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Effect of Organic and Inorganic Amendments on Parameters of Water Retention Curve, Bulk Density and Aggregate Diameter of a Saline-sodic Soil

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ABSTRACT

To study the effects of soil amendments on physical and hydraulic properties of a saline-sodic sandy clay loam soil, a field experiment was carried out as a complete block design with three replications. The treatments in this research consisted of control (B), 10 ton ha-1 gypsum (G), 10 ton ha-1 urban solid compost (C), three levels of vinyl alcohol acrylic acid (S_1= 0.05%, S_2= 0.1%, S_3= 0.2%), CS_1, CS_2, CS_3, GS_1, GS_2, GS_3CGS_1, CGS_2, and CGS_3. Four months after applying the treatments, water contents were measured at 9 pressure heads for each treatment and data obtained were fitted to Van Genuchten equation. The parameters of this equation (i.e. θ_s, θ_r, α, and n) were determined by the least square error method. Also some physical properties including bulk density (Bd), mean weight diameter (MWD) of aggregates, plant available water content (PAWC), and the slope of water retention curve at inflection point (S index) were measured. The results showed that all treatments increased saturated water content (θ_s) significantly ($P< 0.05$) compared with the control (B). A similar trend was observed for residual water content (θ_r). The highest and lowest values of α were noted in B and S_2 treatments, respectively. *PAWCs* increased significantly in all treatments compared with control ones except for G, GS_1, GS_2, and GS_3 treatments ($P< 0.05$). Adding the soil amendments increased the values of S index and MWD and decreased Bd, significantly compared with the B treatment. It seems that the mixture of vinyl alcohol acrylic acid at 0.1% with urban solid compost or gypsum is a suitable amendment for increasing *AWC* and improving physical quality of studied saline-sodic soils.

Keywords: Gypsum, *S* index, Soil water retention curve, Urban solid compost.

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INTRODUCTION

Unsuitable physical properties of saline-sodic soils in arid and semiarid regions restrict root growth and limit plant growth and yield (Karimi and Naderi, 2007). Water holding capacity is important in semiarid and arid regions, where water shortage is very frequent and water is often the main limiting factor in cultivated areas (Andry *et al.,* 2009). Seed germination and plant growth are critically restricted because of low available soil water content and poor soil structure under saline-sodic condition. Therefore, specific soil management is necessary to improve physical properties of these soils. Application of some amendments and alternative irrigation methods are more important, especially in regions with reduced soil water availability (Abedi-Koupai *et al.,* 2008).

In most soils, organic matter is applied as a soil conditioner for increasing water holding capacity and improving soil physical properties. Hammer *et al.* (2011) compared the effect of different organic matter sources and inorganic nutrient supply and an improved soil water holding capacity via

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application of hydrophilic polymers. The strongest effect was caused by organic matter. Karhu *et al.* (2011) applied biochar to boreal agricultural soil and found that water holding capacity increased by 11%. Rawls *et al.* (2003) reported increasing organic matter content led to an increase of water retention in sandy soils, and to a decrease in fine-textured soils. At high organic carbon values, all soils showed an increase in water retention. The largest increase was in sandy and silty soils (Rawls *et al.,* 2013)**.** Ouattara *et al.* (2006) found that organic matter input improved field capacity and soil water content at wilting point.

In modern agriculture, hydrophilic polymers are used to enhance both the nutritional and water status of plants (Andry *et al.,* 2009). There are reports that hydrophilic polymers are capable of retaining water up to 400-1,500 times of their weight (Johnson, 1984a; Bowman and Evans, 1991; Buchholz, 1998). These polymers can build an additional water reservoir for plant-soil system (e.g. Bouranis *et al.,* 1995) and therefore reduce water stress in plants. The performance of such amendments depends on their chemistry, polymer formation, and chemical composition of the soil solution or irrigation water. Flannery and Busscher (1982) and Johnson (1984a) reported that the use of hydrophilic polymers increased the amount of available soil moisture in the root zone, thus permitting longer intervals between irrigations. Hydrophilic polymers are effective in increasing water holding capacity, decreasing deep percolation, reducing evaporation losses in sandy soils (Teyel and El-Hady, 1981; El-Shafei *et al.,* 1992), improving aeration and drainage of soil medium (Bearce and McCollum, 1977), improving market life of container grown plants (Eikhof *et al.,* 1994; Still, 1976; Bearce and McCollum, 1977), and seed coating (Pamuk, 2004). Eventually, the use of hydrophilic polymers leads to an increase in water holding capacity, since water that would have otherwise leached beyond the root zone is captured.

