jotaf
Journal of Tekirdag Agricultural Faculty
Tekirdağ Ziraat Fakültesi Dergisi

Ocak/January 2020, 17(1)
Başvuru/Received: 30/07/19
Kabul/Accepted: 17/10/19
DOI: 10.33462/jotaf.598809

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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Effects of Vermicompost on Aggregate Stability, Bulk Density and Some Chemical Characteristics of Soils with Different Textures*

Vermikompostun Farklı Tekstürlü Toprakların Agregat Stabilitesi, Hacim Ağırlığı ve Bazı Kimyasal Özelliklerine Etkisi

Tezcan AKTAŞ[1], Orhan YÜKSEL[2]**

Abstract

This study was conducted to investigate the effects of vermicompost treatments on some physical and chemical characteristics of two soils with different textures. Experiment was conducted in 30 pots with 2 soil types, 5 vermicompost doses (0, 20, 40, 80, 160 t ha^{-1}) and 3 replications. Vermicompost doses calculated over dry weights were applied to 5 kg pots and soil-vermicompost mixtures were incubated under laboratory conditions for about 90 days. According to analysis results, vermicompost treatments significantly increased organic matter content, pH, EC and cation exchange capacity (CEC) values of both soil types. Vermicompost applied at different doses increased organic matter and salt contents of both soil types parallel to increasing doses. As compared to the control dose, soil salinity greatly increased with the greatest vermicompost dose (16 t da^{-1}). Soil pH values increased in acidic loamy soils and decreased in clay soils with relatively high pH values. Since vermicompost has high organic matter content, it increased soil CEC values significantly. It was found that there were significant positive correlations between organic matter content and CEC values of the soils. Vermicompost treatments had positive effects also on soil physical characteristics, increased aggregate stability and decreased bulk density of the soils. While vermicompost treatments increased aggregate stability of loamy soils remarkably, such effects were not remarkable in clay soils.

Key words: Vermicompost, soil texture, clay soil, aggregate stability, bulk density

Öz

Bu çalışmada, organik bir gübre olan vermikompostun farklı tekstüre sahip iki toprağın bazı fiziksel ve kimyasal özellikleri üzerine etkisi araştırılmıştır. Deneme, 2 toprak tipi, 5 vermikompost dozu (0, 20, 40, 80, 160 t ha^{-1}) ve 3 tekerrür olmak üzere toplam 30 saksıdan oluşmaktadır. Kuru ağırlık üzerinden hesaplanan vermikompost dozları 5 kg'lık saksılara uygulanmış toprak-vermikompost karışımları laboratuvar koşullarında yaklaşık 90 gün inkübasyona bırakılmışlardır. Analiz sonuçlarına göre vermikompost uygulaması her iki toprak tipinde de organik madde miktarını, pH, EC, katyon değişim kapasitesi (CEC) değerlerini önemli düzeyde arttırmıştır. Topraklara farklı dozlarda ilave edilen vermikompost her iki toprak çeşidinde de organik madde miktarını ve tuz içeriklerini dozlara paralel olarak arttırmıştır. Toprakların tuzluluğu en yüksek doz olan 16 t da^{-1} kompost dozunda kontrol dozuna göre oldukça yüksek artış göstermiştir. Toprakların pH değerleri asit karakterli olan tınlı topraklarda yükselmiş, nispeten yüksek pH ya sahip killi topraklarda düşmüştür. Yüksek organik madde içeriğine sahip olması nedeni ile vermikompost toprakların CEC içeriklerini önemli düzeyde arttırmıştır. Toprakların organik madde miktarları ile CEC değerleri arasında pozitif ve önemli korelasyon bulunmuştur. Vermikompost toprakların fiziksel özelliklerini de olumlu etkilemiş ve agregat stabilitesini arttırırken hacim ağırlığını düşürmüştür.

[2]***Sorumlu Yazar/Corresponding Author:** Orhan Yüksel, Tekirdağ Namık Kemal University, Agricultural Faculty, Department of Soil Science and Plant Nutrition, Tekirdağ/Turkey. E-mail: oyuksel@nku.edu.tr OrcID: 0000-0003-0679-8722

[1]Tezcan Aktaş, Soil Laboratory of Keşan Commodity Exchange, Keşan, Edirne, Turkey. E-mail: tezcan_recep@hotmail.com OrcID: 0000-0002-4252-5150
Atıf/Citation: Yüksel, O., Aktaş, T. Effect of vermicompost on aggregate stability, bulk density and some chemical characteristics of soils with different textures, *Tekirdağ Ziraat Fakültesi Dergisi,* 17(1), 1-11.
*Bu çalışma Tezcan Aktaş'ın Yüksek Lisans tezinden özetlenmiştir.

