl was significantly increased in presence of all vermicompost ratios, while at lower salinity levels, were not significantly different from control (data not shown).

The reduction in stomatal conductance in response to water deficiency leads to improved WUE (Raschke, 1976). Increased T_r in the presence of vermicompost, may be due to the physical, chemical and biological structure of vermicompost. Vermicompost increases the amount of water entering roots due to its capacity of holding water and the microorganisms including mycorrhizal fungi. Therefore, the T_r rise along with the increases in plant water. Salinity reduces N accumulation in plants (Feigin et al., 1991). On the other hand, robisco along with other enzymes in photosynthetic cycle and

Table 4. Means comparison of different salinity levels on characteristics related to bean root and shoot physiological features.

Salinity levels (mmol l-1NaCl)	Pr [μmol(CO2) m-2s-1]	Tr [mmol(H2O)m-2s-1]	WUE (Pr/Tr)	Ci (μmol m-2s-1)	MSI (%)	RWC (%)
0	30.51 a	3.521 a	0.0088 bc	364.9 a	75.70 a	72.15 a
20	26.72 b	2.410 b	0.0100 a	340.6 b	70.43 b	ab66.66
40	19.51 c	2.153 b	0.0093 b	335.7 b	58.45 c	69.07 ab
60	14.01 d	1.736 c	0.0086 c	b351.4	48.82 d	66.98 ab
80	11.56 e	1.517 c	0.0077 d	335.8 b	39.22 e	16.80b

Means, in each column, followed by at least one letter in common are not significantly different statistically, using Duncan's Multiple Range Test ($p \leq 0.05$). The data is across all vermicompost levels.

Table 5. Means comparison of different vermicompost ratios on characteristics related to bean root and shoot physiological features.

Vermicompost ratio (V/V)	P_r [μmol(CO_2) $m^{-2}s^{-1}$]	T_r [mmol(H_2O)$m^{-2}s^{-1}$]	WUE (P_r/T_r)	C_i (μmol $m^{-2}s^{-1}$)	MSI (%)	RWC (%)
0	c 20.15	2.05 c	0.0050 d	324.4 b	45.25 c	59.44 c
10	26.44 a	c2.12 b	0.0127 a	352.2 a	66.05 a	78.27 a
25	24.16 b	2.41 b	0.0099 b	355.8 a	64.07 a	67.73 b
50	21.59 c	ab2.45	0.0099 b	347.1 a	57.66 b	65.54 b
75	19.97 c	2.61 a	0.0080 c	352.1 a	59.49 b	74.38 a

Means, in each column, followed by at least one letter in common are not significantly different statistically, using Duncan's Multiple Range Test ($p \leq 0.05$).the data is across all salinity levels.

pigment-proteins combinations in the thylakoid membranes are the first plant requests for nitrogen. Therefore, photosynthetic activity is related to N status in plant (Stewart, 1991). Chow et al. (1990) stated that the high concentration of potassium in the chloroplast stroma is essential for maintaining the balance of photosynthesis under salinity. Also, indole acetic acid (IAA) causes stomatal opening while abscisic acid (ABA) stimulates stomatal closure effecting K^+ channels of membrane (Blatt and Thiel, 1994). IAA increases root hydraulic conductivity and thus water shortage and turgor pressure reduction were compensated (Tal and Imber, 1971).

Since vermicompost is the source of minerals and plant growth hormones such as auxin and other plant growth regulators, including humic acids, and also because of its physicochemical structure, it can have a positive effect on the photosynthetic system and limit the negative effects of salinity on photosynthesis.

Membrane stability index (MSI)

Salinity had a significant effect on MSI, and this index was significantly decreased with increasing salinity levels. The lowest MSI (39.2%) was observed in 80 mmol L^{-1}NaCl, (by about 36% compared to the control) (Table 4). MSI significantly increased in all subjected ratios of vermicompost. Ratios of 10 and 25%, significantly increased the MSI in comparison with 50% and 75%vermicompost (Table 5). In ours experiment all ratios of vermicompost caused an elevated MSI under all salinity treatments except for 20 mmol L^{-1}NaCl, (Figure 2A).

Cell membrane integrity was affected by Salinity through changes in structure and composition of lipids and proteins (Cramer et al., 1996). Kaya et al. (2002) showed that high levels of sodium chloride, induces calcium deficiency and reduces cell membrane stability in strawberry. Gibberellic acid (GA_3) significantly improved cell membrane stability of cut spikes of gladiolus (Lilium longiflorum L.) (Singh et al., 2008). Similarly, electrolyte leakage was reduced in rose (*Rosa damascena*) treated with GA (Sabehat and Zeislin, 1994). Hence, perhaps vermicompost due to having plant hormones including GA and also containing lots minerals such as calcium can improve cell membrane stability of bean leaf.

Leaf relative water content (RWC)

RWC was declined in different levels of salinity but this reduction was only significant in 80 mmol l^{-1}NaCl (Table 4).The highest RWC was observed at vermicompost ratios of 10% and 75% that significantly increased compared to other ratios (Table 5). The results showed that in 20 and 40 mmol l^{-1}NaCl, the ratio of 10% vermicompost significantly increased RWC in comparison with the control (without vermicompost). RWC in 60 and 80 mmol L^{-1}NaCl, was significantly increased in 10 and 75% vermicompost (Figure 2B).