Soil amendments influence infiltration rates, bulk density, structure, compaction, aggregate stability and crust hardness (Helalia and Letey, 1988; Helalia and Letey, 1989). Gehring and Lewis (1980) reported that moisture stress of plants decreased by the incorporation of a super absorbent into the medium. Silberbush *et al.* (1993a) tested the polyacrylamide (PAM) hydrophilic gel Agrosoak (0, 0.15, 0.30, and 0.45% by weight in the upper 25 cm of soil) as a conditioner for corn (*Zea mays* L.) and indicated that soil water storage capacity increased with the rate of Agrosoak. Crop yield components, except shoot dry weight, also increased with the Agrosoak application rate. Furthermore, Silberbush *et al.* (1993b) investigated the effect of Agrosoak hydrogel on cabbage (*Brassica oleraceae* L.) and reported that it increased water availability which indeed contributed to the increase in crop yield after irrigation with saline water.

Johnson (1984b) mixed sand with different cross-linked polyacrylamides to produce a polymer concentration range of 0–2 g kg^{-1} and reported that all polymer treatments increased the field capacity (FC) of coarse sand from 171 to 402%. Also, Johnson (1984b) showed that the permanent wilting point (PWP) of control sand was reached between 2–3 days, in comparison with 1 g kg^{-1} polymer treated sand (6–7 days) and 2 g kg^{-1} polymer treated sand (9–10 days).

Abedi-Koupai *et al.* (2008) examined the effect of PR3005A and Tarawat A100 hydrogels on water retention characteristic curves of three sandy loam, loamy, and clay soil textures. Their results showed that the θ_s values were 2.2, 1.8, and 1.5 times the control values of sandy loam, loam, and clay loam soil textures, respectively. Also the θ_r values were 5, 3.3, and 2.2 times the control in sandy loam, loam, and clay soils, respectively. Abedi-Koupai *et al.* (2008) found that adding and increasing the amount of hydrogel on sandy loam reduced α (empirical curve fitting parameter and related to the inverse of air entry value

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suction), while the required pressure for water release was increased. But in clayey and loamy soils, the air entry value decreased, i.e., α was increased. They also concluded that incorporation of hydrogels may release water at low matric suctions particularly for clay soil texture and application of 8 g kg^{-1} of hydrogel addition in sandy loam soil enhanced available water content approximately 3fold compared to that of the control. Thus, the application of hydrogels can result in significant reduction in the required irrigation frequency, which is an important issue in arid and semi-arid regions of the world (Abedi-Koupai *et al.,* 2008).

Andry *et al.* (2009) evaluated the effects of two hydrophilic polymers, carboxymethylcellulose (RF) and isopropylacrylamide (BF) on the water holding capacity and saturated hydraulic conductivity (K_S) of a sandy soil and found that the soil–absorbent mixtures retained significantly ($P< 0.05$) more water than the control soil, and the water content increased with increasing amount of hydrophilic polymer in the soil. The increase in mixing ratio from 0.1 to 0.2% did have a significant effect ($P< 0.05$) on *PAWC*.

Dexter (2004) showed that the slope of water retention curve at the inflection point can reflect different aspects of soil quality such as infiltration, hard-setting, compaction, organic matter contents, aeration, and root growth, etc. He defined the slope of retention curve as a soil physical quality index (S index). *S* index is an estimation of soil micro-structure and can be measured easily from retention curve.

Quantifying flow and transport in the vadoze zone requires knowledge of the retention and conductivity functions (Haverkamp *et al.,* 2005). Fitting the soil moisture retention curve to a mathematical function such as Van Genuchten and then calculating *S* index or quantifying flow and transport in terms of the parameters of function is more convenient. Here we focus on the description of the soil moisture retention curve.

