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Effect of Vermicompost and Urban Waste Compost on Stability of Soil Aggregates by High Energy Moisture Characteristic Curve

M. Amjadi[1], H. Emami[1*], E. Farahani[1], and A. Gholoubi[2]

ABSTRACT

The aim of this research was to study soil structural stability indices of clay loam soil treated with organic amendments, using High Energy Moisture Characteristic (HEMC). For this purpose, three sizes of soil aggregates (0.5-1, 1-2, and 2-4 mm) were treated with three rates (0, 1.5, and 3 %) of vermicompost and urban waste compost. After three months of incubation, water retention of the slow (2 mm h^{-1}) and fast (100 mm h^{-1}) wetted soil aggregates were measured at six pressure heads from 0 to 50 hPa, and HEMC stability indices such as Volume of Drainable Pores (VDP), Stability Index (SI), and Stability Ratio (SR) were determined. The results showed that only the stability of 0.5-1 mm aggregates was significantly (P< 0.01) affected by organic treatments. The stability indices were significantly influenced by the rates of amendments, and increased with increasing their rates. However, the type of organic amendments had no significant effect on stability of aggregates. The mean of VDP, SI, and SR decreased by increasing diameter of the aggregates and decreasing the rate of the organic amendments, due to breakdown of macro-aggregates and decrease of macropore fraction. In general, to increase structure stability of clay loam soil in arid regions of Iran, application of at least 3% organic amendments is recommended.

Keywords: Drainable pores, Soil amendments, Soil structure, Stability index, Stability ratio.

INTRODUCTION

Successes of many soil management systems and the environmental quality of agro-ecosystems are due to the positive effects of soil quality including aggregation. Many physical and chemical features of soil and agricultural management operations may affect the aggregates and structure stability (Levy and Mamedov, 2002). Pore space collapse by breakdown of aggregates can decrease hydraulic conductivity and water infiltration rate, and increase runoff and erosion, and lead to plant mechanical and drought stress (Levy and Miller, 1997, Farahani *et al*., 2019; Zaker and Emami, 2019; Amiri Khaboushan *et al*., 2019; Amiri *et al.*, 2017).

Stability of soil structure describes the capability of the soil to rearrange solid particles and pore spaces (i.e., aggregates and pores) when exposed to external forces (e.g., tillage, cropping, compaction and irrigation). The relationship between soil structure and soil water content can be exhibited by a soil water retention curve, which relates water content of the soil to the matric potential of the soil water and thus to the equivalent diameter of the water filled pores (Childs, 1940). In well-aggregated soils, the available moisture capacity for plants is higher than the soils with poor aggregation (Childs, 1942). Organic matters such as vermicompost and urban waste compost amendments influence soil structure and water retention (Emami and

[1] Department of Soil Science, Faculty of Agriculture, Ferdowsi University of Mashhad, Mashhad, Islamic Republic of Iran.
[2] University of Texas at Austin, Bureau of Economic Geology, Austin, TX, U. S. A.
*Corresponding author; e-mail: hemami@um.ac.ir

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Astaraei, 2012). Therefore, organic amendments may affect HEMC indices such as VDP, SI, and SR.

Common procedures for aggregate stability determination include wet sieving (Kemper and Rosenau, 1986), the drop test technique (Farres, 1980), application of ultrasonic energy (North, 1976), and controlled rates of wetting (Pierson and Mulla, 1989, 1990). Therefore, using various tests results in a wide ranking of soil structure stability and makes the comparison difficult (North, 1976). Recently, the HEMC method has been considered as a favorable and practical method for determining structural stability of soils in arid and semi-arid or humid regions having a wide range of stability levels (Mamedov *et al*., 2014; Mamedov and Levy, 2013). The HEMC method for determining the structure stability of clay soils was first proposed by Childs (1940). Since this method had some limitation in poor aggregated and coarse textured soils, some modifications were made to increase the appropriateness of the method to soils with a weaker stability (Collis-George and Figueroa, 1984; Pierson and Mulla, 1989). The technique was modified later and currently the most used HEMC method was prepared by Levy and Mamedov (2002). This method, that exactly controls of aggregate wetting, is not very common, but it is less time consuming than wet sieving (Kemper and Rosenau, 1986). In fact, the method is based on interpretation of high energy moisture characteristic curves, where high energy refers to matric potential from 0 to 60 hPa (Collis-George and Laryea, 1972). The energy of hydration and entrapped air and swelling are the responsible forces to break down the aggregates (Avanzi *et al*., 2011). The method of the HEMC has been tested in numerous studies and it has been concluded that this method is able to distinguish little changes in aggregate and structure stability of soils from arid to humid areas (Kelishadi *et al*., 2018; Gholoubi *et al*., 2019).

Soil organic carbon has strong impact on the soil physical quality (Chirinda *et al*., 2010). Organic carbon act as essential factor to make stable aggregates and flocculate soil particles (Tejada *et al*., 2007). The utilization of bio-solids and urban organic wastes in agricultural soils as a nutrient resource and as a soil amendment is common practice, particularly in arid or semi-arid regions, where low organic matter content and degraded soil structure frequently occur in cultivated lands (Graber *et al*, 2006). Soil amendments may influence water infiltration rates, bulk density, compaction, aggregate and structure stability and crust formation and hardness (Helalia and Letely, 1988). It has been well known that the effects of organic amendment vary and are soil-dependent. It has been reported that the effects of some amendments on aggregate stability could be ambiguous during the time of application and aging (Mamedow *et al*., 2014).

Organic matter is used as a soil conditioner in most soils to increase water-holding capacity and to improve soil physical properties (Emami and Astaraei, 2012). Assessing the effect of organic amendments on soil physical quality is imperative to sustainable management practices. Aggregate stability measurement is one of the direct indices of soil physical quality, which can be well represent by HEMC method (Gholoubi *et al*, 2019). Although the effect of some organic amendments on aggregation and soil structure stability have been studied by HEMC using certain aggregate sizes (0.5-1 mm), the effect of vermicompost and urban waste compost on stability of different sizes of aggregates was not investigated by HEMC method. Moreover, in northeastern Iran, due to low organic matter, soil aggregate stability is low. The objective of this study was to evaluate the stability of aggregates (0.5-1, 1-2, and 2-4 mm) treated with vermicompost and urban waste compost amendments using the HEMC technique.

