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Determination of the Best Compost Tea Concentration as a Potential Method to Maximize the Growth of Two Artemisia and Salsola Species in Dryland Region

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ABSTRACT- Little information is available on the effects of applying compost tea to species in dry regions. Compost from agricultural waste can promote drought resistance in plants and increase their growth by improving soil structure and providing nutrients and enhancing the capacity of the soil to store moisture. In order to examine these effects, compost tea was tested on two species growing in dry regions (mountain sagebrush, *Artemisia aucheri* and Salsola, *Salsola tomentosa*) at 5 various concentrations; 0, 10, 20, 30 and 40 (m^3/ha). This research was conducted as a field study at Neiriz (29º 36'N, 53º 59'E, altitude 1776 m) in Fars province, Iran, during the 2009-2010 growth season. The experiment was factorial, based on a randomized complete block design with 10 treatments and 3 replications. The results showed that compost application increased plant height (25.1%), crown diameter (10.5%), and fresh (7.0%) and dry (5.9%) weights up to a concentration of 40 m^3/ha, compared with the control (without compost). It was also found that bulk density, electrical conductivity and soil organic matter all increased after the application of compost. In some cases (e.g. crown diameter and fresh and dry weight), a high concentration of compost had negative effects, which might have been due to osmotic potential. *Salsola* responded better to compost application than *Artemisia*. Overall, 30 m^3/ha was the most effective concentration of compost tea to stimulate growth increase of *Salsola* and *Artemisia* in dryland conditions.

Keywords: Bulk density, Crown diameter, Electrical conductivity, Organic carbon

INTRODUCTION

Drought stress is the main environmental factor with an adverse effect on plant growth and productivity in dry regions. A major challenge in such areas is overcoming the effects of droughts in an economically and environmentally sustainable way (17). Application of bio fertilizers such as compost can promote a plant's resistance to drought and stimulate plant growth via improved soil structure by provideing nutrients and enhancing the water holding capacity of the soil (26).

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Therefore, application of compost to the soil affects a wide array of agronomic and physiological characteristics and is therefore a crucial component for any sustainable agricultural system (5).

Compost is used as an organic fertilizer, examples of which are vermicompost, sewage, seaweed, coffee pulp, domestic waste, solid compost and compost tea otherwise known as liquid compost (14). Using compost tea has the advantage of quickly providing a plant with adequate natural plant food during its growth season. Liquid manure and plant teas are ready for use after two or three weeks (3).

Compost tea can be either applied directly to the soil or to the plant's foliage. Direct application to the soil will move it into the root zone and affect the rhizosphere of the plant (3). Compost tea is essential for plants that grow in restricted environments such as dry regions because if the roots are damaged they cannot take up enough nutrients; as such,liquid compost tea provides the means for the rapid supply of nutrients (14).

Wong et al (28) reported that compost application increases the availability of macro-nutrients (such as N, P, K, Ca, P and Mg) and micronutrients (such as Mn, Zn and Cu) in chinese cabbage *(Brassica chinensis)* and maize *(Zea mays* L.*)*, and this increase varies according to different concentrations of compost. In another study Singer et al., (24) demonstrated that compost application improved maize growth and increased P and K contents in plant tissue. Compost tea concentration has also been investigated with variable results. Elad and Shtienberg (10), as well as Cronin et al., (8) demonstrated that every concentration of compost tea was helpful for plant growth.

Mountain sagebrush, (*Artemisia aucheri)* and Salsola (*Salsola tomentosa*) are two native-growing plants, which are widely used in Iranian traditional medicine. Salsola is a permanent plant belonging to the *Chenopodiaceae* family; growing widely in many areas of Iran (19).

There is very little available information on the effects of compost tea application to dry region species. The aim of this study was to examine the effects of different concentrations of compost tea on growth and morphological and soil characteristics of two dry land species, *Artemisia aucheri* and *Salsola tomentosa*.