Plants grown on hydrophilic polymers amended soil were slower to wilt than those grown on non amended soil (Woodhouse and Johnson, 1991). In addition, the effects of hydrophilic polymers on water retention curve were investigated by Abedi-Koupai *et al.* (2008) and Andry *et al.* (2009). However, the individual and interaction effects of hydrophilic polymers, urban solid compost, and gypsum on water retention curve, plant available water and especially S index were not studied in saline-sodic soils. The aim of the present research was to study the effects of hydrophilic polymers, urban solid compost, gypsum, and mixture of amendments with hydrophilic polymers on soil water retention curve, *MWD*, and Bulk density in a saline-sodic sandy clay loam.

MATERIALS AND METHODS

Site Description

The studied area is located in the eastern part of Shahrood region of Semnan Province in Iran (36° 31' 12.18" N, 55° 54' 43.86" E). The average annual air temperature and precipitation at the studied site are 16°C and 124.7 mm, respectively. The studied soil was a saline-sodic soil with sandy clay loam texture. Winter wheat (*Triticum aestivum)* and barley (*Hordeum vulgare)* are cultivated in the studied area. Sampling was carried out in the root zone (0-25 cm depth) in April 2010 and some chemical and physical properties were determined (Table 1).

A field experiment was executed to study the effects of organic (urban solid compost) and inorganic (gypsum) amendments, vinyl alcohol acrylic acid and a mixture of former and latter with hydrophilic polymers on structural and hydraulic properties of a saline-sodic sandy clay loam soil in a randomized complete block design with three replications. Size of plots was 1.5×1.5 m, with 1 m distance between plots. The treatments consisted of 10 ton ha^{-1} gypsum (G), 10 ton ha^{-1} urban solid compost (C), three levels of vinyl alcohol acrylic acid

Table 1. Physical and chemical properties of the studied soil before applying the treatments.

Texture	Sand (%)	Silt (%)	Clay (%)	TNV[a] (%)	OC[b] (%)	SAR[c]	pH	EC[d] (dS m^{-1})
	(USDA)							
SCL[e]	61	16	23	16.4	0.29	28.7	8.11	25.6

[a] Calcium Carbonate; [b] Organic Carbon; [c] Sodium Absorption Ratio; [d] Electrical Conductivity, [e] Sandy Clay Loam.

(S_1= 0.05%, S_2= 0.1%, S_3= 0.2%), a mixture of urban solid compost (10 ton ha^{-1}) with each level of vinyl alcohol acrylic acid (CS_1, CS_2, CS_3), a mixture of gypsum (10 ton ha^{-1}) with each level of vinyl alcohol acrylic acid (GS_1, GS_2, GS_3), a mixture of gypsum (10 ton ha^{-1}) and urban solid compost (10 ton ha^{-1}) with each level of vinyl alcohol acrylic acid (CGS_1, CGS_2, CGS_3) and one control (untreated soil (B)). Soil amendments were mixed by hand with 0-15 cm of soil in each experimental plot, *Sorghum* (Pegah cultivar) was grown and irrigated during the experiment in 5 day intervals. Four months after sowing of plants and establishing the experiment, soil sampling was performed as undisturbed (by cores of 5 cm diameter and 5 cm height) from the surface layer (ranging from 5 to 10 cm) of the center of each plot.

Laboratory Analysis

Some chemical properties of soil samples were analyzed after air drying and passing through a 2-mm sieve. Soil texture was determined using the hydrometer method (Gee and Bauder, 1986). Organic carbon (OC) content in soil was determined by dichromate oxidation procedure (Nelson and Sommers, 1982). Total $CaCO_3$ equivalent (CCE) was measured by estimating the quantity of the CO_2 produced by HCl addition to the soil (Nelson, 1982). pH was measured in a 1:2.5 soil to water suspension using a pH meter (Mc Lean, 1982). Flame photometry was used for soluble Na^+, and titrations with ethylenediaminetetraacetic acid (EDTA) were conducted for soluble Ca^{2+} and Mg^{2+}. Soil electrical conductivity (EC_e) was measured in saturated paste extract and sodium adsorption ratio (SAR) was calculated as ($SAR= Na^+/[(Ca^{2+}+Mg^{2+})/2]^{0.5}$, where Na^+, Ca^{2+}, and Mg^{2+} are the ionic concentrations in soil solution (mmol L^{-1}).

