Effects of Spent Mushroom Compost Application on Physicochemical Properties of Degraded Soil

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Abstract

Land and laboratory studies show that the application of organic amendments into the soil improves the physicochemical properties of it. The study aims to explore spent mushroom compost (SMC) application on the properties of a weak-structured and degraded soil. The approach involved establishes a pot experiment with spent mushroom compost applications (control, 0.5%, 1%, 2%, 4% and 8%). The soils were incubated at field capacity water content (-33 kPa) for 21, 42, and 62 days. SMC applications into the soil significantly increased the aggregate stability (AS) and decreased the modulus of rupture. SMC increased soil EC, with all treatments having EC values well below the upper limit of 4000 µS cm^{-1}, as suggested for agricultural soils. Application of SMC at the rate of 1%, 2%, 4%, and 8% significantly increased the total nitrogen (N) and soil organic carbon (SOC) contents of the degraded soil at all incubation periods ($p<0.05$). The results obtained from this study clearly indicated that the application of spent mushroom compost reduces the modulus of rupture and increase of total nitrogen and soil organic carbon content.

Keywords: Aggregate stability, modulus of rupture, soil aggregation, soil structure, spent mushroom compost

1 Introduction

Soil quality is defined as the capacity of the soil to function within natural or managed ecosystem and land use boundaries, to sustain biological productivity, to promote the quality of air and water environments, and to maintain plant, animal and human health (Doran et al., 1997; Karlen et al., 1997). Physical and chemical attributes are the main indicators used to assess soil quality (Bone et al., 2014; Paz-Ferreiro and Fu, 2013; Pulido Moncada et al., 2015). Soil quality is threatened by intensive management of the available urbanization and agricultural land, and by the increase in human activities (Paz-Ferreiro and Fu, 2013). Soil quality is another important aspect closely related to soil degradation. Soil degradation decreases land productivity (Yu and Jia, 2014). Degradation of land can be divided into three types: arid, semi-arid, and sub-humid dry areas from various factors, including climatic variations and human activities (Yu and Jia, 2014). Soil degradation problem is particularly serious in the Mediterranean areas, where the effects of anthropogenic activities add to the problems caused by prolonged periods of drought and intense and irregular rainfall (Hueso-González et al., 2014). Vegetation degradation, land use change, and soil degradation factors that causes soil carbon and nitrogen losses (Moreno et al., 2016; Peng et al., 2015). The reduction in soil structure is considered as a form of soil degradation (Chan et al., 2003), and is always with regards to land use and soil crop management practices.

Physical properties of soil include soil structure degradation occurs mostly due to the decrease in soil organic matter caused by excessive soil cultivation (Grandy et al., 2002). Şeker and Karakaplan (1999) reported that the loss of organic matter is generally associated with a decrease in soil porosity and wet aggregate stability, as well as the increase in soil strength indices. Soil water movement and retention, crusting, root penetration, crop yield, erosion, and nutrient recycling are influenced by soil structure (Bal et al., 2012; Bronick and Lal, 2005; Seker, 2003). Organic materials are important soil additives that help to improve soil physical, chemical, and biological properties. Organic materials can improve the fertility of soil and soil amelioration (Wu et al., 2014). Besides good yield, these organic materials have been beneficial for soil chemical and physical fertility and stability that are possible due to organic matter (Mukherjee et al., 2014). Sustaining the productivity of soils is important, particularly in semi-arid regions (such as Turkey) where there is low input of organic materials (Gümüs and Şeker, 2015).

Mushroom cultivation has recently become very popular in Turkey, and is a promising new industry, with many new businesses developing every year. Mushroom production in Turkey is separated into two components: compost production and mushroom cultivation. Compost application to agricultural soil has been widely practiced as one of the approaches to improve crop productivity and soil fertility (Jaiarree et al., 2014). Spent mushroom compost can be used in organic farming to improve soil water infiltration, water holding capacity, permeability, and aeration. Composts provide a stabilized form of organic matter that improves the physical properties of soils by increasing both nutrient and water holding capacity, total pore space, aggregate stability, erosion resistance, temperature insulation, and the decreasing apparent soil density (Shiralipour et al., 1992).

The objective of this study is to indicate the effects of SMC application to degraded soil with specific emphasis on aggregate stability, the modulus of rupture, electrical conductivity (EC), nitrogen, and organic carbon.

