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Change in three dry rangeland species growth and soil properties by compost application

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Abstract

There are different types of compost used as soil conditioners and fertilizers. Plants can have different responses to different forms of compost. This field study was performed to examine the effects of different types of compost on growth factors of three dry rangeland species (Atriplex, *Atriplex lentiformis*; Saltwort, *Seidlitzia rosmarinus*; Haloxylon, *Haloxylon persicum*) and soil properties. The experiment was conducted in the Fars Province of Iran during the year 2010-2011. Compost applications consisted of compost tea, solid compost (SC), solid and liquid mixture (MX) and no compost as the control. The study was a factorial experiment based on a randomized complete block design with 3 replications. The results showed that all the tested compost applications enhanced the growth traits of all three species. It was also demonstrated that the use of compost significantly increased the organic matter (1% probability level [PL]), nitrogen concentration (5% PL), phosphorous (5% PL) and potassium (5% PL) concentrations of the soil. The soil's pH level was unchanged (range, 7.3 to 7.6), and the sodium concentration was also significantly decreased (1% PL) by the use of compost. The higher responses were observed in canopy volume and soil sodium and the lower were observed in stem diameter and soil pH level. Among the three plants in the study, Atriplex showed the best response to the application of compost. Based on the results of this study, it can be recommended that the best compost application to increase growth and improve soil condition is the mixed compost (MX) for Atriplex and the SC for Saltwort and Haloxylon.

Key words: Atriplex, compost, Haloxylon, Saltwort

INTRODUCTION

Atriplex (*Atriplex lentiformis)* is native to the southwestern United States and northern Mexico, where it grows in habitats with saline or sodic soil (Pearcy et al. 1977). Several researches have investigated the ecological aspect of Atriplex (Ranjbar 1991, Emami et al. 1999, Naseri 1999, Ansari 2000, Rahbar et al. 2004, Tajali 2008). Haloxylon or white saxaul (*Haloxylon persicum*) is a small tree and Saltwort (*Seidlitzia rosmarinus*) is a halophyte plant, both of which belong to the Amaranthaceae family. Haloxylon is distributed in Middle and Central Asia, Iran, Turcomania, from Aralo-Caspian to Amu Darya, the lowland areas of Central Asia and China (Huang 2000). Haloxylon species, which grow in dry rangelands and deserts, were planted in Iran Central Falat for sand dune stabilization (Rad et al. 2006). Several earlier studies investigated the ecology of Haloxylon in Iran (Sabeti 1976, Rahbar 1987, Rad et al. 2006). Saltwort is a perennial woody plant grown mostly along the banks of salt marshes and in soils with high saline water tables. It plays an important role in both soil preservation and maintenance (Hadi 2009).

The above species are tree rangeland species that are widely present and cultivated in dry land world pastures.

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In this situation, composting, which has beneficial effects on water maintenance, can be helpful. Compost has been widely used as soil conditioners and soil fertilizers. This practice has been recommended, since soil fertility needs to be sustained (Irvine et al. 2010).

Compost has several beneficial effects as a nutrient source for plant production and does not have deleterious impacts on soil and plant (Hua et al. 2008). Compost contains many enzymes and hormones that can promote plant growth. The usefulness of different types of compost has been demonstrated and positive effects on the growth of crops have been reported such as wheat (Mantovia et al. 2005), barley (Renoux et al. 2007), rice (Rigi 2003), maize (Rezvantalab et al. 2008), sunflower (Anosheh et al. 2010), soybean, cowpea (Araújo et al. 2007), and lentil (Shahhosseini et al. 2010). This effect was also reported for vegetative plants, such as pepper, cauliflower (Casado-Vela et al. 2006), rapeseed and ryegrass (Renoux et al. 2007). Compost also has a significant effect on soil properties. Several studies have documented the beneficial effects of the application of composting operation on several types of soil with proper amendment rate (Singh and Agrawal 2007). Also, it has been reported that composting can stabilize the organic matter and decrease the risks of heavy metals (Planquart et al. 1999).

This study was conducted to better understand how dry rangeland species, such as Atriplex (*Atriplex lentiformis*), Saltwort (*Seidlitzia rosmarinus*) and Haloxylon (*Haloxylon persicum*), respond to application of compost tea and solid compost or solid and liquid mixture (MX) and to examine and compare the effects of these compost types on soil properties and plant growth.