Soil core samples were used to measure bulk density and moisture retention curve. Gravimetric water content was measured at 0, 10, 30, 50, 100, 300, 500, 1,000 and 1,500 kPa pressure heads by pressure plate (Klute, 1986). Data of moisture retention curve were fitted to the Van Genuchten equation (1980). The parameters of this equation were determined by the least square error method. The Van Genuchten equation (1980) for soil moisture retention curve is:

$$\theta = \theta_r + \left(\theta_s - \theta_r\right)\left[1 + \frac{1}{(\alpha h)^n}\right]^{-m} \qquad (1)$$

S index, which is the slope of soil moisture retention curve at the inflection point, in all treated soil samples was calculated as follows (Dexter, 2004):

$$S = -n\left(\theta_s - \theta_r\right)\left[1 + \frac{1}{m}\right]^{-(1+m)} \qquad (2)$$

If *m=1-1/n* is applied:

$$S = -n\left(\theta_s - \theta_r\right)\left[\frac{2n-1}{n-1}\right]^{\left(\frac{1}{n}-2\right)} \qquad (3)$$

Where, n and α are empirical parameters, and θ_s and θ_r are saturated and residual water contents (g g^{-1}), respectively. Since S index is always negative, the modulus of S index was used in this paper. An example of a soil moisture retention curve and *S* index is shown in Figure 1.

Plant available water content *PAWC* (m^3 m^{-3}) was defined according to White (2006) as:

$$PAWC = \theta_{FC}\ (h = -10\ kPa) - \theta_{PWP}\ (h = -1500\ kPa) \quad (3)$$

Mean weight diameter (MWD) was determined by wet sieving method as an index of soil aggregation. The wet sieving method of Kemper and Rosenau (1986) was used with a set of sieves of 4, 2, 1.5, 1, 0.5 and 0.25 mm mesh diameters. After treated soil samples were passed through an 8 mm sieve, approximately 50 g of soil was placed on the first sieve of the set, and gently moistened from below to avoid a sudden rupture of aggregates. Once the soil had been saturated, the set was oscillated in distilled water at the rate of 30 oscillations per hour for 10 min. The soil retained in each sieve was dried. The mean weight diameter was calculated as follows:

$$MWD = \sum_{i=1}^{n} X_i W_i \quad (4)$$

Where, *MWD* is the mean weight diameter of water-stable aggregates (mm), X_i is the mean diameter of each size fraction (mm) and W_i is the weight proportion of the total sample mass in the corresponding size fraction after the mass of stones were subtracted from mass retained on each sieve.

Bulk density was determined by core samples of 98.13 cm^3 volume (5 cm in diameter, and 5 cm in height) (Blake and Hartge, 1986).

Statistical Analyses

The statistical analysis was performed using MSTAT-C software and treatment means were compared using Duncan's multiple range test (DMRT) at $P < 0.05$.

RESULTS AND DISCUSSION

Parameters of Moisture Retention Curve

Results showed that for all treatments θ_s increased significantly ($P < 0.05$) compared to the control (Table 2). The increase in θ_s may be due to the positive effect of soil amendments used (i.e. C, S, and G) on aggregation, improvement of soil structure, and consequently increasing soil porosity. S_1 treatment had the highest θ_s, with 90.7% increase compared to the control (B) (untreated soil), followed by CGS_2, CS_3, CS_2, and CS_1 treatments. Despite significant increases in θ_s of G, GS_1, GS_2, GS_3, and S_3 treatments with respect to the control, the lowest increment of θ_s was observed in these treatments. Apparently, a period of four months was not enough for full chemical reactions of gypsum in soil and some