2 Materials and Methods

Soil was collected from a 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 (latitude of 38° 05' 56" N, longitude of 32° 36' 29" E, 1009 m above mean sea level). 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 (MGM, 2015). Soil moisture and temperature regimes are xeric and mesic, respectively, according to the climate data (Staff, 2006). Soil was classified as Fluvisol (Staff, 2006). The soil sample used in this study has certain problems, such as insufficient seedling emergency, low aggregate stability, crusting problem, and low organic matter content (Bal et al., 2012). The area has a typically rain-fed attribute with cultivation practices and various crops such as grains, sugar beet, and corn with fruit trees of various ages. A portion of the land is located in the fruits trees of different ages and types. The spent mushroom compost (SMC) used in the present study were obtained from private companies dealing with mass mushroom production located in Konya, Turkey.

Table 1. Some properties of the soil

Soil properties	**Values**	**Soil properties**	**Values**
Sand (2-0.05 mm) (%)	7.00	Field capacity (%)	35.6
Silt (0.05-0.002 mm) (%)	34.17	Wilting point (%)	16.19
Clay (<0.002 mm) (%)	59.00	Aggregate stability (%)	10.83
Textural class	C	Bulk density (g cm^{-3})	1.09
pH (H_2O, 1:2.5)	7.96		
EC (H_2O, 1:2.5) µS cm^{-1}	479		
C (%)	1.35		
Total N (%)	0.09		
Carbonates (%)	11.58		

Table 2. Properties of the Spent Mushroom Compost (SMC)

Properties	**SMC**
pH (H_2O, 1:2.5)	7.36
EC (H2O, 1:2.5) µS cm^{-1}	5390
C (%)	38.80
N (%)	2.61
C/N	14.88
Organic matter (%)	66.89

The experiment was carried out in a completely 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, passed through a 2 mm sieve and mixed homogeneously. Firstly, soil samples (2000 g) were placed in each pot (dimensions of pot; 13.5 cm x 17 cm). Six level of SMC, (0% (as control), 0.5%, 1%, 2%, 4%, and 8% by weight) were incubated. During the incubation period, the soil moisture level in the pots was maintained at 50-75% of field capacity. After various incubation periods (21, 42 and 62 days), the soil samples in each pot were mixed to ensure homogeneity in soil sub-sample. The soils were then sub-sampled (250 g) for analyses. So these three samples of each treatment were from three respective pots. Twenty first, 42^{nd} and 62^{nd} days of incubation periods, the samples were analyzed with three replications.

Particle-size distribution was determined by the hydrometer method (Gee et al., 1986). The moisture contents at field capacity and wilting point were determined with a pressure plate apparatus (Cassel and Nielsen, 1986) at -33 and -1500 kPa, respectively. Soil pH and EC values were determined by using a glass-calomel electrode in a 1:2.5 mixture (w/v) of soil and water; SMC pH and EC, samples were mixed with water 1:5 (Rhoades et al., 1996; Thomas, 1996). Soil organic carbon was determined on sample ground to pass through a 0.5 mm sieve by the use of TruSpec CN Carbon/Nitrogen Determinator (Cooperation, 2003). The modulus of rupture was determined at 0.5 kPa sensitivity by the procedure of Richards (1953) using briquettes prepared in moulds made from mild steel of rectangular cross-section, and with interior dimensions of 7 × 3.5 × 1 cm. The briquettes were prepared by using sieved subsoil samples (< 2 mm), taken from each pot, which were then placed in a soaking tank of distilled water filled to the upper surface of the mould. They were allowed to stand for 1 h, and then dried at 50°C. The briquettes were broken by a downward motion of a bar of triangular cross section, the force being applied by water additions to a vessel. The modulus of rupture was calculated as follows:

Where MR is the modulus of rupture (kPa), f is the breaking force in grams of water × 980, L is the distance between the lower supports in cm, b is the width of the briquette in cm, and d is the thickness of the briquette in cm (Reeve, 1965; Richards, 1953). Aggregate stability (AS) 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 and Rosenau, 1986).

The data collected were subjected one-way analysis of variance (ANOVA) test and treatment means were compared at $p<0.05$ using the F-LSD significant difference test (Minitab, 1991).