MATERIALS AND METHODS

A field study was carried out to examine the effects of different compost types on growth parameters of three dry rangeland species (Atriplex, *Atriplex lentiformis*; Saltwort, *Seidlitzia rosmarinus*; Haloxylon, *Haloxylon persicum*) and soil properties. The experiment was performed in the Fars Province, Iran, during the year 2010. The site of the experiment was Neiriz (29°36′ N, 53°59′ E). The area has an arid climate. It was fenced in and thus kept from grazing livestock.

The study was a factorial experiment based on a randomized complete block design with 3 replications. Compost applications included compost tea (CT), solid compost (SC), MX and no compost as the control. Descriptions of the CT and SC preparations are given in Tables 1 and 2, respectively. Amounts of compost used in each replication for CT and the SC treatments were 2 and 5 kg, respectively. Quantities were 2 kg CT and 5 kg SC for the mixed compost treatments, and the control treatment did not contain any compost.

Before the experiment was started, soil analysis was performed to determine soil properties. Soil samples were taken from a depth of 0-30 cm around the rhizosphere, using metal cylinders. The soil texture was sandy clay with pH 7.05, organic matter, electrical conductivity and total nitrogen 0.70%, 1.34 d/Sm, 0.06%, respectively.

At the end of the study, measurements were taken to assess morphological traits; plant height, stem diameter, plant volume, length, width and area of the plant crown. Plant height was measured from the soil's surface to the highest free standing point of the crown. Crown length was measured at its widest point, and the lower crown diameter was measured as the width of a plant's crown. The area of the plant crown was calculated using Eq. 1 (Bonham 1989):

$$CA = \pi \times r^2 \quad (1)$$

where *CA* is the crown area, π is the ratio between the circumference and the diameter of any given circle, it is

Table 1. Characteristics of the solid compost that was used in the experiment*

Used substance	Amount (kg)
Sheep manure	227
Cow manure	420
Poultry manure	144
Dried leaves and stems	841
Fruit wastes	195
Vegetation wastes	195
Sawdust	64
Straw	64
Cardboard and paper	130
Molasses and bagasse	130
Lime	14
Fish powder	2
Animal wastes (poultry, fish, and shrimp)	5

*Total mass weight of solid compost was 2,481 kg.

Table 2. Characteristics of the liquid compost (compost tea) that was used in the experiment

Used substance	Amount
Solid composts (kg)	10
Fish powder (kg)	2
Water (L)	2,000

equal to 3.14159, and r is calculated using Eq. 2 (Bonham 1989):

$$r = \frac{HD + LD/_{2}}{2} \qquad (2)$$

where r is the radius of the plant canopy, HD and LD are the higher and lower plant diameters. The average of HD and LD is considered as the diameter of a circle and its fraction divided by 2 is considered as the radius of a circle. Plant volume was defined and presented as the point of maximum cylindrical volume for each respective plant species and was calculated using Eq. 3 (Hock et al. 2006):

$$PV = CA \times h \qquad (3)$$

where PV is the plant volume (cm^3), CA is the area of each plant crown and h is plant height. Soil characteristics were determined by soil analysis, which included soil organic matter (according to methods described by Cambardella and Elliott 1992), soil pH level (based on description of Clark 1965), nitrogen, phosphorous, sodium, and potassium concentrations (using by atomic absorption, Nouri et al. 2009).

Data were subjected to analysis of variance (ANOVA) and significant differences between the treatment means were determined using the least significant difference test at $P < 0.01$ probability level (PL) by the SAS ver. 9.1 software (SAS Institute, Cary, NC, USA). The correlation between the traits was assessed using MINITAB ver. 14.

RESULTS

Statistical analysis

Results of ANOVA

Data analysis of variance showed that the compost had significant effects on plant height (1%), stem diameter (5%), length, width, area and volume of canopy (1% PL), illustrated in Table 3. The effect of compost application on all growth characteristics (i.e., plant height, stem diameter, length, width, area, and volume of canopy) was found to be statistically significant at the 1% or 5% PL. There was no significant effect on morphological traits for interactions, except on canopy volume (Table 3).