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MATERIALS AND METHODS

HEMC Method

The studied soil was located in 59° 38′ 16″ N, and 36° 21′ 18″ E, in agricultural field of Ferdowsi University of Mashhad (Khorasan Razavi Province of Iran). Soil aggregates were collected from 0-30 cm depth, air dried and sieved (< 4 mm). Three rates (0, 1.5, and 3.0 % weight) of two types of amendments (dry urban waste compost and vermicompost, diameter < 2 mm) were added/mixed to aggregates, with three replications. The treatments were kept at Field Capacity (FC) condition for three months. Then, aggregates were oven dried at 70°C, and divided into three sizes (0.5-1.0, 1.0-2.0, and 2.0-4.0 mm) by sieving. Some properties of the studied soil and organic amendments are given in Tables 1 and 2.

Then, aggregate stability was measured using the High-Energy Moisture Characteristic (HEMC) method. In general, 20 g of treated aggregates were poured into PVC cylinders (3 cm diameter and 3 cm height) to form a 15 mm-thick bed and then were wetted at two rates: slow (2 mm h^{-1}) and fast (100 mm h^{-1}). For fast wetting, each core was suddenly saturated from beneath with distilled water and was left submerged for 24 hours (Poch and Antunez, 2010). For slow wetting, the prepared cores were placed in the sandbox and saturation was performed by changing suction values (50, 25, 20, 15, 10, 5, and 0 hPa) with an equilibration period of 60 minutes per step (Bearden, 2001). Then, the water retention curves of both fast and slow wetted samples were obtained from 0 to 50 hPa (Kelishadi *et al*., 2018), and data were fitted using the modified Van Genuchten (1991) Equation (Equation 1) using Excel Solver tool.

$$\theta = \theta r + (\theta s - \theta r)[1 + (\alpha\Psi)^{n}]^{(1/n-1)} + A\Psi^2 + B\Psi + C \quad (1)$$

Where, θr and θs are residual and saturated gravimetric water content (kg kg^{-1}), respectively; ψ is a matric potential (h Pa); α (m^{-1}) and n (dimensionless) represent the location of the inflection point and the steepness of S-shaped water retention curve, respectively. A, B, and C are the coefficients of polonium added to better predict water retention curve.

A typical water retention curve for aggregates 0.5-1 mm is shown in Figure 1. Structure or aggregate stability index was computed using quantifying the differences between the soil water retention curves obtained by fast and slow wetting. Volume of Drainable Pores (VDP), Modal Suction (MS), Structure Index (SI) and Stability Ratio (SR) were determined in the control sample and those treated with vermicompost and urban waste compost. For a given wetting rate, the SI is defined as a ratio of Volume of Drainable Pores (VDP) to Modal Suction (MS) (Collis-George and Figueroa, 1984). The MS corresponds to the matric potential (Ψ, h Pa) at the peak of the specific water capacity curve ($d\theta/d\Psi$) (Figure 1). Actually, MS is the size of pores that have

Table 1. Physical and chemical properties of the studied soil.

	Clay	Silt	Sand	OC	pH	CaCO3	EC	BD	FC	C/N	N	Na
	%	%	%	%	-	%	dS m^{-1}	G cm^{-3}	g g^{-1}	-	mg kg^{-1}	meq/l
Clay loam	37.04	41.28	21.68	1.19	7.66	14.43	2.1	1.35	21	23.8	0.05	3.20

Table 2. Properties of soil and indices of amendments added to soil.

Amendments	pH	C/N	OC	Na	EC	N	P
	-	-	%	meq l^{-1}	dS m^{-1}	%	meq l^{-1}
Vermicompost	7.7	19.21	27.20	0.4	8.5	1.23	0.6
Urban waste compost	7.6	17.16	26.6	0.8	7.1	1	0.9

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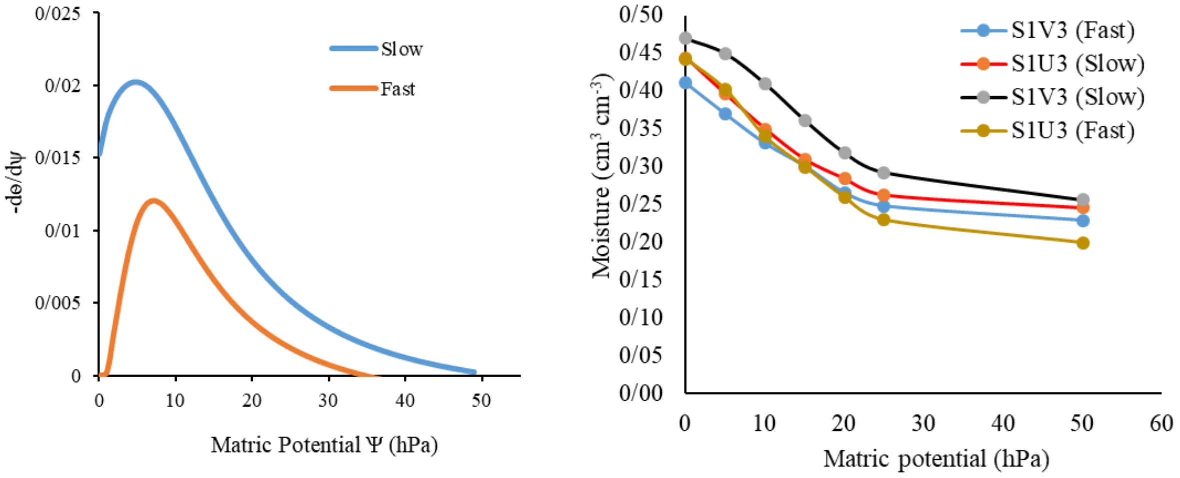

Figure 1. A typical specific water capacity curve (left) and retention curve (right) for aggregate diameter 0.5-1 mm, and 3% compost; S1= Aggregate diameter 0.5-1 mm, V3= 3% of Vermicompost, and U3: 3% of Urban waste compost.

the most abundance to calculate Structure Index (SI). The VDP is defined as the integral of the area under the specific water capacity curve and above its baseline (Figure 1).

