Influence of humic acid applications on soil physicochemical properties

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Abstract

Soil structure is often said to be the key to soil productivity since a fertile soil, with desirable soil structure and adequate moisture supply, constitutes a productive soil. Soil structure influences soil water movement and retention, erosion, crusting, nutrient recycling, root penetration and crop yield. The objective of this work is to study, humic acid (HA) application on some physical and chemical properties in weak structured soils investigated. The approach involved establishing a plot experiment in the laboratory conditions. Different rates of HA (control, 0.5%, 1%, 2% and 4%) were applied to soil at three incubation periods (21, 42 and 62 days). At the end of the each incubation period, the changes in physicochemical properties were measured. Generally, HA addition increased EC values at the all incubation periods. HA applications decreased soil modulus of rupture. Application of HA at the rate of 4% was significantly increased soil organic carbon contents. HA applications at the rate of 4% significantly increased both mean soil total nitrogen content and aggregate stability after at three incubation periods ($p<0.05$). Therefore, HA was potential to improve structure of soil in short term.

Key words**:** Aggregate stability**,** humic acid, soil modulus rupture, soil physicochemical properties soil structure

1 Introduction

The widespread use of unsuitable and unsustainable production techniques in agricultural systems has resulted in extensive deterioration of soil quality and reductions in soil organic matter content and crop production (Verhults et al., 2010; Martinez-Blanco et al., 2011). Soil quality is threatened by the increase in human opulation, by intensive management of cultivable land and by urbanisation and soil degradation. There is a general agreement that oil biochemical, microbiological and biological properties are more than physical and chemical properties for the purpose of estimating alteations in soil quality and hence soil degradation (Paz- Ferreiro nd Fu, 2013). Soil quality can be strongly affected by a wide range of land management techniques (Keesstra et al., 2012). Soil organic matter plays an essential role in nutrient (N, P, S, K) cycles, soil stability and the ecological and environmental aspects of sustainability of soil fertility (Garcıa-Gil et al., 2004). Turkey soils generally have low organic matter levels and are commonly treated with mineral fertilizers that may improve yield in the short-term, but do not enhance the physical properties of the soil and result in soil degradation over the longer-term. Many regions in Turkey, especially the organic matter content of soils in Central Anatolia has fallen below 2% or 1% (Şeker and Karakaplan, 1999).

Organic materials are important soil additives to improve soil physical, chemical and biological properties. This is important to sustain the productivity of soils particularly in semi-arid regions (such as Turkey) where there is low input of organic materials. Usage of organic based materials has gained importance within the last few years for sustainable agriculture and preventing soil degradation (Alagöz and Erdem, 2009).

Soil structure is often said to be the key to soil, its ability to support plant and animal life, and moderate environmental quality with particular emphasis on soil carbon (C) sequestration and water quality. Understanding soil structural formation involves aspects of biology, chemistry, geology and physics within the context of the soil environment (Brevik et al., 2015). Using aggregate size, shape and distinctness as the basis for classes, types and grades, respectively, soil structure describes the manner in which soil particles are aggregated. Soil structure affects water and air movement through soil, greatly influencing soils ability to sustain life and perform other vital soil functions. A soil with a well-developed structure and high aggregate stability are important to improving soil fertility, increasing agronomic productivity, enhancing porosity and decreasing erodibility. Aggregate stability as a reflection of soil structure and soil health in general because it depends on an integrated balance of chemical, physical and biological factors (Brevik et al., 2015). The decline in soil structure is increasingly seen as a form of soil degradation (Chan et al., 2003) and is often related to land use and soil-crop management practices. Structural and physical soil degradation is often associated with a decline in the organic matter content. Reports have indicated that loss of organic matter is generally associated with a decline in soil porosity and wet aggregate stability, and an increase in soil strength indices (Şeker and Karakaplan, 1999).

Certain components of soil organic matter such as polysaccharides, humic substances, root material and fungal hyphae have an important role in structural stabilization. Some synthetic conditioners which have shown promise for use in improving soil structure and physical properties at low application rates are polyacrylamides (PAM) and polyvinyl alcohols (PVA) (Bryan, 1992).