Vermikompost agregat stabilitesini tınlı toprak tipinde önemli düzeyde arttırırken, killi toprak tipinde etkisi belirgin bulunmamıştır.

Anahtar kelimeler: Vermikompost, toprak tekstürü, killi toprak, agregat stabilitesi, hacim ağırlığı

Soil organic matter is one of the most significant factors for sustainable soil fertility. Insufficient soil organic matter levels constitute the greatest problems for soils of the countries with arid and semi-arid climates. Temperature, low precipitations, improper soil tillage practices, stubble burnings and soil erosion are the most important reasons of insufficient organic matter levels in those countries. The soils not able to meet organic matter needs naturally should be supplemented with external sources of organic matter. Soil productivity has long been tried to be improved with mineral fertilizers, but because of increasing interest in organic farming, farmers shifted to meet organic matter needs of the soils through natural sources. Such use of organic fertilizers reduced the use of chemical fertilizers and ultimately improved soil physical and chemical characteristics. For reliable and high yields, as well as chemical characteristics, soil physical characteristics should also be suitable for plant growth and development. Despite increasing awareness of farmers about the significance of organic matter for agricultural lands and increasing use of organic fertilizers, organic matter levels of Turkey's soils are still at quite low levels. The loss of organic matter from the agricultural lands through the above-mentioned reasons is still greater than the organic matter supplemented to the soils. Therefore, various organic matter sources are used in agricultural lands. New sources are introduced in each passing day. Vermicompost is considered among the prominent ones of these sources.

Vermicompost is also known as earthworm manure. It is an organic material obtained through composting of organic wastes by the earthworms. Vermicompost product is also called as vermicast (warm gut, manure) or cast in short. In this process, organic wastes are fermented by ambient microorganisms, then subjected to an accelerated humification and detoxification process while passing through the digestive tracks of earthworms (Şimşek-Erşahin, 2007). Vermicompost is an organic material. Besides improving soil characteristics, is supplies various nutrients to soils, thus can reliably be used in organic farming lands (Demir et al., 2010).

Vermicompost contains quite level of organic matter. As well as chemical characteristics, they have positive impacts on soil physical characteristics (Tejada et al., 2009). Organic matter regulates soil aggregation, thus increases soil porosity, increasing porosity then increase micro pores and resultantly decreases soil bulk density (Erhart and Hartl, 2010).

Organic soil amendments have different effects on soils with different characteristics. Therefore, two different soil types with different physical and chemical characteristics were used in present experiments to better elucidate the effects of vermicompost on soil characteristics. One of these soils had clay texture and the other had loamy texture. Clay-textured soil is Vertisol common in Thrace and known locally as "karakepir". Vertisols are rich in montmorillonite type clays and thus they have quite high swelling potential. Because of heavy clay content, they are stiff and hard to till soils. Such spoiled physical characteristics then limit yield potential of these soils (Dinç et al. 1993; Ozcan et al. 2018). The other soil type, loamy soil, used in this study is also common in northern sections of Thrace region. These soils have low pH values. Low pH is the most significant factor limiting the yield potential. Therefore, agricultural lime is commonly used in the region to increase soil pH and to improve availability of plant nutrients. Vermicompost increases pH of soils with low pH values (Azarmi et al. 2008). With vermicompost supplementations to soils, both plant nutrient support will be provided, and agricultural lime use will be reduced. Therefore, objective of the present study was set as to investigate the effects of increasing vermicompost treatments on physical and chemical characteristics of the soils with different textures and pH levels.

Material and Methods

Material

Experimental soils

Clay (C) and Sandy-Clay-Loam (SCL) textured soils were used in present experiments. These soils were named as Soil 1 (C) and Soil 2 (SCL).

Soil 1: Clay soil (C) was supplied from Altıntaş village of Keşan (Edirne), (41°00′37″ N, 26°40′26″ E). According to Soil Taxonomy, 2010, soils belong to Haploxererts great group of Vertisol ordo (Soil Survey Staff, 2010). Analysis results of clay soil used in present experiments are provided in Table 1.