In relation to soil properties, plant species were significantly affected by soil nitrogen concentration at the 5% PL, and its effect on other soil traits was non-significant, as shown in Table 4. The effect of compost applications on

Table 3. Statistical analysis of the morphological traits of arid region species subjected to different compost applications

Source of variance	Degree of freedom	Mean square					
		Plant height	Stem diameter	Canopy length	Canopy width	Canopy area	Canopy volume
Replication	2	168.25	0.299	56.44	290.25	0.033	0.0024
Plant species (S)	2	3,314.33**	1.715*	1,174.78**	1,015.58*	0.158*	0.013**
Compost application (C)	3	1,447.21**	1.396*	1,329.41**	1,484.25*	0.209**	0.049*
Interaction S × C	6	24.30^{ns}	0.299^{ns}	232.41**	325.81^{ns}	0.042^{ns}	0.037*
Error	22	97.10	0.238	83.69	227.61	0.018	0.0026
Coefficient variance (%)		15.21	24.56	14.56	24.57	19.57	21.32

*Significant at 5% probability levels, **Significant at 1% probability levels.
ns, non-significant.

Table 4. Statistical analysis of the soil properties of arid region species subjected to different compost applications

Source of variance	Degree of freedom	Mean square					
		PH	Organic matter	Nitrogen	Phosphorous	Potassium	Sodium
Replication	2	0.102	0.069	0.0163	2.11	9807.19	0.0003
Plant species (S)	2	0.012^{ns}	0.480^{ns}	0.0433*	4.53^{ns}	1419.53^{ns}	0.0009^{ns}
Compost application (C)	3	0.193^{ns}	5.471**	0.0515*	52.48*	48907.44*	0.0015**
Interaction S × C	6	0.171^{ns}	0.668^{ns}	0.0395*	3.79^{ns}	2234.82^{ns}	0.0000^{ns}
Error	22	0.289	0.480	0.0119	9.93	7547.29	0.0000
Coefficient variance (%)		8.80	21.65	27.16	15.14	17.12	12.80

*Significant at 5% probability levels, **Significant at 1% probability levels.
ns, non-significant.

soil organic matter (1% PL), soil nitrogen concentration (5% PL), and soil phosphorous amount (5% PL), soil potassium amount (5% PL) and soil sodium concentration (1% PL) was found to be statistically significant. Only soil nitrogen concentration was significantly affected by the interaction of compost with species (Table 4).

Correlation results

The correlation between the measured traits is shown in Table 5. All growth traits were positively correlated, but there was a significant correlation among some soil properties. Correlations among the growth traits and soil properties were different. Soil pH showed the lowest significant correlation and was correlated negatively with sodium (-0.171). However soil sodium concentration showed the highest significant correlation and was negatively correlated with all growth and soil traits.

Growth characteristics

Plant height

Saltwort was a shorter plant (average, 45.75 cm) than Atriplex (average, 71.92 cm) and Haloxylon (average, 76.58 cm). This trend in all compost types was similar (Fig. 1). Compost application for any type of compost enhanced the plant height compared to the control treatment, and among composts, the CT had greatest effect on plant height. The effect of soil compost and mixed compost were close together. Overall, the tallest plants grown in the experiment were Atriplex and Haloxylon in the SC treatment (Fig. 1a).

Stem diameter

The difference between stem diameter of Atriplex (average, 2.3 cm) and Haloxylon (average, 2.1 cm) was non-