The specific water capacity curve needed $\frac{d\theta}{d\Psi}$ (Equation 2) to obtain the value of VDP and MS, which is computed by differentiating Equation (1) with respect to Ψ:

$$\frac{d\theta}{d\Psi}=\frac{(\theta s-\theta r)[1+(\alpha\Psi)^{n}]^{\left(\frac{1}{n}-1\right)}\left(\frac{1}{n}-1\right)(\alpha\Psi)^{n}n}{[\Psi(1+(\alpha\Psi)^{n})]}+2\alpha\Psi+B \quad (2)$$

Where, θ is the water content (kg kg^{-1}) and Ψ the matric potential (cm).

Soil structure and/or aggregate stability can be expressed in terms of SI and/or Stability Ratio (SR). An index of aggregate stability (SI) that is the ratio of volume of drainable pores to modal suction was obtained as below:

$$SI=\frac{VDP}{MS} \quad (3)$$

The Stability Ratio (SR) was calculated by proportion of fast wetting SI to slow wetting SI based on Equation (4).

$$SR=\frac{SI(fast)}{SI(slow)} \quad (4)$$

Generally, the SR is used to compare stability of aggregates on a relative scale of zero to one (0< SR< 1). SR= 0 indicates that fast wetting destroyed the aggregates to the extent that all pores are drained at the applied matric potential range (Collis-George and Figueroa, 1984). Vice versa, the more value of SR, the higher aggregate stability.

Statistical Analysis

Statistical analysis was made by JMP 8.0 software to determine the significant effects of the two organic amendments and three rates of organic amendments on structural stability of the three sizes of aggregate diameters. For this purpose, a completely randomized design with factorial arrangement was applied and comparison of means were made by Tukey test at P< 0.01.

RESULTS AND DISCUSSION

The results analysis of variance for indices of structure stability (i.e. SI, VDP, and SR) determined by the HEMC method are presented in Table 3. According to analysis of variance, effects of aggregate sizes, wetting rates of organic amendments, and their interaction effects on VDP $_{fast}$, and VDP $_{slow}$ were significant. Also, ANOVA

Table 3. Analysis of variance (mean of squares) for indices of soil structure stability.[a]

Source of variation	df	VDP		MS		SI		
		Fast	Slow	Fast	Slow	Fast	Slow	SR
Aggregates size (A)	2	0.048**	0.039**	45.98**	32.74**	0.003**	0.002**	0.089**
Type of amendments (B)	1	0.004*	0.003*	15.36	10.52	0.001	0.0001	0.0004
Rate of amendments (C)	2	0.064**	0.051**	10.95	8.26	0.010*	0.009*	0.098*
A×B	2	0.039**	0.027*	50.15**	26.94**	0.002**	0.001**	0.216**
A×C	4	0.072**	0.058**	48.95**	28.54**	0.007**	0.006**	0.813**
B×C	2	0.042**	0.029**	49.32**	26.42**	0.002**	0.001**	0.006**
A×B×C	4	0.083**	0.070**	51.26**	29.73**	0.010**	0.001**	0.978**
Error	36	0.018	0.012	5.75	1.36	0.0001	0.0003	0.016
CV (%)	-	26.95	16.15	36.99	12.20	28.61	13.95	25.21

* and **: Significant at P< 0.05 and P< 0.01, respectively. [a] df: Degrees of freedom, VDP: Volume of Drainable Pores, SI: Stability Index, SR: Stability Ratio.

showed that the effects of aggregate sizes, rates of amendments, and interaction effects of amendment (type and rate) and aggregate size on SI_{slow}, SI_{fast}, and SR were statistically significant (P< 0.01) in most cases (Table 3).

The effect of aggregates diameters on SI_{Slow}, SI_{Fast} and SR indices is shown in Figure 2. The results of the means comparison showed that the values of SI_{Slow}, SI_{Fast} and, consequently, SR had significant differences in different aggregates sizes. The values of SI_{Slow}, SI_{Fast} and SR in aggregates with a diameter of 0.5-1 mm were significantly higher than the two coarser aggregate sizes, and the value of these indices decreased by increasing the diameter of aggregates. The lowest values of SI_{Slow}, SI_{Fast} and SR indices were found for the aggregate size of 2-4 mm, which was significantly (P< 0.01) smaller than both 0.5-1 mm, and 1-2 mm sizes. The values of SI_{Slow}, SI_{Fast} and SR indices decreased by 45, 64, and 36% when the size of the aggregates increased from 0.5-1 to 2-4 mm, respectively. This significant value can be due to the fact that the effective size of the aggregates is 0.5-1 mm. The potential of the amendments to increase aggregate stability in soil with stable aggregates is lower than the soil with less stable aggregates (Mamedov *et al*., 2014); because the aggregates are already stable and amendments may not improve their stability. On the other hand, when the size of aggregate increases, their stability decreases, especially in arid regions where the amount of organic matters as the binding agents of solid particles is low (Hosseini *et al*., 2015). In general, the SI_{Fast} values were approximately half of the SI_{Slow} values. Kay (1997) indicated that the macropores are unstable unless the process of creating the pore does not substantially increase the organic carbon content of the pore wall, as it happens with root channels or some faunal pores.