MATERIALS AND METHODS

Experimental Description

A field study was carried out to examine the effects of different concentrations of compost tea on the growth of two dry region species (Mountain sagebrush, *Artemisia aucheri* and Salsola *Salsola tomentosa*) and the soil properties in Tam-shouli Research Central, Fars Province, Iran, during the year 2009-2010 (24th February 2009 – 2010 30th February, 2010). The site of the experiment was located at Neiriz City (29^{o} 36' N, 53^{o} 59' E, at an altitude of 1776 m above sea level). The region was semi-desert with hot summer weather and a temperate winter climate (Table 1). The area was fenced and protected therefore it was not grazed upon.

The study was a factorial experiment based on a randomized complete block design with 10 treatments in 3 replications. The treatments included concentrations of compost at five levels: 0 (without compost, as the control), 10, 20, 30 and 40 m^3/ha and two plant species: *Artemisia aucheri* and *Salsola tomentosa*. Before the study, plants at the same growth stage (with similar biomass) were selected for the experiment.

Table 1. Weather characteristics of the experimental site at Neiriz, Fars province, Iran during the study period (annual and mean of 10 years)

Month	Rain (mm)		Mean Temperate(°C)		Mean Humidity (%)		Evaporation (mm)	
	Annual	10-yrs	Annual	10-yrs	Annual	10-yrs	Annual	10-yrs
April	17.6	31.99	18.0	16.58	39	40.65	217.1	193.80
May	4.7	5.93	22.6	22.47	32	29.10	263.5	277.45
June	0.0	0.14	28.8	30.86	18	21.85	429.1	443.95
July	0.0	2.46	21.8	29.88	16	20.70	484.2	482.35
September	0.0	12.58	28.6	27.26	18	23.05	438.7	458.05
October	0.0	0.19	27.0	22.38	21	24.70	356.7	272.10
November	0.01	0.0	23.6	16.25	25	26.00	250.1	263.05
December	0.0	5.81	15.9	10.42	27	36.87	160.6	158.3
January	0.0	36.08	11.0	7.31	23	47.55	90.5	73.75
February	17.5	45.49	7.8	7.31	43	54.20	57.3	37.65
March	13.21	36.11	7.5	8.80	61	52.25	45.2	55.6
September	30.7	20.63	15.2	13.30	39	43.00	106.0	128.9

Compost Tea Preparation

Compost tea or liquid compost was prepared by solid compost, based on Inckel et al., (14) with slight modification. For this, 1000 liters of water and 15 kg of residue and livestock waste (cattle manure) were used (Table 2). The amount of time taken for preparing the compost was 6 to 8 hours. A bundle of straw was placed in the heap to test the compost water; if turned clammy after 5 min, the moisture level was considered to be good. If it was still dry, the moisture level was considered as too low. Prior to the beginning of the experiment compost tea was mixed with the soil (14).

Table 2. Chemical properties of compost tea used in the experiment.

Characteristic	Acidity pH	EC† dS m^{-1}	P	K	Fe	Zn	Cu	Pb	Br	Cd
			Mg kg^{-1}							
Values	7.54	3.24	9160	35000	8423	286	175	0.053	27.4	0.006

†- **EC**, Electrical conductivity; **P**, Phosphorus; **K**, Potassium; **Fe**, Iron; **Zn**, Zinc; **Cu**, copper, **Pb**, Massicot; **Br**, Bromine; **Cd**, Cadmium

Samplings and Measurements

Before the experiment, soil analysis was carried out to determine soil properties. The soil texture was found to be sandy clay with a pH = 7.15 and EC=1.87 dS m^{-1}. Soil samples were taken from 0-30 cm depths around the rhizosphere, using metal cylinders. At the end of the study, measurements were taken for the following morphological traits; plant height, plant crown length, and dry and fresh weight. Plant height was measured from the soil surface to the highest freestanding point of the plant's crown. The plant's crown length was measured at its widest point. Water content was measured using the following formula.

$$WCd = \frac{FW - DW}{DW}$$

Where WCd is water content based on dry weight, and FW and DW are fresh and dry weights respectively. Also, soil characteristics were determined from a soil analysis, which included soil organic matter (according to methods described by Cambardella and Elliott, 1992), soil acidity (7), electrical conductivity (using an EC meter and based on Rhoades et al., 1999) and bulk density (using the core method; 4).

Statistical Analysis

The collected data were subjected to polynomial regression, order 2 and significant differences between the treatment means were determined by an LSD (least significant difference) test at a $P \leq 0.01$ probability level by SAS (*V. 9.1*) Software. Correlational analysis between the traits was carried out by MINITAB (*v. 14*).