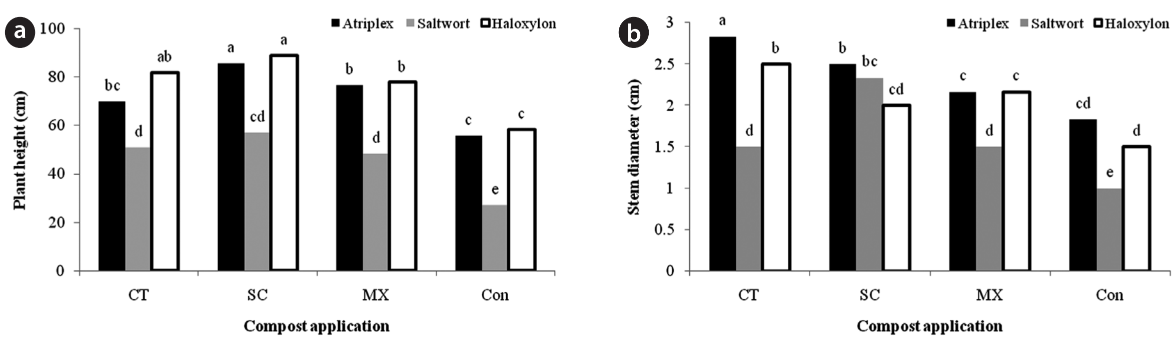

Fig. 1. Responses of Atriplex, Saltwort, and Haloxylon plant height (a) and stem diameter (b) to compost application. There were no significant differences between columns with similar letters. CT, compost tea; SC, solid compost; MX, mixture compost; Con, control.

Table 5. Correlation between measured traits for both growth characteristics and soil properties

	Pt	SD	CW	CL	CA	pH	OM	N	P
SD	0.675^{**}								
CW	0.769^{**}	0.566^{**}							
CL	0.679^{**}	0.485^{**}	0.73^{**}						
CA	0.721^{**}	0.509^{**}	0.9^{**}	0.939^{**}					
pH	0.161^{ns}	0.054^{ns}	0.123^{ns}	0.06^{ns}	0.092^{ns}				
OM	0.22^{ns}	0.231^{ns}	0.349^{*}	0.329^{*}	0.362^{*}	0.079^{ns}			
N	0.401^{*}	0.107^{ns}	0.429^{**}	0.181^{ns}	0.287^{ns}	0.023^{ns}	0.255^{ns}		
P	0.264^{ns}	0.239^{ns}	0.293^{ns}	0.227^{ns}	0.257^{ns}	0.035^{ns}	0.394^{*}	0.282^{ns}	
K	0.215^{ns}	0.214^{ns}	0.326^{*}	0.313^{*}	0.321^{*}	-0.094^{ns}	0.392^{*}	0.396^{*}	0.212^{ns}
Na	-0.459^{**}	-0.384^{*}	-0.458^{**}	-0.479^{**}	-0.437^{**}	-0.171^{*}	-0.47^{**}	-0.523^{**}	-0.508^{**}

*Significant at 5% probability levels, **Significant at 1% probability levels.
Pt, plant height; SD, stem diameter; CW, canopy width; CL, canopy length; CA, canopy area; pH, soil pH; OM, organic matter; N, nitrogen; P, phosphorous; K, potassium; Na, sodium; ns, non-significant.