Soil 2: Loamy soil (sandy-clay-loam (SCL)) was supplied from Ballıhoca village of Muratlı (Tekirdağ), (41°12′12″ N, 27°30′45″ E). According to Soil Taxonomy, 2010, soils belong to Xerofluvents great group of Entisol ordo (Soil Survey Staff, 2010). Analysis results of loamy soil used in present experiments are provided in Table 1.

Table 1. Analysis results of experimental soils

Toprak	pH	EC dS m^{-1}	O.M %	$CaCO_3$ %	CEC cmol kg^{-1}	P mg kg^{-1}	K mg kg^{-1}	Texture (%)			
								Clay	Silt	Sand	Class
Soil 1	7,22	0,01	1,87	6,92	20,42	5,85	362,50	43,92	18,20	38,38	C
Soil 2	4,20	0,06	1,15	0,00	11,21	23,62	91,43	27,74	14,16	58,10	SCL

Vermicompost

The vermicompost used in present experiments was supplied from a commercial vermicompost manufacturer in Tekirdağ. The facility produces vermicompost through composting of manure. Analysis results of vermicompost are provided in Table 2.

Table 2. Chemical characteristics of vermicompost used in the experiment

O.M. (%)	Moisture (%)	pH	EC (dS m^{-1})	Dry matter (%)	Total N (%)	Avaliable P (mg kg^{-1})	Total K_2O (%)	Total CaO (%)
51,80	70,60	7,60	5,70	42,57	2,20	1,20	1,80	5,90

Methods

Experimental design and sampling

A pot-experiment was conducted under laboratory conditions. The soils with different textures were air dried and ground to pass 2 mm sieve. Experimental soils were supplemented with 0 (100% soil)-2-4-8-16 t da^{-1} vermicompost in dry weight basis. Vermicompost supplemented soils were then placed into 5 kg plastic pots. Vermicompost-soil mixtures were incubated for about 90 days.

Following the incubation, soils were removed from the pots. A portion of soils were ground to pass 2 mm sieve and prepared for chemical analyses. Samples were subjected to pH, electrical conductivity (EC), organic matter (OM) and cation exchange capacity (CEC) analyses. Another portion of soils were ground to pass through 2-1 mm sieves and subjected to aggregate stability (AS) analysis. The remaining original sample was used for bulk density (BD) analysis.

Analysis methods

Soil pH was determined in 1:2.5 soil:distilled water solution with a pH meter. Soil electrical conductivity was determined also in 1:2.5 soil:distilled water solution with an EC meter (US. Salinity Lab. Staff, 1954). Soil organic matter content was determined in accordance with Walkley-Black method (Nelson and Sommers, 1996); $CaCO_3$ contents were determined with a Scheibler calcimeter (Loeppert and Suarez, 1996). Soil cation Exchange capacity was determined in accordance with ammonium acetate (pH: 7) method (Sumner and Miller, 1996). Soil aggregate stability (on 1-2 mm aggregates) was determined by using an Eijkelkamp wet-sieving apparatus (Kemper and Rosenau, 1986) and bulk density was determined with the clod method (Blake and Hartge, 1986).

Statistical Analyses

Experimental data were subjected to variance analysis with the aid of TARİST statistical software (Açıkgöz et al., 1994) and significant means were compared with the aid of LSD tests (Steel and Torrie, 1960).

Results and Discussion

Soil Chemical Properties

Organic matter

Organic matter content of both soils increased with increasing vermicompost doses. Organic matter content of Soil 1 was 1.87% in control treatment and the value reached to 3.31% at 16 t da^{-1} vermicompost dose. Organic matter content of Soil 2 was 1.15% in control treatment and the value reached to 2.55% at 16 t da^{-1} vermicompost dose (Figure 1).