RESULTS AND DISCUSSION

Morphological Traits

Compost tea application increased plant height in both species as compared to the control, and these increases were commensurate with compost concentrations (Fig. 1A). In *Salsola,* by increasing compost concentrations, growth also increased, as the tallest *Salsola* plants were recorded in the fifth treatment. However, this trend was not replicated in *Artemisa*, as 40 m^3/ha compost decreased plant height and 30 m^3/ha (the fourth treatment) resulted in the tallest plants. On average, plant height for *Salsola* was more than that of *Artemisia. The* regression between compost concentration and plant height for both species was significant.

Although the trends of changes in crown diameters of *Salsola* and *Artemisia* were similar; the response of *Salsola* was higher than that of *Artemisia*, as shown in Figure 1B. In both species compost applications increased crown diameter; and the effect of compost application was related to its concentration. The highest crown diameters in *Salsola* and *Artemisia* were observed in plants grown under 20 and 30 m^3/ha applications of compost tea, respectively. On average, the crown diameter of *Salsola* was larger than that of *Artemisia.*

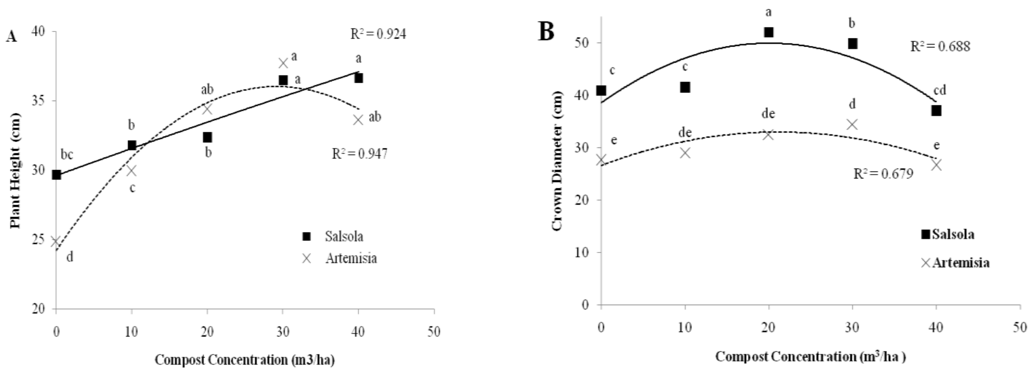

Fig. 1. Changes in plant height (A) and crown diameter (B) of *Salsola tomentosa* and *Artemisia aucheri* that treated with different compost concentration (m^3/ha), Means followed by similar letters are not significantly different (LSD ≤ 0.05)

Compost application enhanced the fresh and dry weights, and these enhancements were associated with the concentrations of the compost (Fig. 2A and B). In *Salsola*, compost application increased fresh weight and to a lower degree, the dry weight up to the concentration of 30 m^3/ha. After that a reduction was observed. In the comparison between dry weight and fresh weight, a sharp drop was observed in the last treatment. In *Artemisia*, compost application increased fresh weight, but this response was lower than that of *Salsola* (Fig. 2A). Changes in dry weight, as affected by compost application and among different concentrations, were not significant (Fig. 2B). On average, *Salsola* had greater amounts of fresh and dry weights as compared to *Artemisia*.