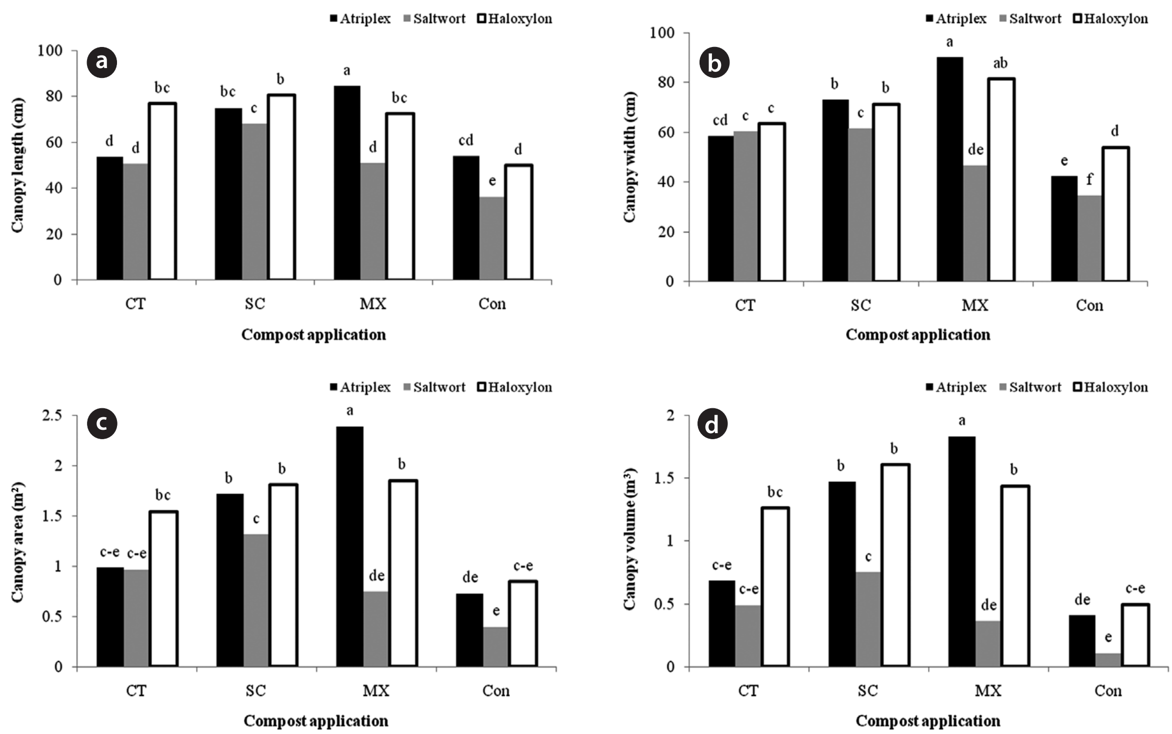

Fig. 2. Responses of canopy length (a), width (b), area (c), and volume (d) of Atriplex, Saltwort, and Haloxylon to compost application. There were no significant differences between columns with similar letters. CT, compost tea; SC, solid compost; MX, mixture compost; Con, control.

significant and higher than Saltwort (average, 1.6 cm). Compost significantly increased stem diameter of each species when compared to the control treatment. There was no significant difference among the three compost types (CT, 2.28 cm; SC, 2.29 cm; and MX, 2.00 cm). In this respect, CT was the most effective on Atriplex and Haloxylon and SC was the best treatment for Saltwort. The thickest stem was observed in Atriplex treated with the CT (Fig. 1b).

Canopy length and width

Atriplex and Haloxylon had higher canopy lengths (66.8 cm and 70.0 cm, respectively) and widths (65.9 cm and 67.5 cm, respectively) than Saltwort (51.5 cm and 50.8 cm, respectively). Plant canopy length and width was increased by compost application. The effect of CT on canopy length was higher than that for the other compost types, but in terms of canopy width, there were no significant differences among the compost types.

There were no significant differences between canopy length and width of plants treated with CT, but in other compost types, significant differences were observed (Fig. 2a and 2b). The better compost types for canopy length (Fig. 2a) and width (Fig. 2b) of Atriplex, Saltwort and Haloxylon were the mixed compost (MX), CT and mixed compost (MX), respectively. Atriplex had the highest canopy length and width when treated with mixed compost (MX) when compared to other the compost treatments.

Canopy area and volume

Results of the effect of plant species and compost application on canopy area and volume were similar (Fig. 2c and 2d). Accordingly, higher canopy length and width were recorded in Atriplex and Haloxylon, which also had greater canopy areas (on average 1.4 m^2 and 1.5 m^2, respectively) and volume (on average 1.1 m^3 and 1.2 m^3, respectively) than Saltwort (on average 0.85 m^2 and 0.42 m^3, respectively). Compost application resulted in an increase in the area and volume of the canopy. In addition, mixed compost and SC had higher effects on canopy area (Fig. 2c) and volume (Fig. 2d), respectively, when compared to the others. Overall, the highest canopy area and volume was obtained in Atriplex treated with the mixed compost.

Soil properties

Soil pH

There were no significant differences among plants and composts, in terms of soil pH levels (Fig. 3a). On average, the soil pH for all treatments ranged from 7.3 to 7.6.