4 Results and Discussion

4.1 Aggregate stability (AS)

Aggregate stability values of the soil treated with different doses SMC application was measured after 21, 42, and 62 day's incubation periods, respectively (Fig 1). The effects of SMC application on soil aggregate stability values were significant by statistically. Generally, aggregate stability increased with SMC applications. These results may be explained by aggregate stability and soil organic matter that are two parameters and indicators for sustaining soil productivity. Aggregate stability is a key factor of soil fertility (Abiven et al., 2009). The recovery in aggregate stability of such physically degraded soils is important, as those studied was expected to follow the incorporation of any cementing agent, such as SMC (Curtin and Mullen, 2007). Aggregate stability decreased at 42 and 62 days of incubation periods in all SMC rates, when compared to a 21-day incubation period. These results may be explained by the decomposition of soil organic matter (Carrizo et al., 2015; Seker, 2003). Aggregate size distribution and stability can be used as an indicator of soil condition or degradation (Boix-Fayos et al., 2001). Soil organic matter was suggested to be the most important factor in determining soil aggregate stability as significant positive relationships between these two parameters (Aksakal et al., 2015; Candemir and Gülser, 2010; Cerdà, 1998). Organic matter shows a direct relationship with aggregate stability (Cerdà, 1998). In addition, the aggregate stability of the soil samples decreased due to the mechanical mixing of the pots contents to simulate repeated cultivation (Seker, 2003). Similarly, it is reported that there is an increase in the soils organic carbon concentration after organic matter application, and thus, a higher formation of stable aggregates (Arthur et al., 2011; Ferreras et al., 2006; Gümüs and Şeker, 2015; Murphy, 2001).

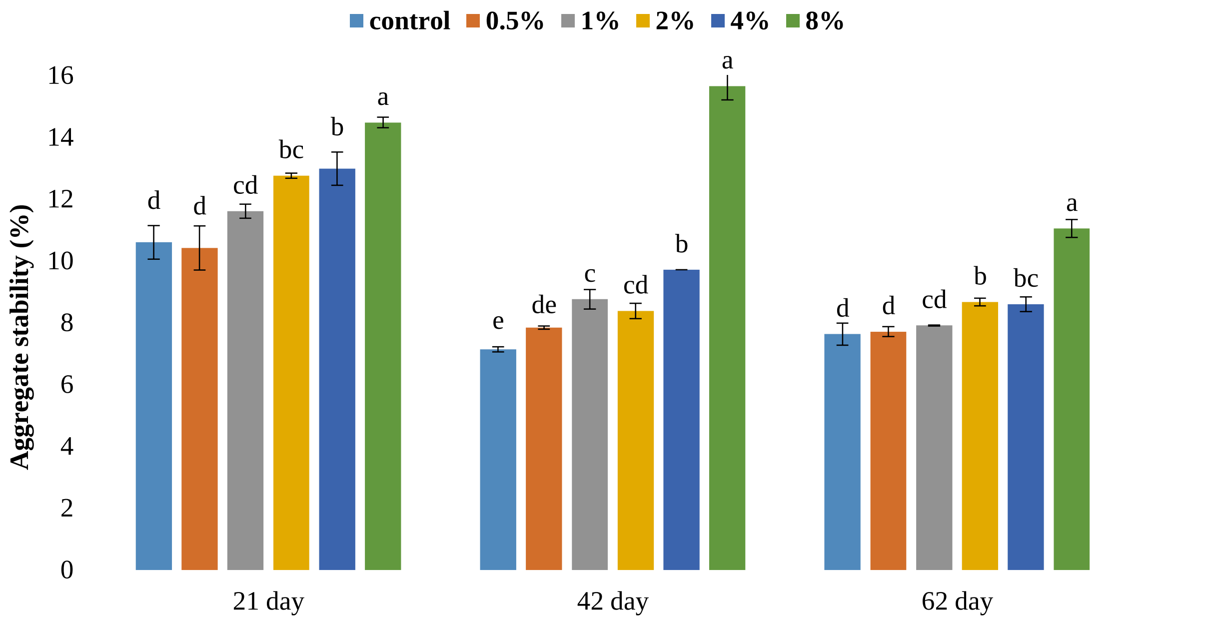

Fig 1. Effects of different rates of SMC applications on aggregate stability, Error bars indicate least significant difference (P<0.05). For additional information regarding results of one way ANOVA LSD test. 0.5, 1, 2, 4 and 8% SMC