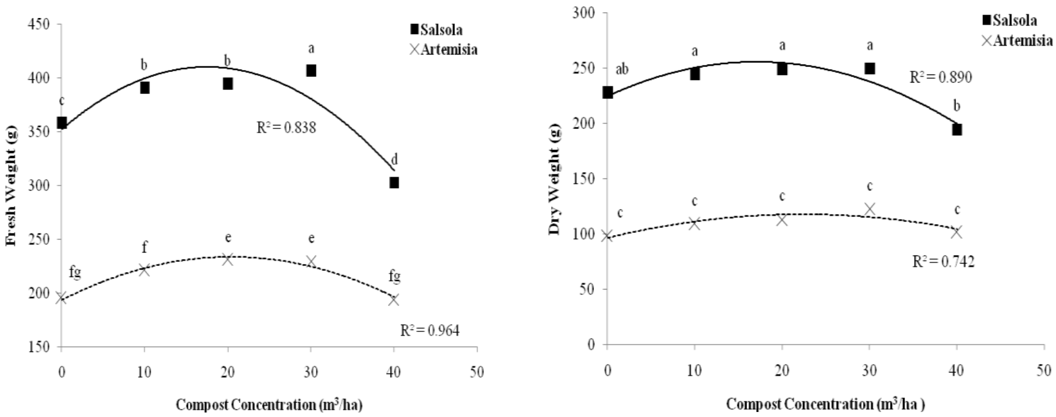

Fig. 2. Changes in fresh (A) and dry weight (B) of *Salsola tomentosa* and *Artemisia aucheri* that treated with different compost concentration (m^3/ha), Means followed by similar letters are not significantly different (LSD ≤ 0.05)

Among the morphological traits, only dry weight was significantly and positively correlated with both fresh weight and crown diameter (Table 3).

Table 3. Correlation between soil and morphological traits

	BD†	OC%	EC	pH	Ht	Cr	FW
OC	0.785**‡	1					
EC	0.391ns	0.075ns	1				
pH	0.1ns	-0.193ns	0.033ns	1			
Ht	0.676*	0.648*	0.068ns	-0.109ns	1		
Cr	0.391ns	0.665*	0.207ns	0.404ns	0.299ns	1	
FW	0.216ns	0.646*	0.427ns	0.39ns	0.196ns	0.945ns	1
DW	0.234ns	0.683*	0.432ns	0.365ns	0.195ns	0.929**	0.993**

†- BD, Bulk Density; OC, Organic Carbon; pH, Soil Acidity; Ht, Plant Height; Cr, Crown Diameter; FW, Fresh Weight

‡- ns is non-significant, * and ** are significant at 5 and 1% probability levels

Soil Properties

Bulk density increased significantly as affected by compost application in both plots (both species), and this enhancement was improved by increasing compost concentration (Fig. 3A). In the treatment without compost Artemisia had a higher level of soil bulk density; however, this trend was reversed by compost application (Salsola treatment had higher values). The highest amount of soil bulk density was achieved from the concentration of 40 m^3/ha for both Salsola and Artemisia. Bulk density was higher in the plots growing Salsola than those growing Artemisia. Regression between compost concentration and bulk density for both species was significant.

Compost tea application could enhance soil organic carbon, while compost concentration enhancement led to increased organic carbon levels (Fig. 3B). However, for Artemisia, the last compost concentration (i.e. 40 m^3/ha) organic matter only had a light reduction. In the treatment without compost, Salsola and Artemisia both had non-significant differences, but with compost application, differences emerged and intensified by increasing compost concentrations. On average, Artemisia plots had higher organic carbon than Salsola plots. Overally, the highest amount of soil organic carbon was observed in the Artemisia plots treated with 30 m^3/ha compost tea.

The response of soil electrical conductivity of Salsola and Artemisia plots to composttea treatments was almost similar, so in both of them electrical conductivity increased with compost application. Furthermore, electrical conductivity increased with intensified concentrations of compost (Fig. 4A). The highest amount of electrical conductivity was observed in the last compost concentration (i.e. 40 m^3/ha) for both plant species. Compost application at any concentration had a non-significant effect on soil acidity, and was the same for the plots of both species (Fig. 4B).