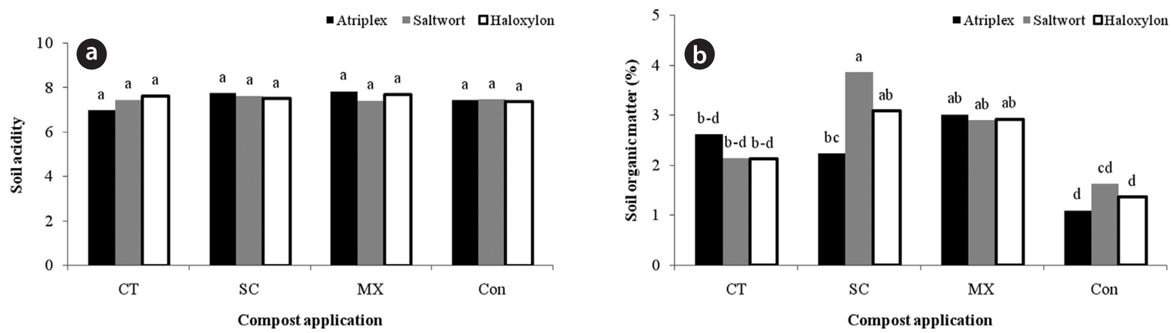

Fig. 3. Effect of compost application on the soil pH (a) and organic matter (b) of the soil on which Atriplex and mesquite with different compost treatments were grown. There were no significant differences between columns with similar letters. CT, compost tea; SC, solid compost; MX, mixture compost; Con, control.

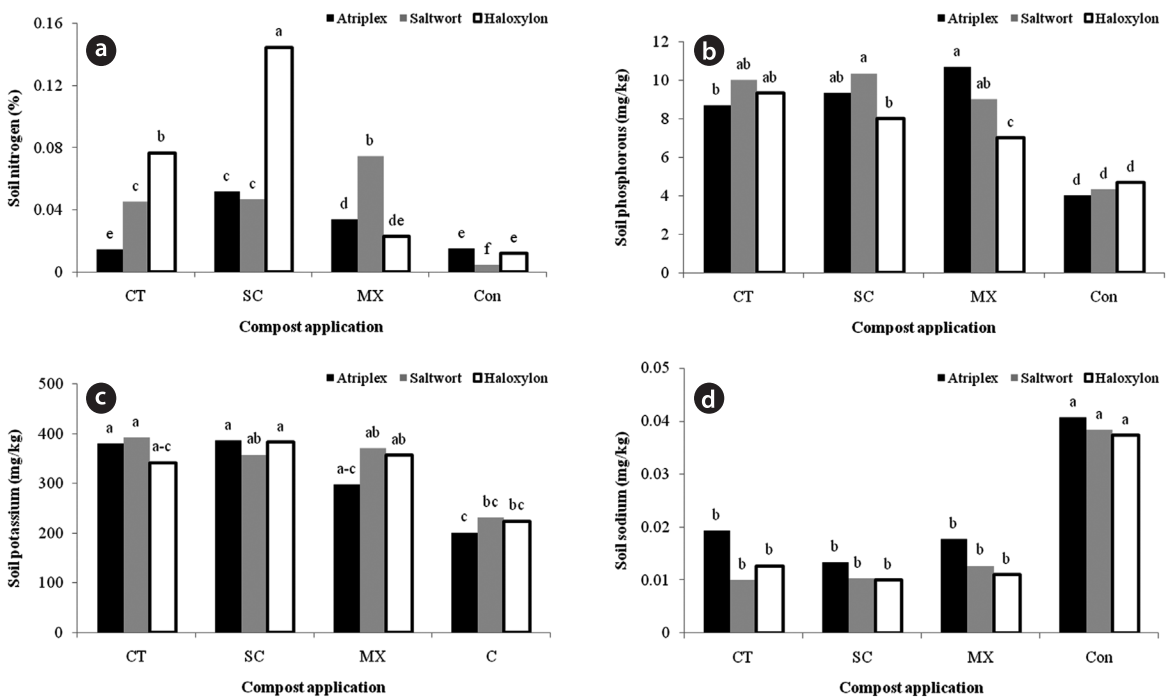

Fig. 4. Effect of compost application on soil content element (a, nitroegn concentration; b, phosphorous; c, potassium; and d, sodium) on which Atriplex and mesquite with different compost treatments were grown. There were no significant differences between columns with similar letters. CT, compost tea; SC, solid compost; MX, mixture compost; Con, control.