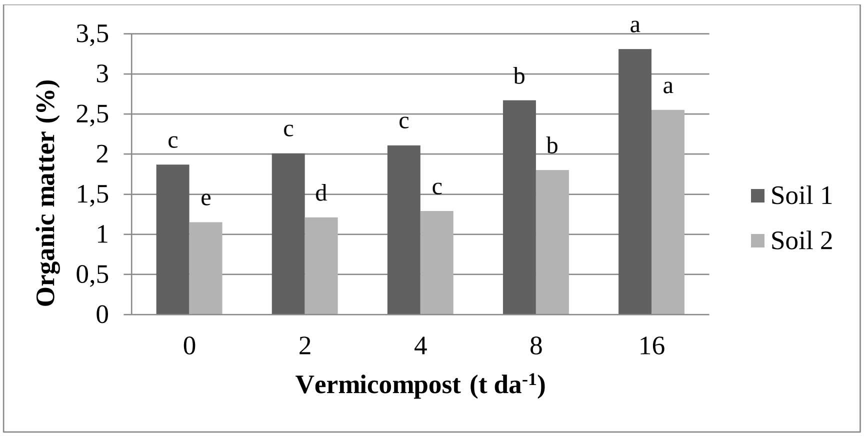

Figure 1. Organic matter contents of experimental soils

According to variance analysis, compost doses had significant positive effects on organic matter content of both soils (P<0,01). Experimental vermicompost had an organic matter content of about 50%. Therefore, significantly increased organic matter content of the soils. Significant increases in organic matter contents with vermicompost treatments were also reported in previous studies (Mahmoud and Ibrahim, 2012; Tavalı et al., 2014).

Soil reaction (pH)

Vermicompost treatments reduced pH values of Soil 1 and increased pH values of Soil 2. The pH of Soil 1 was 7.22 in control treatment and the value decreased to 7.01 at 16 t da^{-1} compost dose. The pH of Soil 2 was 4.20 in control treatment and the value increased to 5.17 at 16 t da^{-1} compost dose (Figure 2). Soil 1 was slightly alkaline, thus pH values decreased with increasing compost doses. Soil 2 was slightly acidic, thus pH values increased with increasing vermicompost doses. Effects of vermicompost treatments on pH were found to be significant in both soils (P<0.01).

Since vermicompost used in experiments had a high CaO (5,90%) content, it can be stated that it could increase pH of the soil with low pH levels (Soil 2). Romaniuk et al. (2011) reported that in low pH soils, 20 Mg ha^{-1} vermicompost treatment increased soil pH from 6,06 to 6,45. Such an increase was attributed to greater pH of vermicompost than the soil. In slightly alkaline Soil 1 on the other hand, vermicompost treatments decreased soil pH from 7,22 to 7,01. In a previous study, Manivannan et al. (2009) applied vermicompost to soil with two different textures and reported decreasing soil pH values with vermicompost treatments. Researches attributed such decreases in pH values to acidification effects of organic acids produced during the decomposition of organic amendments. Besides, Gutierrez-Miceli et al. (2007) applied vermicompost produced from sheep manure to alkaline soils and reported that vermicompost reduced soil pH levels. Tavalı et al. (2014) applied vermicompost to clay soils and reported that vermicompost reduced soil pH from 7.92 to 7.68. indicated that vermicompost at high doses slightly, but significantly increased soil pH.

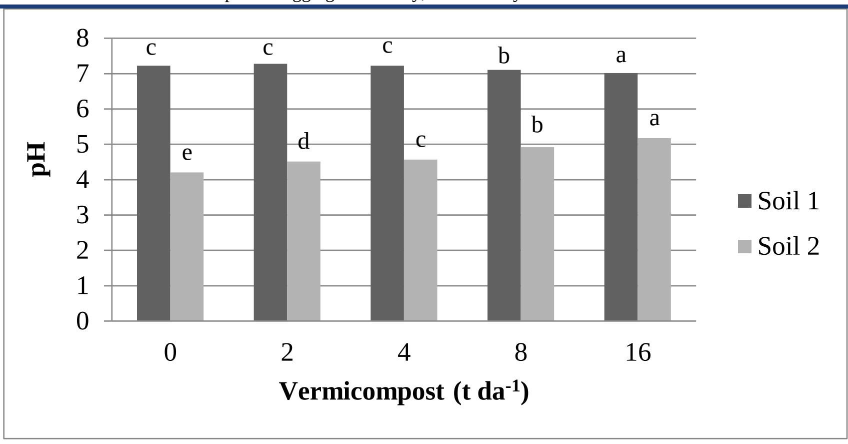

Figure 2. pH results of experimental soils

Soil salinity (EC)

Vermicompost treatments increased electrical conductivity (EC) of both soils. EC of Soil 1 was 1,45 dS m^{-1} in control treatment and the value increased to 2,76 dS m^{-1} at 16 t da^{-1} compost dose. EC of Soil 2 was 0,59 dS m^{-1} in control treatment and the value increased to 2,63 dS m^{-1} at 16 t da^{-1} compost dose (Figure 3). Increases in soil EC values with vermicompost treatments were found to be significant (P<0.01).