Changes in soil structure following breakdown of aggregates usually result in the rearrangement of the larger number of small particles; this, in turn, causes the inter-aggregate or Particle Size Distribution (PSD) move toward a greater number of smaller pores (from macro to micropores), and consequently decreases the value of VDP and increases the MS value (Mamedov and Levy, 2013). Entrapped air within the aggregates lead to slaking and destruction of coarse aggregates during the fast wetting process, which is the important mechanism to decrease the stability ratio of soil structure (Amezketa, 1999). Amending soil with organic matter can enhance water-stable aggregates by improving macro-aggregate stability (> 0.25 mm) through binding soil

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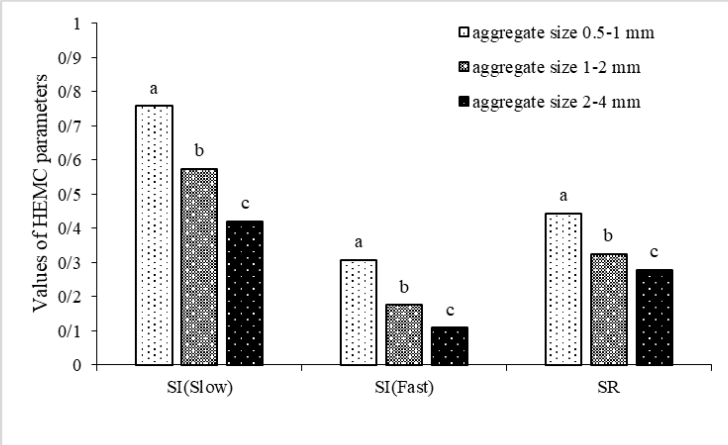

Figure 2. Effects of soil aggregate sizes on HEMC parameters (SI $_{Slow}$, SI $_{Fast}$, SR). Different letters on the columns indicate significant differences (P< 0.05).

particles, but it can also enhance clay dispersion (Farahani *et al*., 2019 and 2020) and thus contribute to slaking and disintegration of apparent micro-aggregates as noted in the studied soils (Mamedov *et al*., 2014).

The qualitative analysis of the HEMC indices indicated that the improvement in aggregate stability was in various ranges of matric potential, corresponding to macro- and micro-porosity or apparent macro- and micro aggregate stability (Figure 2), as it was in line with previous studies (Amézketa,1999; Mamedov and Levy, 2013), allowing better understanding of the mechanisms responsible for aggregates disintegration.

The effect of organic amendment type on SI $_{Slow}$, SI $_{Fast}$ and SR indices is shown in Figure 3. The results of means comparison indicated that the type of organic amendment had no significant effect on SI $_{Fast}$, SI $_{Slow}$ and, therefore, SR, as mentioned earlier. The results of the different rates of organic amendment showed that with increasing the amount of organic amendment, the stability indices (i.e. SI $_{Slow}$, SI $_{Fast}$, SR) increased and differences among treatments containing organic amendment and control in all cases was significant (P< 0.05) (Figure 4). However, the type of organic amendment only showed a significant effect on VDP (Figure 5.), and VDP in vermicompost was significantly greater than the urban waste compost. It seems that in addition to organic carbon content, organic components of vermicompost and urban waste compost, and activity of microorganism may affect soil structure, especially VDP. In fact, due to the activity of earthworms, which are found abundantly in vermicomost, the amount of macro pores and consequently VDP were increased in vermicompst treatments. However, since the properties of both organic amendments such as organic carbon content and even C/N ratio were similar (Table 2), their difference was not significant and both of these organic amendments increased the stability of aggregates. The amount of organic carbon in vermicompost and urban waste compost were almost similar (27.2 and 26.6 %, respectively), so, the type of organic amendment had no significant effect on increasing the stability of the aggregates. The different effects of organic matter may depend on the interaction between the organic amendment and the clay particles, and the size of the negatively charged organic molecules (Mamedov *et al*., 2016). If these molecules are relatively high molecular weight (> 5,000 Da), they will attach to the edges of several clay particles, bind them together, and stabilize the aggregates against slaking and disaggregation. However, if the molecules have low molecular weight (< 1,000 Da) and unable to attach to clay particles, disaggregation may occur once these bonds are broken (Shanmuganathan and Oades 1983). Pierson and Mulla (1990) found a positive correlation between SI $_{Fast}$ and soil organic carbon. However, Pierson and Mulla (1989) reported no significant correlation between aggregate stability indices and SOC under either long-term organic or traditional farming. They concluded that this observation was likely caused by temporal factors related to the effect of SOM on soil water content and cohesion recovery of disrupted aggregates. Mamedov *et al*. (2014) also reported that application of organic amendments highly affected the aggregate stability of coarse-textured soils. It seems that the relative impact of cementing agents on structural stability would be intensified in small aggregates with low SOC and unstable structure.

Mean comparison results of different organic amendment rates showed increase in the stability indices of aggregates (i.e. SI $_{Slow}$, SI $_{Fast}$, and SR) with increasing the rate of organic amendment. Also, the differences among all rates of organic amendments and the control (0% of organic amendment) were significant ($P< 0.05$) (Figure 4). In general, the lowest values of these indices were found in the control, while their greatest values were obtained when 3% of organic amendments was applied; for example, by addition of 3% organic amendments, SR increased up to 16% in comparison to the control. The details of aggregate stability indices results indicated that the organic content had the greatest effect on SI $_{Slow}$. Wu *et al*. (2017) stated that organic matter could significantly improve aggregate stability. Mamedov *et al*. (2014) studied the effects of soil texture and organic matter on SI in Smectite and Kaolinite soils and concluded that, in Smectite soils, SI increased exponentially when content of organic matter increased. In semi-arid areas, where soils contain low organic matter content, the effect of clay content on SI was found to be more under slow wetting conditions than fast wetting (Levy and Mamedov, 2002). However, the combination of clay and organic matter content has more effect on fast wetting than clay and organic matter content separately, and it can contribute to increase soil structure stability. As Table 2 shows, the clay content was also found high in the studied soil. Clay particles can generate organic-mineral complexes, which result in an increased accumulation of organic matter (Scott *et al*., 1996). Organic matter and clay content are the most important factors for negative charge in soils. Reichert and Norton (1994) also observed that aggregate stability was positively related to Cation Exchange Capacity (CEC) for soils, suggesting that increasing CEC may increase aggregate stability by binding soil particles. Thus, the stability of aggregates, especially 0.5-1 mm, was increased. In addition, organic amendment that includes low C/N ratios can also increase the structure stability, as shown in Table 2, both organic amendments had low C/N ratio, which led to increase in SI and SR indices. SI represents the degree of aggregate porosity, which is concentrated in the extend of pore sizes (Mamedov, 2014). The higher values of SR, the more stability of soil aggregate (Levy and Mamedov 2002; Mamedov, 2014). Similar to Gholoubi *et al*. (2019), our results showed that the HEMC method is highly sensitive to changes in the macro aggregate stability and SI can be used as a structural stability index.