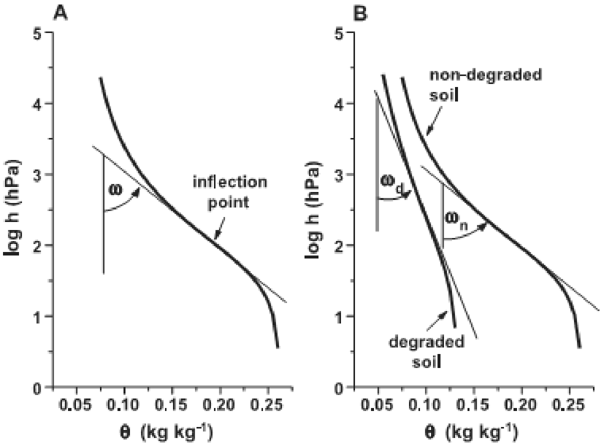

Figure 1. Example of a soil moisture retention curve and its slope at the inflection point (from Dexter, 2004).

Table 2. The effects of studied treatments on soil water retention curve parameters, MWD, and Bd in a saline-sodic sandy clay loam soil.

Treatments	θ_s (g g^{-1})	θ_r (g g^{-1})	α parameter (cm^{-1})	*n* parameter	*PAWC* (g.g^{-1})	*S* Index	*MWD* (mm)	*Bd* (g.cm^{-3})
B	0.21^{g}	0.0^{i}	0.0301^{b}	1.183^{e}	0.11^{f}	0.024^{g}	1.94^{g}	1.56^{a}
G	0.281^{f}	0.0^{i}	0.0392^{a}	1.2^{e}	0.11^{f}	0.035^{f}	2.66^{d}	1.24^{de}
C	0.35^{bcd}	0.039^{e}	0.02433^{c}	1.286^{bcd}	0.151^{bc}	0.050^{bcd}	2.17^{f}	1.14^{f}
S_1	0.40^{a}	0.039^{e}	0.0107^{h}	1.346^{ab}	0.15^{bc}	0.066^{a}	1.92^{g}	1.33^{c}
S_2	0.30^{ef}	0.040^{e}	0.0102^{h}	1.352^{ab}	0.14^{bcd}	0.048^{bcde}	1.94^{g}	1.40^{b}
S_3	0.29^{f}	0.059^{a}	0.01097^{h}	1.406^{a}	0.13^{bcd}	0.048^{bcde}	1.99^{g}	1.41^{b}
GS_1	0.28^{f}	0.0^{i}	0.02237^{d}	1.228^{cde}	0.12^{ef}	0.038^{ef}	2.78^{c}	1.25^{de}
GS_2	0.291^{f}	0.0^{i}	0.01697^{e}	1.231^{cde}	0.13^{bcd}	0.040^{cdef}	2.90^{ab}	1.25^{de}
GS_3	0.296^{f}	0.0^{i}	0.0151^{fg}	1.218^{de}	0.11^{f}	0.039^{def}	2.99^{a}	1.22^{de}
CS_1	0.359^{bc}	0.044^{d}	0.01393^{g}	1.308^{bc}	0.17^{a}	0.053^{b}	2.23^{f}	1.21^{e}
CS_2	0.361^{bc}	0.049^{c}	0.01337^{g}	1.305^{bc}	0.16^{ab}	0.052^{b}	2.5^{e}	1.33^{c}
CS_3	0.365^{b}	0.054^{b}	0.01153^{h}	1.310^{bc}	0.13^{bcd}	0.053^{b}	2.93^{ab}	1.28^{cd}
CGS_1	0.326^{de}	0.028^{g}	0.0167^{ef}	1.300^{bcd}	0.15^{bc}	0.049^{bcde}	2.80^{c}	1.26^{de}
CGS_2	0.386^{ab}	0.039^{e}	0.01603^{ef}	1.355^{ab}	0.15^{bc}	0.064^{a}	2.91^{ab}	1.40^{b}
CGS_3	0.331^{cd}	0.035^{f}	0.01583^{ef}	1.319^{b}	0.16^{ab}	0.051^{bc}	2.87^{bc}	1.28^{cd}

θ_s: Saturated water content; θ_r: Residual water content; α and n: Empirical parameters of soil water retention curve; AWC: Plant available water content; MWD: Mean weight diameter of aggregates, Bd: Bulk density.
* Means with same letter in each column are not significantly different at 5% probability level.

reactions of gypsum might have influenced the optimum operation of the absorbent in the mixture of soil-gypsum–absorbent system. In general, increasing levels of vinyl alcohol acrylic acid did not further increase θ_s.