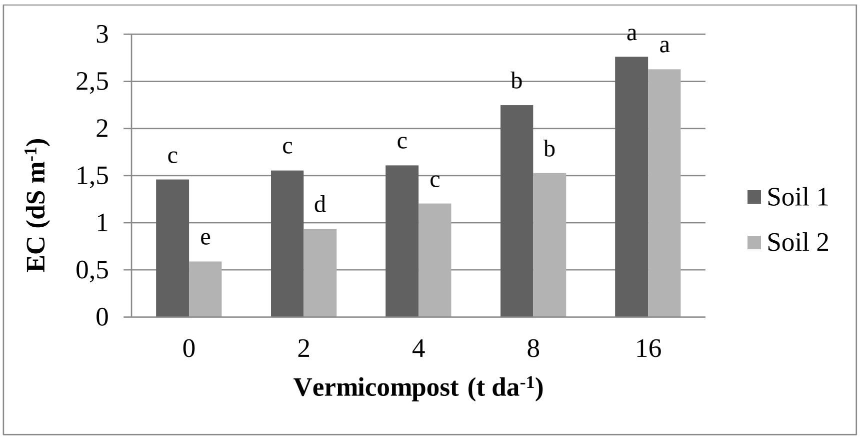

Figure 3. EC results of experimental soils

The vermicompost used in present experiments had an EC value of 5,70 dS m^{-1} and such a value was a quite high value. Highly saline vermicompost treatments thus increased soil EC levels. Closed drainage of the pots prevented salt leaching. Reduced salt accumulation through leaching under natural conditions is an expected case but increasing EC levels with vermicompost treatments in closed drainage conditions is usual. Increasing EC values with vermicompost treatments were also reported in previous studies (Romaniuk et al., 2011; Tavalı et al., 2014).

Cation exchange capacity (CEC)

Vermicompost treatments increased CEC of both soils. The CEC of Soil 1 was 20.72 cmol kg^{-1} in control treatment and the value increased to 27.85 cmol kg^{-1} at 16 t da^{-1} vermicompost dose. The CEC of Soil 2 was 11.09 cmol kg^{-1} g in control treatment and the value reached to 16.00 cmol kg^{-1} at 16 t da^{-1} compost dose. Effects of vermicompost treatments on CEC values were found to be significant in both soils (P<0.01) (Figure 4).

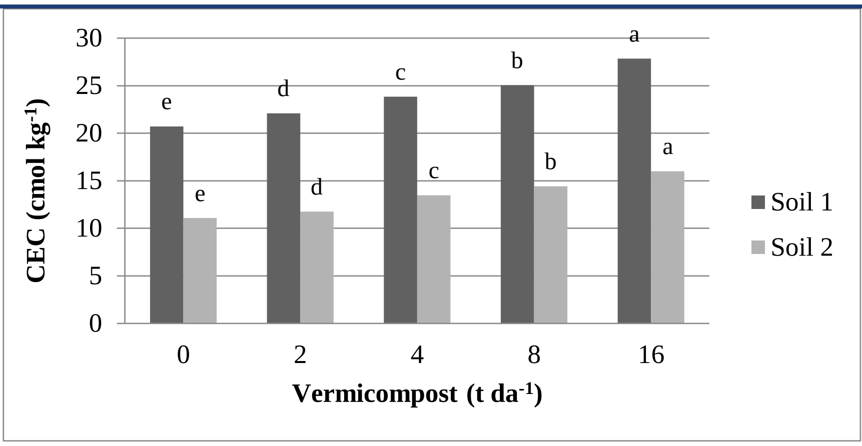

Figure 4. Cation exchange capacity (CEC) values of experimental soils

Vermicompost has quite high organic matter contents, thus it increase soil CEC values (**Mahmoud and Ibrahim, 2012; Manivannan et. al.,** 2009**). There were significant positive correlations between** organic matter **content and CEC both soils at 1% level** (Table 3 and Table 4). Loveland and Webb (2003) also reported significant correlations between organic matter and CEC and reported increasing CEC values with increasing organic matter contents. Amlinger et al. (2007) reported that organic matter increased soil CEC values by 20-70% and Hemmat et al. (2010) reported that organic matter increased CEC values of the soils by 25-90%.