Soil organic matter

Organic matter concentrations in the soil of all three species were similar and there was no significant difference. Compost application could increase soil organic matter and the CT plots had higher organic matter concentrations. There was no significant difference between the SC (on average, 3.0%) and the mixed compost (on average, 2.9%) compost type. The responses of the three plant species to compost type did not show a clear trend (Fig. 3b); nonetheless, the mixed compost was the most effective compost for Atriplex and Haloxylon and the SC was the most effective for Saltwort.

Soil nitrogen concentration

Haloxylon plots had higher soil nitrogen concentrations (on average, 0.064%) than Saltwort and Atriplex (average, 0.042% and 0.028% respectively without significant difference). But the SC plots had higher nitrogen contents than the controls (plots without compost application) and nitrogen concentration in the other compost types was similar to the control treatment. The differences among the response of plant species to compost application were remarkable, where the responses of Atriplex and Haloxylon to the SC was high and the response of Saltwort to the mixed compost was high (Fig. 4a). Haloxylon treated with

SC had exceptionally high nitrogen content.

Potassium and phosphorous concentrations

There were no significant differences between the plant species in terms of soil phosphorous and potassium concentrations. Compost application could increase phosphorous (on average, 9.1 mg/kg vs. 4.3 mg/kg) and potassium concentration (on average, 363.1 mg/kg vs. 218.7 mg/kg) of the soil, but no significant differences was observed among the types of compost. Effects of interaction of plant species with compost applications on soil nutrition were not significant (Table 4) as were the responses of the three plant species to compost types (Fig. 4b and 4c). Differences between phosphorous concentrations (Fig. 4b) in the three plants as a result of compost application were higher compared to the results for potassium (Fig. 4c).

Soil sodium concentration

There were no significant differences between the three plant species in any of the compost levels in terms of soil sodium concentration (on average Atriplex, 0.028%; Saltwort, 0.042%; Haloxylon, 0.064%). Compost application decreased sodium concentration in the soil when compared to the control treatments, but there were no significant differences between the three types of compost. The soil in all three treatments of plant species had higher sodium concentrations than the control treatments (Fig. 4d).

DISCUSSION

Atriplex were first planted in Iran to improve and develop the rangeland about 35 years ago (Tajali 2008). Haloxylon establishes and survives under extremely hostile conditions that are intolerant to other plant species (Rahbar 1987).

In this study, the main effects of plant species and compost application on all growth characteristics were significant and there was no significant interaction effect.

For all of the growth characteristics (as shown Tables 3 and 4), Atriplex and Haloxylon had higher values than Saltwort and there were no significant differences between these two plants. The greater canopy recorded for Atriplex could be attributed to its shape and size. It is a spreading, communal shrub reaching more than three meters in height and generally more than that in width (Pearcy et al. 1977). Furthermore, Haloxylon is a hardy tree that can grow in nutritionally poor soil and can tolerate drought (Huang 2000); so its growth is not restricted by hostile conditions. In contrast, Saltwort is a halophyte plant that is very well adapted to grow in dry and salty desert soil (Hadi 2009) and it has a low canopy that does not produce dense forage.

However, the composting operation increased the growth of all three species (see Figs. 1 and 2). The response of the plants to each of the tested compost types was similar, so for all plants, the results for growth (height) were highest (on average, 77.1 cm) and lowest (on average, 47.0 cm) under solid composting and control conditions, respectively. The stem diameter of Atriplex and Haloxylon was higher when treated with CT but the most effective treatment for Saltwort was SC. In addition, the stem diameter of Atriplex and Haloxylon in all compost treatments increased when compared to the control. With respect to Eqs. 1 and 3, the canopy area and volume depended on canopy length and width. These results were in agreement with previous studies that reported enhanced the vegetative growth of Barley (*Hordeum volgure* L.) (Kumawat et al. 2006), Maize (*Zea mays* L.) (Jat and Ahlawat 2004), Papaya (*Carica papaya* L.) (Acevedo and Pire 2004), Sorghum (*Sorghum bicolor*) (Cavender et al. 2003) and in Canola (*Brassica napus*) (de Freitas et al. 1997), Gram (*Cicer arietinum*) (Jat and Ahlawat 2004) and Sunflower (*Helianthus annuus* L.) (Anosheh et al. 2010) after biofertilizer application. Plant performance was also found to be considerably better due to compost application in a study by Wong et al. (1999).