The values of VDP $_{Fast}$ for Vermicompost had no significant differences with urban waste compost (Figure 5). Although the values of VDP $_{Fast}$ and VDP $_{Slow}$ for both organic amendments were not significantly different, the values of VDP for both organic amendments significantly increased by increasing their rates (Figures 6 and 7). In addition, comparison of Figures 6 and 7 shows that the values of VDP $_{Fast}$ are lower than VDP $_{Slow}$, which is due to the increased number of small aggregates and particles during the fast wetting process because of slaking and destruction of aggregates as a results of entrapped air within the macro

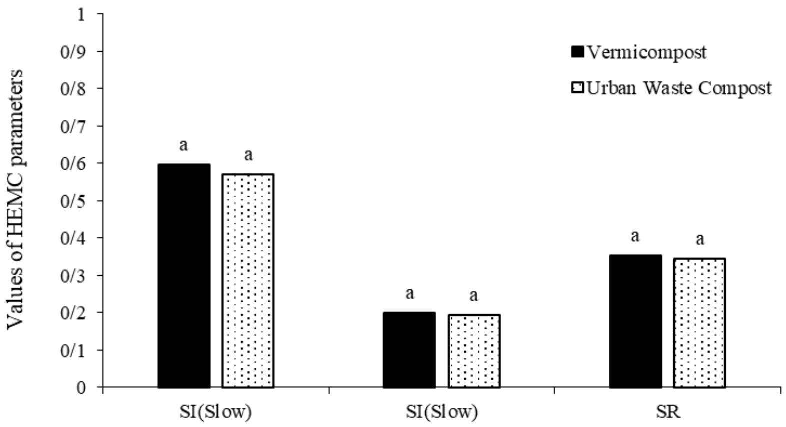

Figure 3. Effect of organic amendment on HEMC parameters (SI $_{Slow}$, SI $_{Fast}$, SR). The same letters on the columns indicate no significant differences (P< 0.05).

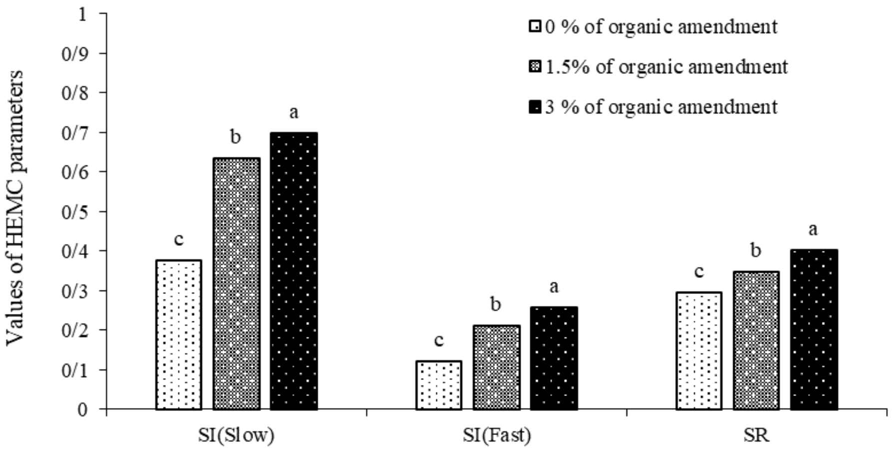

Figure 4. Effects of application rates of organic amendments on HEMC parameters. Different letters on the columns indicate significant differences (P< 0.05).

aggregates. This, in turn, causes the macro pore transform toward large numbers of smaller pores and, consequently, reduction in the VDP (Mamedov, 2014). This finding might be explained by hierarchical organization of soil structural elements as suggested by Tisdall and Oades (1982) and Dexter (1988). They showed that stable organic matter would stabilize micro-aggregates and incorporates in the micropores between the domains and clusters, and stability of macro-aggregates is usually lower than micro-aggregates (Tisdall and Oades, 1982). It is evident from that the volume of drainable pores (equivalent to the area under the specific water capacity curve) decreases as the extent of aggregate breakdown increases (Pierson and Mulla (1989). It seems that organic compounds released by organic amendments are important aggregate-stabilizing agents, which are adsorbed on soil particle surfaces and cement particles together (Alami *et al*., 2000). The higher organic matter content was believed responsible for the lower degree of surface crusting found on the organic farm. The organic carbon promotes microbial activity in the soil and, in turn, produces extracellular polysaccharide and carbohydrate compounds stabilizing the soil aggregates (Caravaca *et al*., 2002).

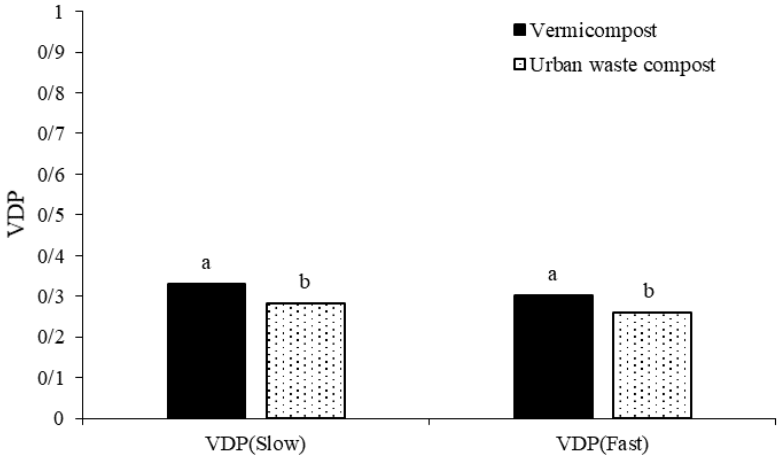

Figure 5. Effect of organic amendments on volume of drainable pores. Different letters on the columns indicate significant differences (P< 0.05).