Soil Physical Properties

Aggregate stability (%)

Vermicompost treatments increased aggregate stability of Soil 2 at all doses as compared to the control, but increased aggregate stability of Soil 1 only at 2 t da^{-1} and 8 t da^{-1} compost doses. While vermicompost treatments had significant effects on aggregate stability of Soil 2 ($P<0.01$), effects of vermicompost treatments on aggregate stability of Soil 1 were not found to be significant (Figure 5).

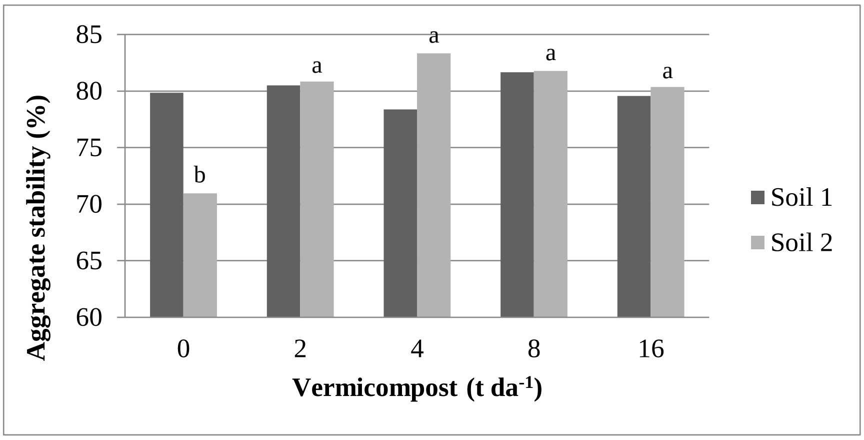

Figure 5. Aggregate stability results of experimental soils

Vermicompost is an organic material rich in humic acid (Arancon et al., 2006). The substances with high humic acid contents improve soil structure and thus increase aggregate stability (Karami et al., 2012). There is a significant correlation between aggregate stability and humic acid (Piccolo et al., 1992).

Effects of vermicompost treatments on aggregate stability of Soil 1 were not found to be significant since Soil 1 had quite high clay content. The soils with high clay contents already have high aggregate stability because of binding effects of clay on soil particles (Bahtiyar, 1997). Therefore, effects of vermicompost on aggregate stability of Soil 1 were quite limited. On the other hand, vermicompost treatments significantly increased aggregate stability of Soil 2 with loamy texture at all doses as compared to the control treatment. Aggregate stability of Soil 2 initially increased rapidly, but decreased gradually at high doses. Such a decrease in aggregate stability at high doses can be attributed to increasing salinity of these soils. EC of Soil 1 at the greatest dose (2,63 dS m^{-1}) was about 5 times greater than the EC of control treatment (0,59 dS m^{-1}). Soil salt content (especially Na salts) may have negative impacts on aggregate dispersion of the soils (Mamedov, 2014).

Bulk density (db)

Bulk density values of the soils remarkably decreased with increasing vermicompost doses. Bulk density of Soil 1 was 1,51 g cm^{-3} in control treatment and the value decreased to 1,31 g cm^{-3} at 16 t da^{-1} compost dose. Bulk density of Soil 2 was 1,56 g cm^{-3} in control treatment and the value decreased to 1,35 g cm^{-3} at 16 t da^{-1} compost dose. Effects of vermicompost treatments on bulk density were found to be significant in both soils (P<0.01) (Figure 6).