Humic acids and their salts, derived from coal and other natural sources, which have modes of action similar to synthetic conditioners, have been evaluated as potential soil conditioners. The advantage of humic substances is the refractory nature of their chemical structures that makes them more resistant to microbial attacks. Piccolo et al., (1997) reported that humic subtances have a potential as soil conditioners in conversation practices aimed at increasing the structural stability of soils. Ersoy and Şeker (2004) reported that urban waste compost (UWC), cattle manure (CM), chicken manure (CHM) and leonardite (L) improved soil aggregate stability values. Şeker (2003) reported that adding portland cement and wheat straw to a soil having a crusting problem increased its aggregate stability and in turn seedling emergence of wheat was improved by decreased modulus of rupture and penetration resistance. Imbufe et al., (2005) suggested that potassium humate is potentially effective as a soil conditioner in improving aggregate stability of acidic and sodic soils against adverse effects of cyclic seasonal wetting and drying conditions. Bal et al., (2011) determined crusting problems of the Konya-Sarıcalar research satiation soils and offer some recommendations for solution of its. As a result, it is required to increase the organic matter content and to reduce the agricultural practices to the minimum tillage in order to prevent the crusting problems in the research soils.

The aim of this study was to determine effects of humic acid applications on crust resistance, aggregate stability, electrical conductivity (EC), nitrogen and organic carbon of weak structured soils.

2 Materials and Methods

2.1 Material

Humic acid (trade name DELTA K-Humate) was supplied from a company. The soil sample used in this study has the problems such as insufficient seedling emergency, low aggregate stability and crusting problem (Bal et al., 2011) Composited soil samples were taken from a problematic plot in the Agricultural Faculty of Selçuk University experiment station (0-20 cm soil depth) near the Konya Sarıcalar-Village located in central Anatolia, Turkey (38° 06' N, 32° 36' E, 1010 m). The climate is semi-arid, with an annual precipitation of 379.38 mm, an annual mean temperature of 11.5 ˚C and an annual mean evaporation of 1226.4 mm.

2.2 Methods

The study was carried out in a randomized plot design with three replications and conducted under laboratory conditions as a pot experiment. Surface soil samples (0-20 cm) were air-dried, ground pass a 2-mm sieve and mixed homogeneously. Firstly, soil samples (2000 g) placed in each pot (dimensions of pot; 13.5 cm x 17 cm). Five levels of HA, (0% (control), 0.5%, 1%, 2% and 4%) were incubated. During the incubation period, the soil moisture level in the pots was maintained 50-75% of field capacity. After various incubation (21, 42 and 62 days), the soil samples in the pots were mixed to ensure homogeneity in physical, chemical and biological properties. The soils were then sub-sampled (250 g) for analyses. 21, 42 and 62 days incubation periods after the incubations soil samples were analyzed with three replications.

Particle-size distribution of the soil was determined by the hydrometer method (Day, 1965). Soil water retention at field capacity (-0.33 kPa) suction was determined by using a ceramic plate (Peters, 1965). Soil EC values were determined using a glass-calomel electrode in a 1:2.5 mixture (v/v) of soil and water (Jackson, 1967). Soil organic carbon was determined on sample ground to pass through a 0.5 mm sieve by the using the TruSpec CN Carbon/Nitrogen Determinator (LECO Corporation 2006). The methodology used for measuring modulus of rupture (MR) as an index of crusting was that proposed by Reeve (1965). Aggregate stability was determined by immersing the sieves, containing the aggregate samples (between 1-2mm size), in distilled water at up and down oscillating on screens through 55 mm at 30 strokes min-1 for 5 min (Kemper, 1965). The data collected from the experiment were analyzed using analysis of variance tests based on randomised- plot design (using F-LSD at $P < 0.05$) according to the procedures outlined by Snedecor and Cochran (1980). All statistical results were calculated using the one-way Analysis of Variance procedure on MINITAB statistic software package (Minitab, 1995).