Similar to this study, other studies have shown that plants exposed to stress, change their internal water potential (Tester and Davenport, 2003). Rafiq and Nusrat (2009) stated that osmotic potential and subsequently leaf water potential of sunflower were decreased with increasing salt concentration, whereas using organic fertilizers significantly increased these factors. The researchers interpreted that to change internal water potential need an increase in osmotic potential either by absorption of

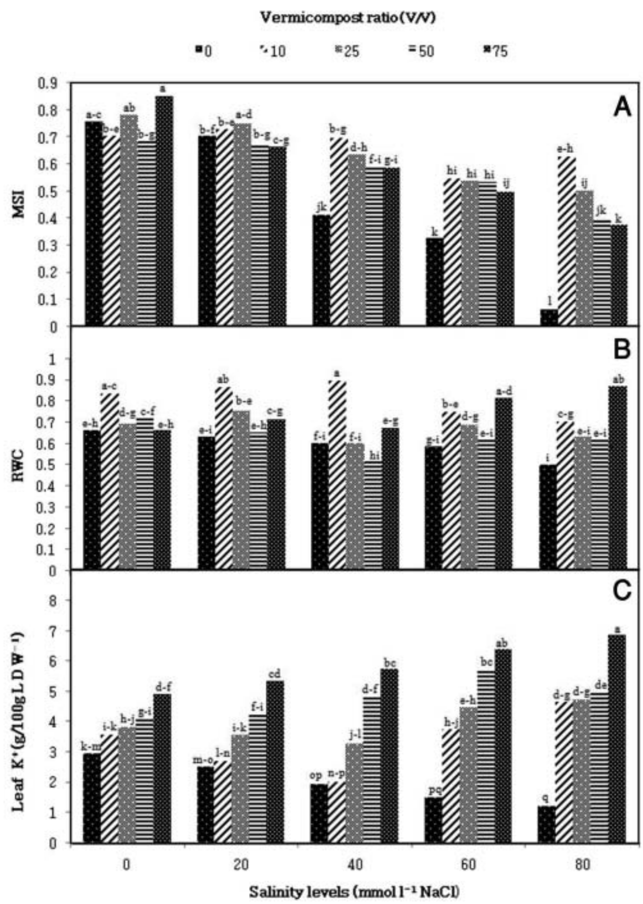

Figure 2. Effect of vermicompost and salinity interaction on the A) membrane stability index (MSI), B) relative water content, and C and leaf K^+. Columns with the same letter(s) are not significantly different at $p \leq 0.05$ probability.

minerals or by metabolic synthesis, and application organic fertilizer increases the water potential of cells and preserves turgor pressure of leaves through regulation of stomatal guard cells. In this regard, some reports suggest that plant hormones and calcium play an important role in regulating stomata (Sage and Reid, 1994). These results confirm that vermicompost can effectively improve the bean leaf water potential, due to having plant hormones, organic ions, porous structure and high water holding capacity.

Concentration of mineral elements in leaf and root tissues

The results showed that the Na^+ concentration in leaves significantly increased by 40, 60 and 80 mmol l^{-1}NaCl and in roots at all studied salinity levels, compared to control. However, the concentrations of Na^+ in root in 80 mmol L^{-1}NaCl were declined comparing with20, 40 and 60 mmol l^{-1}NaCl. It seems that the bean roots at 80 mmol L^{-1}NaCl have activated the inhibition mechanism of Na^+ adsorption. Ca^{2+} concentrations were elevated in the leaves treated by subjected salinity levels, but this elevation was not significant in roots except for 20mmol L^{-1}NaCl. A decrease in root K^+ concentrationswas observed in 60 and 80mmol L^{-1}NaCl. Salinity had no significant effect on K^+ concentration of leaf (Table 6).

Na^+ concentrations of leaves were increased in 10, 25 and 50% vermicompost and were significantly decreased in 75% compared to the control. Leaf K^+ concentrations in subjected ratios of the vermicompost were higher than the control and this increase was significant. The highest leaf K^+ concentration

Table 6. Means comparison of different salinity levels on characteristics related to bean root and shoot concentration of mineral elements.

Salinity levels (mmol l^{-1}NaCl)	Leaf Na^+ (g/100 g dw)	Leaf K^+ (g/100 g dw)	Leaf Ca^{2+} (g/100 g dw)	Root Na^+ (g/100 g dw)	Root K^+ (g/100 g dw)	Root Ca^{2+} (g/100 g dw)
0	0.4053 d	3.868 a	2.370 c	2.064 d	2.064 a	2.482 a
20	0.3945 d	3.684 a	3.027 a	4.010 b	2.168 a	2.297 b
40	0.5997 c	3.561 a	2.792 b	4.808 a	2.003 a	2.373 ab
60	1.5650 b	3.879 a	2.854 b	4.618 a	0.786 b	2.372 ab
80	2.1310a	3.895 a	2.740 b	3.445 c	0.856 b	2.437 a

Means, in each column, followed by at least one letter in common are not significantly different statistically, using Duncan's Multiple Range Test ($p \leq 0.05$). The data is across all vermicompost levels.

was in vermicompost ratio of 75% which was increased by 65% compared to the control. Vermicompost increased Ca^{2+} concentration of leaves except in ratio of 50%. A decreased Na^+ and increased K^+ concentrations were measured in root. Root Ca^{2+} concentration significantly increased only in vermicompost ratio of 75% (Table 7).