Results showed that the changes of θ_r were similar to those of θ_s. The values of θ_r obtained from Van Genuchten equation (1980) were zero in control, G, GS_1, GS_2, and GS_3 treatments, but the application of absorbent (S), C, and their mixtures increased θ_r significantly ($P< 0.05$) and S_3 treatment had the highest θ_r (Table 2). Although gypsum application improved chemical properties of the studied saline-sodic soils and decreased exchangeable sodium percentage (i.e. initial and final ESP were 33 and 22% respectively, indicating 15% reduction of ESP in G treatment), its effect on soil moisture retention at high suctions was not noticeable after a period of four months.

Results also indicated that treatments affected the *α* parameter of Van Genuchten equation (1980). The highest values of α were noted in G and control treatments and their differences ($P< 0.05$) compared to each other and also to other treatments were significant (Table 2). 1/α reflects the air entry value. Thus, the pressures required for water to be released in G and control were 25.5 and 3.32 kPa, respectively. Due to increasing content of macro-pores in G treatment, the *α* value was increased and water was released under lower matric suction. The lowest *α* values were found in S_2, S_1, S_3, and CS_3 treatments. Therefore, by applying different levels of the absorbent, air entry values were increased significantly ($P< 0.05$) compared to the control. For example, the air entry value in S_2 was 98 cm H_2O. The *α* value was reduced in all treatments (except G treatment), consequently the pressure for water to be released increased (Table 2).

The shape parameter of moisture retention curve (n) in most treatments increased significantly compared to the control ($P<0.05$). In G, GS_1, GS_2, and GS_3 treatments, the *n* parameter showed no significant differences compared to the control. S_3 treatment had the highest *n* value (Table 2). Soil amendments such as absorbent (S), C and their mixture in this study changed pore size distribution as well as affected moisture retention and/or release of soil moisture, thereby changing the retention curve shape and n parameter value.

Plant available water content (PAWC)

Urban solid compost (C) and absorbent (S) application increased plant available water content (Table 2) significantly ($P< 0.05$). *PAWC* increased significantly in all treatments compared with the control except for G, GS_1, GS_2, and GS_3 treatments ($P< 0.05$). Maximum amount of *PAWC* was obtained in CS_1 with an increase of 70% compared to the control. Since C and especially absorbent have a good capacity for water absorption, organic matter can be considered as the best amendment for most soils due to its increase in water retention capacity and physical properties improvement of soils (Karimi and Naderi, 2007). Andry *et al.* (2009) reported the effects of two hydrophilic polymers, carboxymethylcellulose (RF) and isopropyl acrylamide (BF), on water holding capacity and saturated hydraulic conductivity (K_S) of a sandy soil and found that the available water content increased up to 4 and 5 times with RF and BF treatments, respectively, compared with the control soil.

Many studies that used absorbents in sandy soils reported that the absorbents' efficiency values were higher than those obtained in this study. The soil texture used in this study was sandy clay loam. Therefore, despite leading to an increase in *PAWC*, its increase was lower than those reported by other authors (e.g. Abedi-Koupai *et al.,* 2008; Andry *et al.,* 2009). However, water uptake and plants growth in saline-sodic soils are more restricted than non-saline or non-sodic soils, especially in arid and semi-arid regions such as the studied area. Minimum and maximum significant increments of *PAWC* were 30% in S_2 and 70% in CS_3, respectively. It has been reported that the impact of hydrogel polymers decreases by increasing salinity (Taylor and Halfacre, 1986; Chen *et al.,* 2004; Seyed Dorraji *et al.,* 2010). The studied soil in this research was a saline-sodic soil and therefore, the maximum values of super absorbent did not have a noticeable impact on *PAWC*. The studied soil is located in an arid region and sodicity and salinity are the main limiting factors for water uptake and plant growth in this area. Therefore, 70% increment of *PAWC* can help increase water uptake by plant, promote nutrient uptake, and improve plant growth and crop yield.