3 Result and Discussion

Some physical and chemical properties of the soil and humic acid are given Table 1 and 2. The soil was characterized by having a clay texture, a alkaline soil pH (7.80) and organic matter and $CaCO_3$ contents of 2.95 % and 11.17 %, respectively.

Table 1. (Soil properties of the experimental sites.) Properties of the soil used in the experiment. **This sentence has been rewritten at the request of the referee.**

Soil properties	Values	Soil properties	Values
Sand (2-0.05 mm)(%)	7.36	Field capacity (%)	31.14
Silt (0.05-0.002 mm)(%)	37.72	Wilting point (%)	15.39
Clay (<0.002 mm)(%)	54.92	Aggregate stability (%)	14.37
Textural class	Clay	Bulk density (g cm^{-3})	1.34
pH (H_2O, 1:2.5)	7.80		
EC (H_2O, 1:2.5) d S m^{-1}	0.556		
Organic matter (%)	2.95		
Carbonates (%)	11.17		
CEC (cmol kg^{-1})	33.6		

CEC, cation exchange capacity

Table 2. Properties of the humic acid

Properties	HA
pH (H_2O, 1:2.5)	11-13
Organic matter (%)	30
Humic and fulvic acid (%)	80
K_2O (%)	10

3.1 Effects of different rates humic acid (HA) applications on soil modulus of rupture

The effects of HA on soil modulus of rupture was given in Fig. 1. Modulus rupture of the soil treated with different doses HA application was measured after 21, 42 and 62 days incubation periods, respectively. The effects of HA application on modulus of rupture was significantly ($P<0.05$). Generally, soil modulus of rupture decreased with the increasing amendment rates of HA. These results may be explained by buildup of soil aggregate systems during incubation periods. The modulus of rupture was reduced because of the increase in HA treatments which allowed less cohesion among the soil particles. Soil degradation caused by which may have led to a reduction in soil organic matter decomposition, soil erosion and nutrient leaching. The decreased soil erosion risk, nutrient leaching an organic matter decomposition rate helped in improving soil quality (Zhang et al., 2015). Similar positive effects were recorded with various forms of organic matter addition (Özdemir, 2002; Şeker, 2003). The possible mechanisms by which coal-derived humic acids improve soil physical properties are the formation of organomineral complexes by functional groups of the humic acids (Glaser, Lehmann and Zech, 2002).

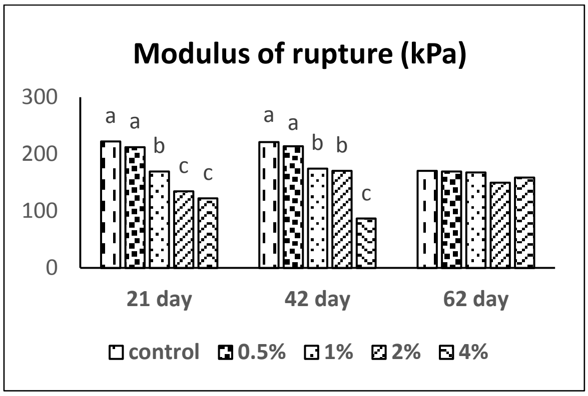

Fig. 1. Effects of different rates of HA applications on soil modulus of rupture

3.2 Effects of different rates humic acid (HA) applications on aggregate stability (AS)

The effects of HA on soil aggregate stability values was given in Fig. 2. Aggregate stability values of the soil treated with different doses HA application was measured after 21, 42 and 62 days incubation periods, respectively. The effects of HA application on soil aggregate stability values was significant ($P<0.05$). Generally, aggregate stability were increased with HA applications. These results may be explained by biological and physicochemical (especially, metal ions, humic or fulvic acids and carbohydrates content) can play role in initial aggregate formation. Stability of micro-aggregates is strongly correlated with the humic matter content (humic or humic+fulvic acid) (Piccolo and Mbagwu, 1990). Kütük et al. (2000) reported that the highest amount of water resistant aggregates was obtained in the highest dose of humic acid application. Aggregate stability decreased in the 42 and 62 days incubation periods in all humic acid rates comparing to 21 day incubation period. It was well known that soil organic matter, especially, humic materials are cementing agents in soil particles, and however, certain organic components can play role paradoxically as a dispersion element in clay-water systems (Tarchitzky et al., 1993). Reduced input rate of organic matter and translocation of surface soils with water erosion are also reasons for low organic matter content of cultivated soils (Ozgoz et al., 2011). Lower organic carbon content in farmland caused a significant difference aggregate stability value (Ozgoz et al., 2011). Shanmuganathan and Oades (1983) were reported that addition of anions to soils cause to dispersion in clay fraction associated with decreasing isoelectric point, and it is known that fulvics acid especially, are the most efficient anions. In addition, aggregate stability of the soil samples decreased after incubation periods due, most probably, to mechanical mixing practices (Şeker, 2003). Aggregate stability should be used judiciously and in concert with other indicators for an overall assessing of the soil physical quality condition (Moncada et all., 2013).