Responses of plants to different compost applications, in terms of canopy covering, were not similar, and the biggest difference was demonstrated in CT. SC was the most effective treatment in regards to canopy length and width. Since compost application increases nitrogen availability (Inckel et al. 2005), this may be attributed to increased foliage due to plant growth. Furthermore, compost contains many nutrients that decompose and become available for plant use (Pattnaik and Reddy 2010). The effects of plant species on soil nitrogen concentration of compost application on organic matter, nitrogen concentration, phosphorous, potassium concentration and sodium concentration of soil and the interaction effect of species and compost on soil nitrogen concentration was significant (Table 4). The soil pH level was unchanged when composting was used for all three plants, which was likely due to high soil buffering. The organic matter of plants treated with all types of compost was increased when compared to the controls. Organic matter is a key factor needed to improve the structure of soil. The highest organic matter was observed in CT for Atriplex and in SC for Saltwort and

Haloxylon. There was no significant difference among the plants in the mixed compost (MX), in terms of organic matter.

Inckel et al. (2005) demonstrated that compost application could enhance the organic matter in soil. The study asserted that organic matter contains a substantial amount of nutrition important for plant growth, and these improve the water maintenance capacity of soil. Thus, it is possible that the compost treatments that had higher organic matter contents improved plant performance and soil properties. Compost increased soil nutrition, that is to say nitrogen, phosphorous and potassium, but the variation in nitrogen concentrations was higher than in phosphorous and potassium. Another study reported that nutrient availability increased incrementally according to composting application (Soumaré et al. 2002) and treated plants performed better when compared to the controls.

In terms of nitrogen, SC was recommended for use with Atriplex and Haloxylon and the mixed compost was the best for Saltwort. SC is ready for use after about six weeks. In terms of phosphorous and potassium, differences among compost types and plants were negligible. In this respect, Sundara et al. (2002), Soumaré et al. (2002), Cavender et al. (2003), Jat and Ahlawat (2004) and many researchers hold the opinion that bio fertilizers, such as compost, improves soil characteristics and soil nutrition contents. The advantage of compost in terms of nutrition is that it facilitates the slow release of nutrients, which extends the long term benefits of compost treatment (Inckel et al. 2005).

In contrast to all earlier studies, compost treatment was shown to decrease soil sodium concentration; nevertheless this reduction also benefits plant growth. Because of the high levels of sodium in the soil solution, a plant's ability to uptake water is limited due to decreased soil water holding potential (Subbarao et al. 2003); therefore, this might cause plants to wilt. There were no significant differences among all treatments, except the three plants that were grown in the controls. Although there are nitrogen, sodium, chlorides, and sulfate salts present in SC (Zhang et al. 1998), the amount of sodium was lower than the amount of the other elements. Higher soil sodium within the cytoplasm of the cells can lead to enzyme inhibition, which may result in symptoms such as necrosis, chlorosis, and possible plant death (Pessarakli 2001). So, compost application could be used to combat the destructive and harmful effects of sodium in soil.

CONCLUSION

Atriplex and *Haloxylon* spp. are dry rangeland species and there were no considerable differences in most of the physiological traits, although the demonstrated higher growth than Saltwort. A similar trend was demonstrated in soil properties. Compost application increased plant growth and improved soil properties, effects that facilitated good plant performance. This can be attributed to the fact that compost is a ready decomposed material. The results of this study showed that all types of compost tested effectively enhanced the growth traits of all three species of plants in this study. Among the plants that were tested, Atriplex was the most affected by applications of compost. Compost treatment enhanced organic matter, nitrogen, phosphorous and potassium concentrations of the soil. Furthermore, compost improved the physical properties of the soil; bulk density, soil structure, and soil water maintenance capacity. However, the soil pH level was unchanged and sodium concentrations decreased with compost application.

These results demonstrate that compost application in soils, especially soil compost, was an effective method to supply nutritions for plant growth. Compost is used in combination with chemical fertilizers in advanced agricultural systems. Finally, from the results of this study it can be recommended that the best compost application to increase growth and improve soil conditions were mixed compost (MX) for Atriplex and SC for Saltwort and Haloxylon.

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