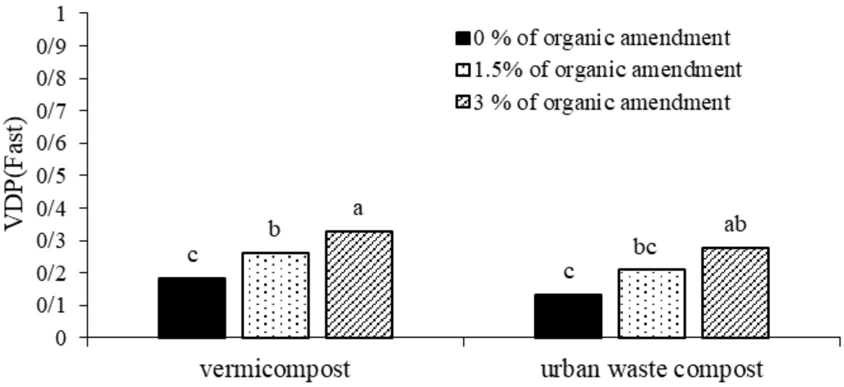

Figure 6. Effect of the application rates of organic amendment on volume of drainable pores (fast wetting). Different letters on the columns indicate significant differences (P< 0.05).

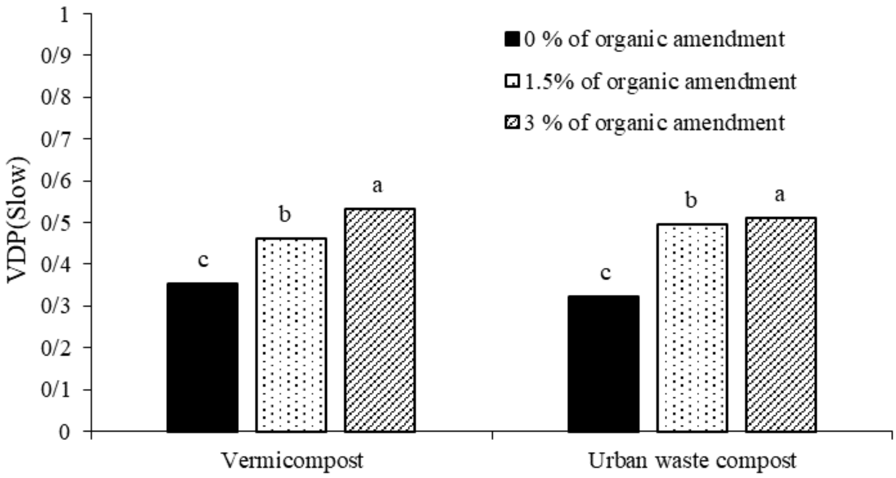

Figure 7. Effect of the application rates of organic amendment on volume of drainable pores (slow wetting). Different letters on the columns indicate significant differences (P< 0.05).

Interaction effects of aggregate size and organic amendment showed that by increasing the size of aggregates the SR significantly decreased; however, the difference between each size of aggregates for vermicompost and urban waste compost was not significant (Figure 8). Based on Figure 9, the differences among different rates of both organic amendments were significant, and the higher the value of organic amendments, the higher the value of SR. However, for each rate of organic amendment, difference between SR values of vermicompost and urban waste compost was not significant. Finally, the interaction effects of aggregate size and rates of organic amendments showed that, for each size of aggregates, when the rate of organic amendment increased, the SR values significantly increased, and the highest values at each rate of organic amendment was found for aggregate size of 0.5-1 mm (Figure 10).

Higher values of SR indicate greater stability of soil aggregates (Levy and Mamedov, 2002; Mamedov, 2014). Comparing the SR values (Figures 8-10) suggests that aggregate susceptibility to slaking depended strongly on aggregate size and the rates of organic amendments: slaking of aggregate size of 0.5-1 mm at higher rates of organic amendments was minimal, such that stability ratio for aggregate size of 0.5-1 mm at the rate of 3% of vermicompost was greater than 0.5 (Figure 10). The non-significant difference between vermicompost and urban waste compost was due to having equal soil

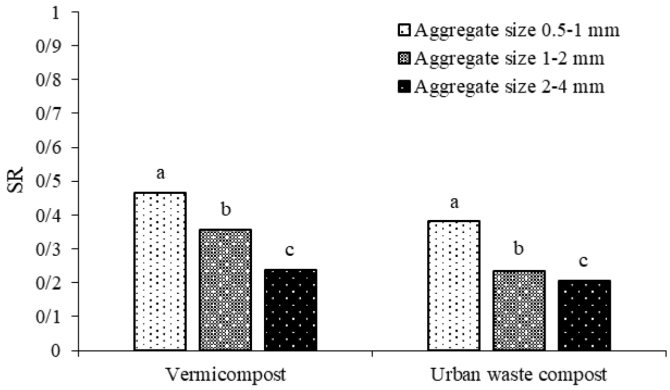

Figure 8. Interaction effect of organic amendment and aggregate size on stability ratio. Different letters on the columns indicate significant differences (P< 0.05).