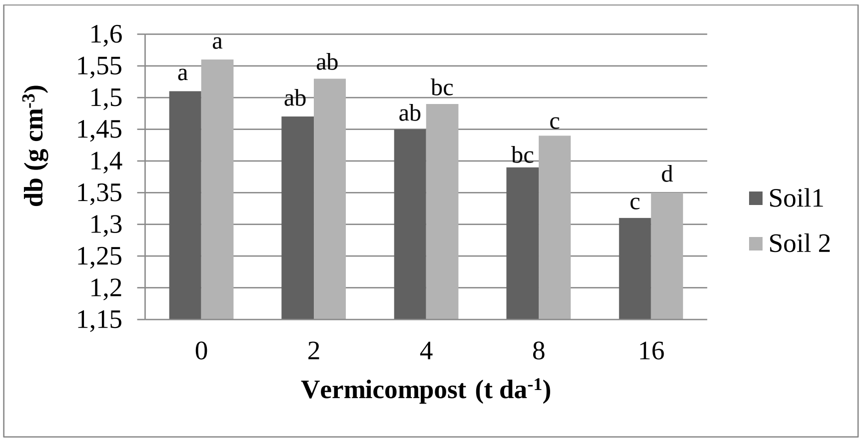

Figure 6. Bulk density results of experimental soils

There are two primary reasons of decreasing soil bulk densities with vermicompost-like organic soil amendments. The first is the reduced soil bulk density with the supplementation of low-density organic matter (Maylavarapu and Zinati, 2009) and the second is increased porosity through improved soil aggregation with such substances (Hemmat et al., 2010; Eibisch et al., 2015). There were significant negative correlations between soil organic matter contents and bulk densities of both soils (Table 3 and 4).

Table 3. Correlations between soil characteristics (Soil 1)

	pH	EC	OM	CEC	AS	BD
pH	1.000					
EC	-0.934**	1.000				
OM	-0.946**	0.925**	1.000			
CEC	-0.881**	0.904**	0.938**	1.000		
AS	-0.146ns	0.047ns	0.113ns	0.008ns	1.000	
BD	0.812**	-.868**	-0.880**	-0.856**	-0.122ns	1.000

*= significant at %5, ** = significant at %1, ns: non-significant

Table 4. Correlations between soil characteristics (Soil 2)

	pH	EC	OM	CEC	AS	BD
pH	1.000					
EC	0.918**	1.000				
OM	0.885**	0.962**	1.000			
CEC	0.927**	0.938**	0.889**	1.000		
AS	0.546*	0.399ns	0.235ns	0.505ns	1.000	
BD	0.907**	-0.934**	-0.913**	-0.955**	-0.441ns	1.000

*= significant at %5, ** = significant at %1, ns: non-significant

Conclusion

Vermicompost treatments significantly increased organic matter content, pH, EC and CEC values of both soils with different textures. While pH value of acidic loamy soils increased and pH values of clay soils with high pH levels decreased with vermicompost treatments. Because of high organic matter contents, vermicompost treatments increased CEC values by 35% in Soil 1 and by about 45% in Soil 2.

While vermicompost treatments remarkable increased aggregate stability of Soil 2, the increases in aggregate stability of Soil 1 with high clay content were not remarkable. Vermicompost treatments decreased bulk density of both soils remarkably.

In vermicompost treatments, salt content of vermicompost should be taken into consideration. Soil EC values remarkable increased with vermicompost treatments. At the end of the experiments, as compared to the control treatments, EC of Soil 1 was doubled, and EC of Soil 2 increased about 4 folds with the greatest vermicompost dose (16 t da^{-1}). Although not reached to thresholds, salinity significantly increased in soils. Despite high organic matter and plant nutrient content of vermicompost, they are costly materials. Although high doses were used in this study, they are used at low doses in field and under-cover production systems, thus become economic. Leaching through irrigation and precipitations also reduce salinity problems. However, long-term use of vermicompost in greenhouses and pot cultures may exert a salinity problem.

In present study, high vermicompost doses were applied just to better see the effects on physical characteristics. Pot also had closed drainage conditions. Thus, increasing EC values were an expected case. Under field conditions, less quantities will be applied, precipitations will leach salts beneath the rootzone, thus minimize salinity problem. However, salinity may generate a problem in case of long-term use in pot under greenhouse conditions.

Vermicompost is preferred as a fertilizer material just because of positive impacts on plant growth and soil chemical characteristics. However, present findings revealed that vermicompost had significant effects also on soil physical characteristics because of high organic matter content. Vermicompost is a costly product, thus it is not widespread in field culture. Therefore, it is commonly used small-scale productions, especially in greenhouses. Regardless of the type and size of farming, vermicompost or similar organic materials should be applied to soils for sustainable soil fertility.

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