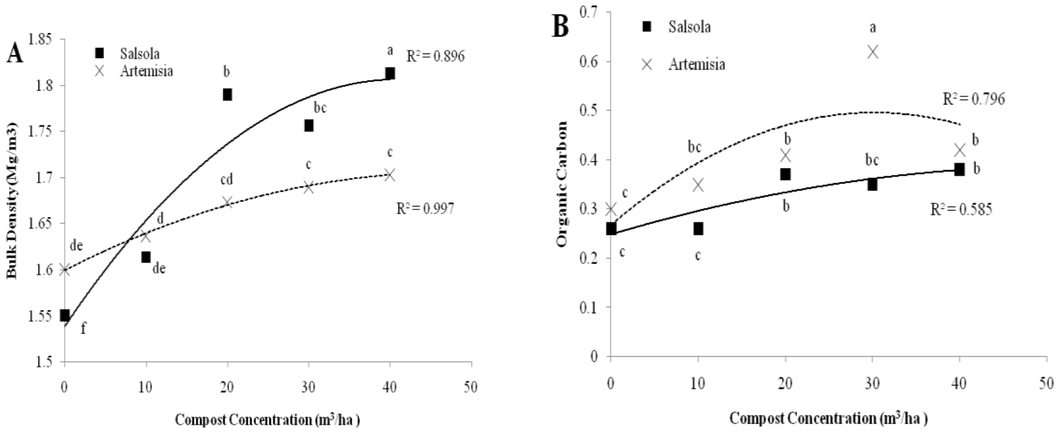

Fig. 3. Changes in soil bulk density (A) and soil organic carbon (B) of *Salsola tomentosa* and *Artemisia aucheri* plots that treated with different compost concentration(m^3/ha), Means followed by similar letters are not significantly different (LSD ≤ 0.05)

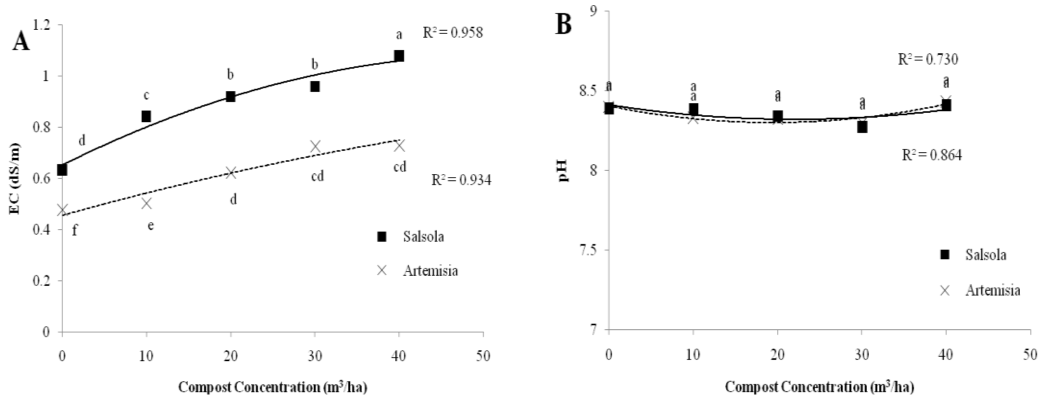

Fig. 4. Changes in soil electrical conductivity, EC (A) and soil acidity, pH (B) of *Salsola tomentosa* and *Artemisia aucheri* plots that treated with different compost concentration (m^3/ha), Means followed by similar letters are not significantly different (LSD ≤ 0.05)

Among soil characteristics, only bulk density had significant and positive correlation with organic carbon (Table 3). Between the morphological traits and the soil characteristics, organic carbon positively and significantly correlated with all growth traits. Bulk density and plant height also correlated significantly.

DISCUSSION

Considering the fact that *Salsola* has more canopy (crown width and length) and growth than *Artimisia*; *Salsola*, was more responsive to applications of compost. Although, in some conditions *Artimisia* had more growth, for example higher plant height in 0 and 40 m^3/ha compost. In the present study, compost concentration caused differences between *Salsola* and *Artimisia* plant heights. Both plant species are specific to dry regions that have high resistance to drought and salt stress (19).

In control plots those with *Artimisia* showed equal or greater soil bulk density, organic carbon and soil acidity than *Salsola*. Upon compost application, this difference was smaller and *Salsola* was higher in terms of soil characteristics. This trend might be due to the better growth rate of *Salsola* as affected by applications of compost tea.

Artimisia is a plant which is highly resistant to environmental stress, especially salinity. It has a slow and steady growth (20), leading to a lower response to the application of compost. The higher water content of *Artimisia* as compared to *Salsola* in the current study, is a possible reason for this high level of resistance to stress (Table 4).