Slope of Moisture Retention Curve at Inflection Point (S Index)

The results showed that the lowest S index was found for the control (Table 2). According to Dexter (2004) and Reynolds *et al.* (2009), our soil structure is classified as poor. Soil *SAR* and organic carbon are 28.7 and 0.29 %, respectively (Table 1), indicating that the studied soil has a poor structure due to lower organic carbon content and higher amount of soluble and exchangeable Na^+. Application of soil amendments to this poor soil not only resulted in a significant increase in *S* index compared to the control, but also improved soil physical quality. *S* index in all treatments increased at least up to 0.035 (compared to the control) (Table 2). For temperate and tropical soils, $S\geq 0.050$ indicates “very good” soil physical or structural quality, while $0.035\leq S\leq 0.050$ is “good physical quality”, $0.020\leq S\leq 0.035$ is “poor physical quality”, and $S\leq 0.020$ is “very poor” or “degraded” physical quality (Dexter, 2004; Dexter and Czyz, 2007; Tormena *et al.,* 2008; Reynolds *et al.,* 2009). The theoretical limits of S are $0\leq S\leq \infty$, however, agricultural soils tend to fall within the range of $0.007\leq S\leq 0.14$ (Dexter and Czyz, 2007). The values of S index for C, CS_1, CS_2,

S_1, CGS_2, and CGS_3 treatments were equal to (C) and beyond 0.050. Therefore, the amendments employed in this study proved their superiority in improving the soil physical or structural quality of the saline- sodic soil, and they can help to improve root development and plant growth.

Mean Weight Diameter of Aggregates (MWD)

Application of amendments resulted in an increase in *MWD* (Table 2). However, different levels of absorbent had no significant effect on *MWD*. In contrast, the mixture of C, gypsum and absorbent increased *MWD* significantly ($P< 0.05$) compared with the control. Among different treatments, the highest value of *MWD* was noted in GS_3, CS_3, CGS_2 and GS_2 treatments. It seems that Ca^{++} in gypsum effectively substituted Na^+ at exchange sites in the studied saline-sodic soil, acted as bonding agent among soil particles and improved the *MWD* of aggregates. The results of *MWD* showed that, except for S treatments which were not significant compared with B, the increasing percentage of *MWD* for other treatments varied in the range of 12 to 54.5%. Some authors reported that soil amendments can improve soil structure through the increase in *MWD*. For example, Levy and Miller (1999) found that adding a polyacrylamide to two different soils (Typic Ochraquults, and Typic Hapludults) increased *MWD* in both soils.

Bulk Density (Bd)

Application of amendments resulted in a significant decrease in *Bd* ($P< 0.05$). The lowest *Bd* was obtained for C treatment being 37% smaller than the one for the control. Mixtures of C with absorbent and gypsum with absorbent treatments also showed significant reductions in *Bd* compared with the control ($P< 0.05$). In spite of the significant differences in *Bd* among different levels of absorbent compared with the control, the decrease in *Bd* in absorbent treatments was comparatively smaller than those for the treatments with C, G, and their mixture with absorbent (Table 2). The application of gypsum and urban solid compost resulted in aggregation, soil structure improvement, soil porosity increase, and macro-pores formation in the studied saline-sodic soil and consequently bulk density decrease, and as a result an increase in θ_s was observed.