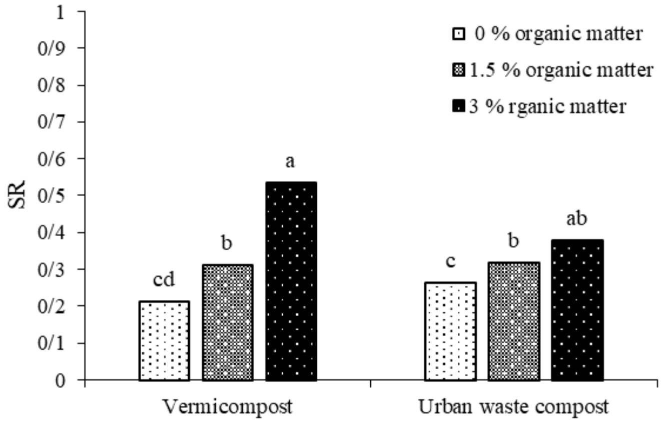

Figure 9. Interaction effect of the type and rate of organic amendment on stability ratio. Different letters on the columns indicate significant differences (P< 0.05).

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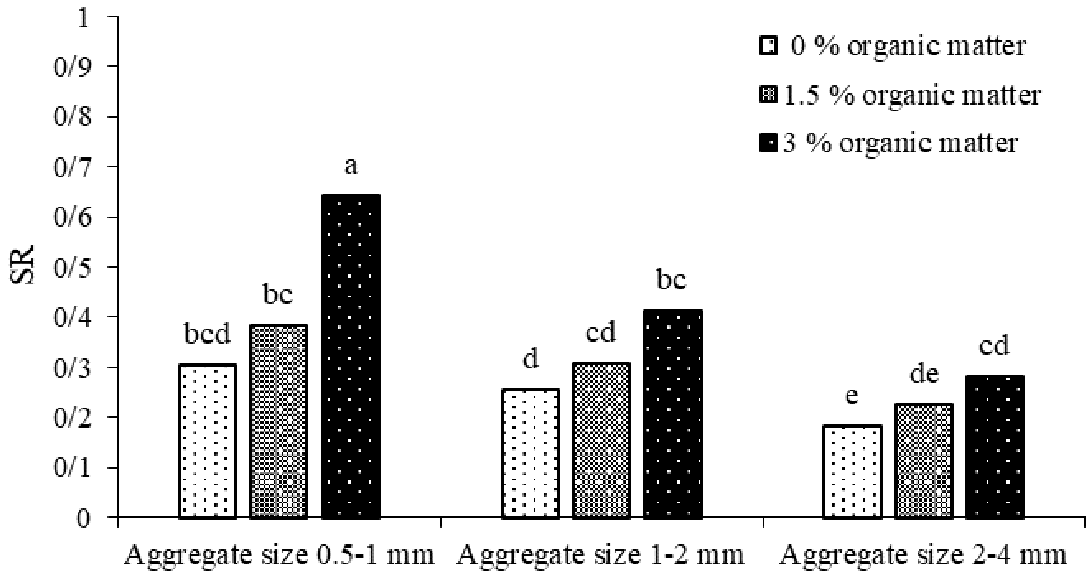


Figure 10. Interaction effect of the application rates of organic amendment and aggregate size on stability ratio. Different letters on the columns indicate significant differences (P< 0.05).

organic carbon, which demonstrated that the source of organic amendment is not important; therefore, increasing the organic matter reduced the sensitivity to slaking. In contrast, for macro aggregates with lower organic carbon, slaking significantly decreased drainable porosity and the SR. Therefore, decreasing the soil organic carbon by deteriorating soil structure leads to greater amounts of dispersed clay due to mechanical disruption and affects the microbial activity in soil (Amezketa, 1999).

Generally, the results indicated that SR and SI of HEMC method were affected by soil organic carbon. Therefore, reduction in soil organic carbon, especially in arid regions, decreases soil aggregate stability. These differences can be related to the aggregate size and the range of water retention curves used in HEMC method, which is only related to soil structural pores (0 to 50 hPa matric suctions, i.e. macrospores). Tisdall and Oades (1982) have shown that under certain conditions, the stability of macro-aggregates can be enhanced by the addition of decomposable organic material. Le Bissonnais and Arrouays (1997) reported a strong link between aggregate stability and soil organic matter. These findings imply that the macropores in soils with weak structure and low organic matter are mostly destroyed.

Interaction effect of the type and the rate of organic amendments showed that modal suction for both fast and slow wetting significantly increased by increasing the rate of organic matter. Among the studied treatments, the difference between 1.5% and 3% of urban waste compost was not significant. Also, the lowest and highest values of modal suctions were found for 0% of both organic amendments and equal rates of these amendments had no significant differences. In addition, modal suction for slow wetting was slightly more than fast wetting rate (Figure 11). The interaction effect of the application rate of organic amendment and aggregate size showed that modal suction for both fast and slow wetting rates at each aggregate size was significantly increased Figures (12 a-b), but for fast wetting the difference between 1.5 and 3% of aggregates was not significant Figure (12-a). Pierson and Mulla (1989) also found that the smallest modal pore size occurred with the fast wetting treatment, using aggregates