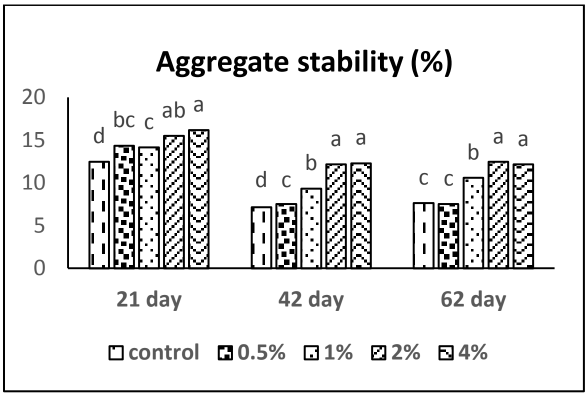

Fig. 2. Effects of different rates of HA applications on aggregate stability

3.3 Effects of different rates humic acid (HA) applications on soil EC

The effects of HA on EC values of the soil was given in Fig. 3. As illustrated in Fig. 3, the EC values significantly increased with respect to elevated HA application. According to investigation at 21 day expect for 0.5% application which resulted in significant increased. Investigation performed at 42 and 62 days revealed that soil EC linearly increased in response to increment in HA dose. The increasing EC values in experiment for different doses HA application may be explained by rich nutrient composition of organic fragments and remains from the materials at during incubation periods (Yılmaz, 2010). Imbufe et all., 2004 reported that potassium humate application increased in soil pH and electrical conductivity. The present findings including the previous studies indicate that the increment in HA dose accompanies with the elevation in soil EC level. For this reason, excessive use of HA should be avoided when HA is considered to use as solvent substance for calcareous soils in agriculture.

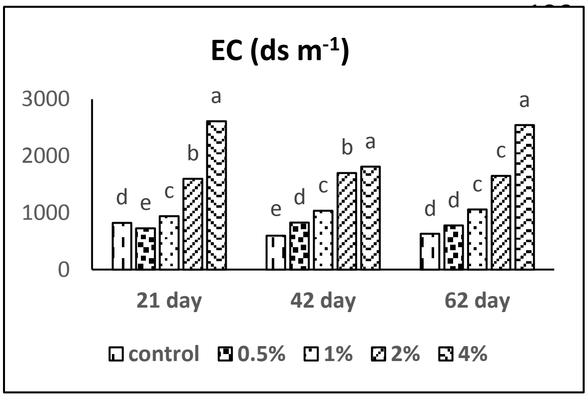

Fig. 3. Effects of different rates of HA applications on soil EC

3.4 Effects of different rates humic acid (HA) applications on soil organic carbon (SOC)

The effects of HA on SOC values of the soil was given in Fig. 4. As illustrated in Fig. 4, the SOC values significantly increased with respect to elevated HA application. According to investigation at 21 day expect for 0.5% application which resulted in significant increased. Investigation performed at 42 and 62 days revealed that soil SOC linearly increased in response to increment in HA dose and the strongest effect obtained with the doses 2% and