In ours experiment Na^+ concentration in root in different levels of salinity was significantly declined in all ratios of vermicompost, compared to the control (without vermicompost) while the concentration of K^+ in roots at subjected levels of salinity was significantly elevated in 10, 25 and 75% vermicompost.Ca^{2+} concentrations of leaves and roots were significantly increased in all studiedsalinity levels in both 10 and 75% vermicompost (in the leaves) and in 75% (in the roots) (data not shown).K^+ concentrations of leaves were significantly increased in all subjected combination of vermicompost and salinity co-treatments (except for 10% vermicompost ratio in 20 and 40 mmol l^{-1}NaCl) (Figure 2C).

Many plants, particularly those that are highly sensitive to salt, preferably collect more K^+ than Na^+ in their vacuoles in low to moderate salinity conditions (Jeschke and Wolf, 1988). Therefore, salinity may have no effect on leaf K^+ concentration. Hasegawa et al. (2000) stated that the Na^+ and K^+ competes for transfer by the cell, because the transport of Na^+ and K^+ cations is carried out through a common carrier. Reducing water content of the soil decreases the movement of K^+ and itsavailability for plant roots (Hu and Schmidhalter, 2005). Ca^{2+} ions may also play an important role for the plant in responding to salinity (Hasegawa et al., 2000). Researchers have shown that, if the Na^+/Ca^{2+}ratio is high outside the cell, the afflux of Na^+ would increase (Song and Fujyiama, 1996). Saleh et al. (2003) showed that application of organic fertilizer in onion (*Allium cepa* L.), supplies some essential minerals for plants during the growing period, therefore increasing salt tolerance. Most saline soils are subjected with low nitrogen, phosphorus and potassium. Adding compost to soil, the rhizosphere would be rich with macro and micro nutrients resulting in compensation of nutrients deficiency (Lakhdar et al., 2008). Basker et al. (1993) reported that K^+ in vermicompost is 2–3 times higher than in the soil. K^+ needed for plant growth was increased through the rise in cation exchange capacity through application of compost under conditions of salinity stress (Walker and Bernal, 2008).Since stabilization of K^+ in dry soils is more than wet soils (Raschke, 1975) and vermicompost can increase water holding capacity by having porous structure, it results in better absorption of K^+. Studies have shown that cytokine in hormone can increase K^+

Table 7. Means comparison of different vermicompost ratios on characteristics related to bean root and shoot concentration of mineral elements.

Vermicompost ratio (V/V)	Leaf Na^+ (g/100 g dw)	Leaf K^+ (g/100 g dw)	Leaf Ca^{2+} (g/100 g dw)	Root Na^+ (g/100 g dw)	Root K^+ (g/100 g dw)	Root Ca^{2+} (g/100 g dw)
0	0.7199 c	2.025 e	2.478 c	5.558 a	0.9119 d	2.318 bc
10	0.9631 b	3.338 d	2.996 a	3.571 c	1.793 c	2.391 b
25	1.6220 a	3.969 c	3.005 a	3.924 b	1.940 b	2.263 cd
50	0.9852 b	4.794 b	2.458 c	2.953 d	0.8990 d	2.150 cd
75	0.2300 d	5.862 a	2.846 b	2.939 d	3.334 a	2.812 a

Means, in each column, followed by at least one letter in common are not significantly different statistically, using Duncan's Multiple Range Test ($p \leq 0.05$). The data is across all salinity levels.

absorption (Ilan, 1971) and vermicompost contains plant growth hormones including cytokinin. Therefore, vermicompost can improve the nutrient absorption, particularly K^+, and can reduce Na^+ absorption in salt stress condition and can alsoameliorate the harmful effects of salinity by having plenty of nutrients, plant hormones, and high water storage capacity.

Conclusions

Bean is sensitive to salinity which has adverse effects on its morphological and physiological traits. In non-stress environment, different ratios of vermicompost can improve the bean growth. The positive effect of volume ratio of 50% vermicompost was less effective than other ratios. In this regard, the middle and high ratios of vermicompost, act probably as a source of salinity, but in high ratios (75%), beneficial effects of vermicompost is more than negative effects and therefore the outcome was positive. At low salinity level, including 20, 40 and 60 mmol l^{-1}NaCl in 10, 25, 50 and 75% vermicompost and at higher salinity level (80 mmol l^{-1}NaCl) in 10 and 75% vermicompost have the ability to limit the negative effects of salinity. Thus vermicompost can improve bean growth under saline conditions. The suggest of this experiment is use of 10% vermicompost in both salinity and non-salinity stress conditions for optimum growth of bean plant.

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