CONCLUSIONS

The effect of organic and inorganic amendments (urban solid compost, gypsum and vinyl alcohol acrylic acid) on the Van Genuchten retention curve parameters (θ_s, θ_r, n, α), plant available water (PAWC) and soil physical properties mean weight diameter (MWD) and bulk density (Bd) showed that the application of amendments resulted in a significant increase in θ_s, θ_r, and *PAWC*, but a decrease in α parameter. Application of gypsum had no effect on moisture retention at high matric suctions (θ_r). It seems that gypsum can increase the content of macro-pores and as a result, θ_s. The studied soil was saline-sodic with low organic carbon content and poor physical and structural quality. All treatments lead to *S* index increase up to the critical limit (0.035) of soil physical quality with a significant ($P< 0.05$) difference compared with the control. In addition, the application of amendments decreased Bd, but *MWD* was increased significantly ($P< 0.05$). Furthermore, Na^+ content and electrical conductivity are high in the studied soil. Therefore, soil moisture retention which increases plant available water content and soil physical and structural quality are important factors for plant growth in this area. Our results show that the mixture of 0.1% ($g\ g^{-1}$) of vinyl alcohol acrylic acid with C or gypsum seems to be a suitable amendment for the retention of moisture, supplying more plant available water content, and improving soil physical and structural quality. Because supplying more *PAWC* is very important in arid and semiarid regions, increasing soil quality up to the 0.050 value, and decreasing Bd are important as well. Therefore, the mixture of 0.1% vinyl alcohol acrylic acid and 10 ton ha^{-1} urban solid compost, i.e. $CS_{1,}$ was found to be the best amendment among the studied treatments for increasing *PAWC* and improving physical quality of the studied saline-sodic soil.

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تاثیر اصلاح‌کننده‌های آلی و غیرآلی بر پارامترهای منحنی رطوبتی، جرم مخصوص ظاهری و میانگین وزنی قطر خاکدانه‌ها در یک خاک شور-سدیمی

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چکیده

جهت مطالعه تاثیر مواد بهساز بر ویژگی‌های هیدرولیکی و فیزیکی خاک، آزمایشی در قالب طرح بلوک‌های کامل تصادفی با سه تکرار در یک خاک شور – سدیمی با بافت لوم رسی شنی انجام شد. تیمارهای این تحقیق شامل تیمار شاهد (B)، ۱۰ تن در هکتار پودر گچ (G)، ۱۰ تن در هکتار کمپوست زباله شهری (C)، ماده سوپرجاذب وینیل اکریلیک اسید در سه سطح ($S_1=$ ۰/۰۵٪، $S_2=$ ۰/۱٪ و $S_3=$ ۰/۲٪)، CS_1، CS_2، CS_3، GS_1، GS_2، GS_3، CGS_1، CGS_2 و CGS_3 بودند. بعد از گذشت ۴ ماه از اعمال تیمارها، رطوبت تیمارهای مختلف در نه مکش اندازه‌گیری شدند و داده‌های به دست آمده با معادله وان‌گن‌اختن برازش داده شدند. سپس با استفاده از روش حداقل مربعات خطا، پارامترهای (θ_s، θ_r، α و n) معادله مذکور تعیین شدند. همچنین بعضی از ویژگی‌های فیزیکی خاک مثل جرم مخصوص ظاهری (Bd)، میانگین وزنی قطر خاکدانه‌ها (MWD)، رطوبت قابل استفاده گیاه (PAWC) و شیب منحنی رطوبتی در نقطه عطف آن (شاخص S) نیز اندازه‌گیری شدند. نتایج نشان دادند که تمام تیمارهای آزمایشی رطوبت اشباع خاک(θ_s) را به طور معنی‌داری نسبت به تیمار شاهد افزایش دادند ($P< 0.05$). روند تقریبا مشابهی در مورد رطوبت باقی مانده (θ_r) نیز مشاهد شد، بیشترین مقدار α مربوط به تیمار شاهد و کمترین مقدار پارامتر مذکور نیز متعلق به تیمار S_2 بود. غیر از تیمارهای G، GS_1، GS_2 و GS_3 در بقیه تیمارها رطوبت قابل استفاده گیاه به‌طور معنی‌داری نسبت به شاهد افزایش نشان داد ($P< 0.05$). افزودن مواد بهساز به خاک به طور معنی‌داری شاخص S و مقادیر MWD را افزایش و Bd را نسبت به شاهد کاهش داد. به نظر می‌رسد ترکیب ۰/۱ درصد وینیل اکریلیک اسید با

۱۰ تن در هکتار کمپوست زباله شهری و گچ، اصلاح کننده مناسبی برای افزایش AWC و بهبود کیفیت فیزیکی در خاک شور-سدیمی باشد.

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