4%. Where differences in SOC values depending on incubation periods and rates of HA were noticed. SOC content of soil increased with increasing amendment rates of HA. Generally, SOC content values in experiments increase with the increase of amendment rates of organic materials. Total organic matter has long been recognized as an important determinant of soil performance. It depends on how much organic matter is added to the soil, how quickly it decomposes, and how much can be held by the soil. The amount, type and location of organic matter may be some of the best integrating indicators of many physical, chemical and biological processes (Lewandowski and Zumwinkle, 1999). SOC have been reported as dynamic soil quality indicators (Shukla et al., 2006; Zhao, 2013). Therefore, to asses the effect of changes in SOC content on soil structure condition, the aggregate stability can be considered as a good indicator (Moncada et al., 2013). SOC content, nitrogen and phosphorus is one of the most important chemical soil quality indicators for soil recovery and can drive changes in the biological, chemical and physical soil attributes (Vasconcellos et al., 2013). Similar positive effects were recorded with various forms of organic matter and arbuscular mycorrhizal fungi addition (Ferreras et al., 2006; Kavdır and Killi, 2008; Yılmaz, 2011; Vasconcellos et al., 2013).

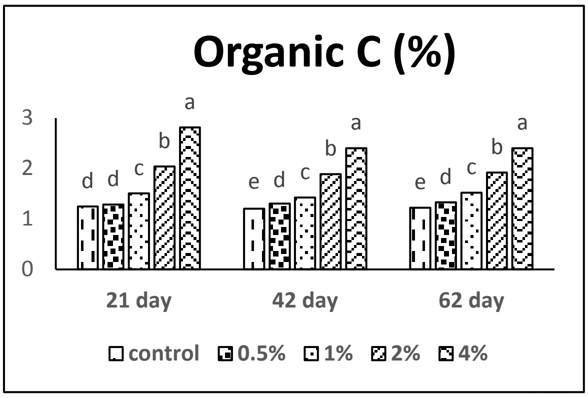

Fig. 4. Effects of different rates of HA applications on soil organic carbon

3.5 Effects of different rates humic acid (HA) applications on total nitrogen (N)

The effects of HA on total nitrogen values of the soil was given in Fig. 5. As illustrated in Fig. 5, the total nitrogen values significantly increased with respect to elevated HA application. According to investigation at 21, 42 and 62 days expect for 0.5, 1 and 2% applications which resulted in significant increased and the strongest effect obtained with the doses 2% and 4%. However, amendments rates of doses 2 and 4% are similar. Generally, total nitrogen content of soil increased with increasing amendment rates of HA. Yılmaz (2011) reported that biological and physicochemical properties of organic materials (especially C/N, decomposition and mineralization level) can play roles in mineralization of nitrogen from organic materials at during incubation periods.

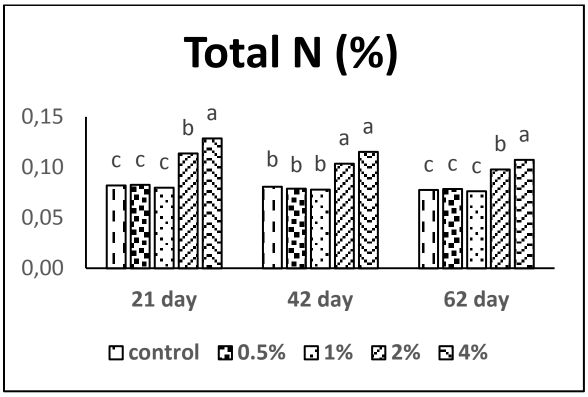

Fig. 5. Effects of different rates of HA applications on total nitrogen

4 Conclusions

In conclusion, the results of this laboratory study indicate that humic acid applications can improve the stability of structurally soils. Chemical and physical properties of soil such as soil organic carbon, total nitrogen, modulus of rupture and aggregate stability were improved by HA amendment. Chemical and physical properties of soil such as soil organic carbon, total nitrogen, modulus of rupture and aggregate stability were improved by HA amendment. HA increased soil EC and aggregate stability during the incubation period. Soil modulus of rupture was the most dramatically affected by the HA application. The use of HA may contribute to enhancing the level of organic carbon and nitrogen in soil. According to the results, HA (K-Humate) has potential to be used as an effective conversation and management tool for sustainability of the soil environment.

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