Table 4. Effect of compost tea concentration on water content in two dry species

Species	Compost Tea Concentration (m^3/ha)					Average
	0	10	20	30	40	
Salsola tomentosa	**0.56^{g}**	**0.60^{f}**	**0.64^{e}**	**0.71^{d}**	**0.55^{g}**	**0.61^{B}**
Artemisia aucheri	**0.99^{ab}**	**1.02^{a}**	**1.04^{a}**	**0.87^{c}**	**0.91^{b}**	**0.96^{A}**
Average	**0.77^{BC}**	**0.81^{B}**	**0.84^{A}**	**0.79^{B}**	**0.73^{C}**	

†- Means followed by similar letters are not significantly different (LSD ≤ 0.05)

Compost applications enhanced the growth traits of plant height, crown diameter, and fresh and dry weights. The maximum response was observed in plant height (Fig. 1A), which increased under 10, 20, 30 and 40 m^3/ha compost tea treatment to 7.5, 9.4, 23.3 and 23.8% respectively, as compared to the control treatment (without compost). Similarly, as Arguello et al. (1) suggested, garlic height increased as a result of compost application.

Among growth traits, only plant height was higher in all compost concentrations than the control treatments (Fig. 1A), but in the other growth traits, plants treated with 40 m^3/ha compost had equal or lower growth than the controls (Fig. 1B and 2). Enhancement in compost concentration was associated with an increase in plant growth traits, up to 40 m^3/ha. The most effective compost concentrations for obtaining plant height, crown diameter, fresh and dry weights were 40, 20, 30 and 30 m^3/ha for *Salsola*, respectively. For all growth traits in *Artimisia*, the compost concentration of 30 tL/ha was the most effective.

A commensuration of growth with compost concentration was also reported in anise (*Pimpinella anisum*) by Darzi et al., (9), in chamomile (*Matricaria chamomilla*) by Azizi et al., (2) and in garlic (*Allium sativum*) by Arguello et al., (1). Li et al., (16) showed that the aboveground biomass of two turf grass species increased by compost treatment.

Several factors may have contributed to improved growth, especially the increased supply of N, P, and organic matter (14). The addition of compost to the soil can increase the soil water-holding capacity, decrease soil bulk density, increase soil aeration and root penetrability, and stimulate soil microorganism activity (13, 15 and 11). It has also been reported that compost can increase organic matter and decrease the risk of heavy metal contamination in the soil (12, 18).

The adverse impact of the highest compost concentration (e.g. 40 m^3/ha) may have been due to its role in the reduction of water absorption by plants. Since more highly concentrated compost could reduce water osmotic potential in the soil, the plant's ability to absorb water decreased. Water absorption decreases in a more negative osmotic potential (17). This phenomenon was also revealed in tissue water content. Water content in treated plants with 40 m^3/ha compost was the lowest; even lower than the control condition (Table 4). The high water content was observed in the plants that were treated with 20 m^3/ha compost.

Soil acidity remained unchanged in plots of both species and was not affected by the application of compost. Soil acidity notwithstanding, compost use increased all other soil properties such as soil bulk density, electrical conductivity and organic carbon. Results for electrical conductivity and bulk density were higher at 40 m^3/ha compost for both *Salsola* and *Artemisia*. *Artemisia* and *Salsola* plots both had increased organic carbon after the applications of 30 and 40 m^3/ha compost respectively. Compost provides a stabilized form of organic matter that improves the physical properties of the soil by increasing nutrient and water holding capacities, total pore space, aggregate stability, resistance to erosion, temperature insulation and a decrease of apparent soil density (22)

On average, bulk density in both species increased from compost tea applications of 10, 20, 30 and 40 m^3/ha to 4.0, 15.4, 13.4, and 16.9 % respectively in comparison to the control treatment. Somare et al., (25) reported that bulk density increased by two different compost concentrations, and this led to better plant growth. Wong et al., (28) documented the relationship between bulk density and compost concentration. *Salsola* demonstrated a sharp increase in bulk density in response to increasing compost concentrations.

In the current study, the improved status of the soil might be the reason for better growth as the results of compost application, and were attributed to soil organic matter (according to the correlation coefficients, Table 3). Compost tea at each concentration increased soil organic matter, and was higher in *Salsola* and *Artemisia* plots at concentrations 40 and 30 m^3/ha respectively. Most agricultural benefits of compost application to the soil are because of improved physical properties of the soil as related to increased organic matter content rather than its value as a fertilizer (23).