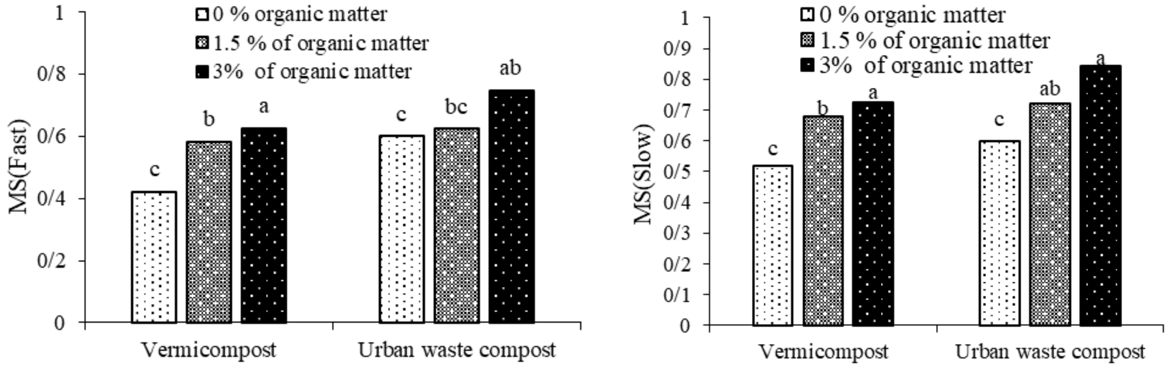
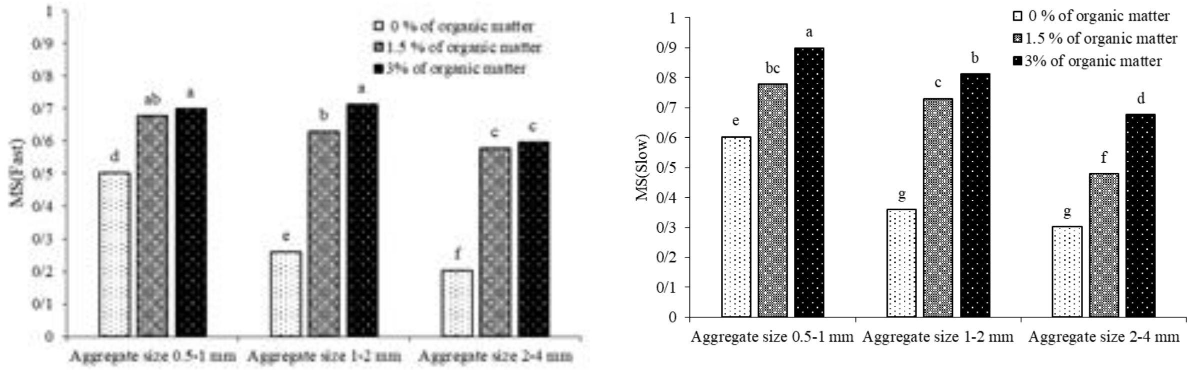


Figure 11. Interaction effect of the type and rate of organic amendment) on modal suction for fast (right) and slow (left) wetting. Different letters on the columns indicate significant differences (P< 0.05).



(a) (b)

Figure 12. Interaction effect of the application rate of organic amendment and aggregate size on modal suction (a) for fast wetting (b) for fast wetting. Different letters on the columns indicate significant differences (P< 0.05).

from the organic farm. When the content of organic matter increases the number of macro aggregates, modal suction, and, consequently, VDP increase; vice versa, in soils containing low organic carbon content, the aggregates may be destroyed as a results of entrapped air within the aggregates. This, in turn, causes the macro pore transform toward large numbers of smaller pores, modal suction, and consequently reduction in the VDP (Mamedov, 2014).

CONCLUSIONS

In this research, the effect of 0, 1.5, and 3% of vermicompost and urban solid waste compost on stability of 0.5-1, 1-2, and 2-4 mm aggregate sizes was studied using HEMC method. The results showed that organic amendment rates had a significant (P< .01) effect on soil structure stability indices (SI $_{Fast}$, SI $_{Slow}$, SR, MS and VDP) while the type of the two amendments had no significant effect, which means that farmers can use either of organic amendments to improve soil physical quality. It can be concluded that the use of HEMC method is recommended to evaluate the stability of aggregates. For this purpose, the aggregate size of 0.5-1 mm is more appropriate to evaluate the stability of soil structure, and use of larger aggregates may need larger PVC cylinder. Generally, organic matter addition is essential to increase the stability of soil structure, and 3% of vermicompost or urban solid waste compost can improve soil aggregate stability more than lower vermicompost percentages in arid regions such as Iran. In this research, application rates higher than 3% is recommended in future researches.

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تاثیر ورمی کمپوست و کمپوست زباله شهری بر پایداری خاکدانه‌ها به روش رطوبت پرانرژی

م. امجدی، ح. امامی، ا. فراهانی، و آ. قلوبی

چکیده

هدف از این پژوهش مطالعه شاخص‌های پایداری ساختمان خاک با استفاده از رطوبت پر انرژی (HEMC) در یک خاک لوم رسی تیمار شده با اصلاح کننده‌های آلی بود. بدین منظور، خاکدانه‌های با سه اندازه (0/5-1، 1-2 و 2-4 میلی‌متر) با سه سطح (0، 1/5 و 3 درصد) ورمی‌کمپوست و کمپوست زباله شهری تیمار شدند. بعد از گذشت سه ماه، خاکدانه‌ها در معرض دو سرعت خیس شدن کند (2 میلی‌متر بر ساعت) و تند (100 میلی‌متر بر ساعت) قرار داده شدند. سپس مقدار آب خاک در شش مکش از 0 تا 50 هکتوپاسکال (0، 5، 10، 15، 20، 25 و 50 هکتوپاسکال) اندازه‌گیری شد و شاخص‌های HEMC مثل حجم منافذ قابل زهکشی (VDP)، شاخص پایداری (SI) و نسبت پایداری (SR) تعیین شدند. نتایج نشان داد فقط پایداری خاکدانه‌های 0/5-1 میلی‌متر به طور معنی‌داری ($p < 0.01$) تحت تاثیر اصلاح کننده‌های آلی بیشتر سایر اندازه‌ها بود. مقدار اصلاح کننده‌های آلی تاثیر معنی‌داری بر شاخص‌های پایداری خاکدانه‌ها (VDP، SI و SR) داشت، به طوری که پایداری خاکدانه‌ها با افزایش مقدار اصلاح کننده‌های آلی افزایش یافت. با این وجود، نوع اصلاح کننده آلی اثر معنی‌داری بر شاخص‌های پایداری خاکدانه‌ها نداشت. پایداری خاکدانه‌ها و در نتیجه میانگین مقدار منافذ قابل زهکشی، شاخص پایداری و نسبت پایداری با افزایش قطر منافذ و کاهش مقدار اصلاح کننده آلی به دلیل تخریب خاکدانه‌ها و منافذ درشت کاهش یافت. به طور کلی کاربرد حداقل 3 درصد اصلاح کننده‌های آلی برای افزایش پایداری ساختمان خاک در مناطق خشک مثل ایران پیشنهاد می‌شود.

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