Electrical conductivity increased with compost use, and had the strongest relationship with compost concentration (with R^2= 0.94). Application of compost improved the chemical properties of soil including electrical conductivity, cation exchange capacity, and soil nutrient content (23). Increased soil EC as a result of compost application might be due to the high amount of total dissolved salts, known as TDS, which led to the accumulation of soluble salts in the soil (27). Our result agreed with the findings of Wong et al. (28).

CONCLUSIONS

Compost can be applied both to increase growth of Artemisia and Salsola and to improve soil properties. Improvement of soil properties led to increased plant growth. The organic matter content of the composts was high, therefore, its addition to the soil improved soil physical and chemical properties and enhanced its biological activities. Since Salsola had higher growth rate, it was more sensitive to applications of compost. However, the better concentration of compost for Salsola and Artemisia was 30 m^3/ha. Concentrations of 30 and 40 m^3/ha had the highest additive effect on growth and soil traits, respectively. With regards to economic aspects, 30 m^3/ha was the recommended concentration of compost tea for application to the plots in this study.

Nomenclature

Salsola, *Salsola tomentosa*; *Artemisia*, *Artemisia aucheri*

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تعیین بهترین غلظت کمپوست چای به عنوان یک روش بالقوه برای به حداکثر رساندن رشد دو گونه‌ی درمنه کوهی و شوربیابانی در مناطق خشک

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چکیده- اطلاعات در مورد تاثیر کاربرد کمپوست چای بر گونه‌های مناطق خشک بسیار کم است. در این نواحی کمبود آب یکی از عوامل اصلی محیطی است که به طور مضری رشد و تولید گیاهان را تحت تاثیر قرار می‌دهد. فرآیند کمپوست دهی که از ضایعات کشاورزی تهیه می شود، می‌تواند موجب مقاومت گیاهان به خشکی شود. کمپوست همچنین، از طریق بهبود ساختمان خاک، تغذیه گیاه و افزایش ظرفیت نگهداری خاک، رشد گیاه را افزایش می دهد. به منظور بررسی اثر غلظت‌های متفاوت کمپوست چای (در پنج سطح: ۰، ۱۰، ۲۰، ۳۰ و ۴۰ متر مکعب در هکتار) در کشت دو گونه گیاه منطقه خشک (درمنه کوهی Artemisia aucheri و شور بیابانی Salsola tomentosa)، یک مطالعه مزرعه‌ای در سال‌های ۱۳۸۸ و ۱۳۸۹ در مرکز تحقیقات تم شولی (شهرستان نیریز) طراحی و اجرا گردید. این پژوهش به صورت یک آزمایش فاکتوریل بر پایه طرح بلوک‌های کامل تصادفی به ۱۰ تیمار و ۳ تکرار انجام شد. نتایج این آزمایش نشان داد که کاربرد کمپوست تا غلظت ۴۰ متر مکعب در هکتار موجب افزایش ارتفاع گیاه (۲۵/۱٪)، قطر تاج پوشش (۱۰/۵٪)، وزن تر و خشک گیاه (به ترتیب ۷/۰٪ و ۵/۹٪) نسبت به تیمار شاهد (بدون کاربرد کمپوست) گردید. همچنین چگالی ظاهری، هدایت الکتریکی و محتوای کربن آلی خاک با کاربرد کمپوست در کرت‌های هر دو گونه افزایش یافت. در برخی موارد (مانند قطر تاج پوشش، وزن تر و خشک) غلظت بالای کمپوست تاثیر منفی داشت؛ که ممکن بود به دلیل ایجاد پتانسیل اسمزی منفی‌تر باشد. عکس‌العمل گونه شور بیابانی به کاربرد کمپوست در مقایسه با گونه درمنه کوهی بیشتر بود. در مجموع، نتایج این آزمایش نشان داد که غلظت ۳۰ مترمکعب در هکتار توانست بهترین غلظت برای افزایش رشد هر دو گونه شور بیابانی و درمنه کوهی در شرایط خشک بیابانی باشد.

واژه‌های کلیدی: چگالی ظاهری، قطر تاج پوشش، کربن آلی، هدایت الکتریکی

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** مکاتبه کننده