4.2 Soil modulus of rupture

All the SMC applications resulted in significantly lower modulus of rupture at 21st and 42nd days, except for the 62nd day incubation (Fig 2). In general, soil modulus of rupture decreased with the increasing application rates of SMC. The effects were especially due to the high organic matter contents of SPM that improved soil structure mechanically (Gümüs and Şeker, 2015; Seker, 2003). The SMC used in the study contains significant amounts of organic substances. Reason for its modulus of rupture can be related to the inhibitory effects of SMC on the tight unity formation of soil particles. The structural stabilization is related to organic matter inputs (Caravaca et al., 2002; Ferreras et al., 2006), and thus, a significant decrease in the modulus of rupture was attained with the application rate of SMC. These results may be explained through the formation of aggregates during the incubation periods. The modulus of rupture was reduced because of the increase in organic amendments, which allowed less cohesion among the soil aggregates (Seker, 2003). Organic amendments are known to decrease bulk density and particle in soil (Moreno et al., 2016). The absence of such effects in 62 days can be related to the decrease in aggregate stability and organic substances. This, most probably, resulted from the breakdown of soil structure and the aggregates of soil organic matter by mixing pot contents to simulate repeated cultivation (Carrizo et al., 2015; Seker, 2003).

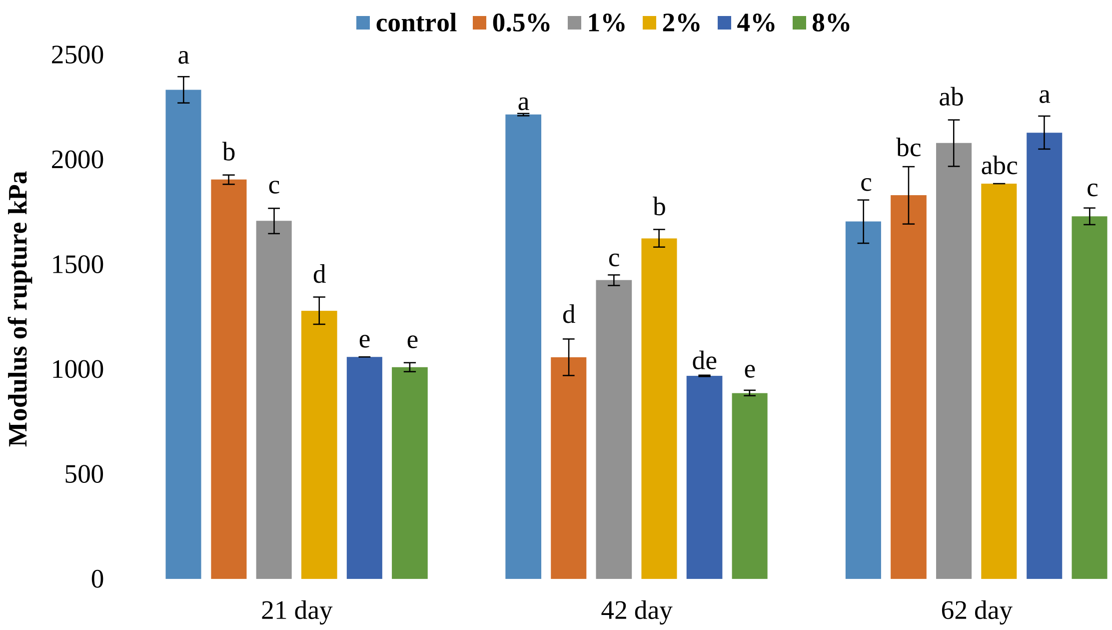

Fig 2. Effects of different rates of SMC applications on soil modulus of rupture, Error bars indicate least significant difference (P<0.05). For additional information regarding results of one way ANOVA LSD test. 0.5, 1, 2, 4 and 8% SMC

4.3 EC

The EC values significantly elevated with increased SMC application (Fig 3). Soil EC values gradually increased with incubation periods significantly, and the magnitude of such increase was higher in the SMC-amended soil than the control soil. The increasing EC values in an experiment for different doses of SMC application may be explained by the high content of solutes nutrient composition of organic fragments, and the remains from the materials during incubation periods (Yilmaz, 2010). EC can serve as a measure for the presence of nutrients for both cations and anions (Roy and Kashem, 2014). Soil EC indicates the mineralization of organic matter in soil and many authors have found positive correlations between EC and compounds from organic matter degradation in soil (Arthur et al., 2012; Gulser et al., 2010; Medina et al., 2012). However, EC values were still below the upper limit of 4000 µS cm^{-1}suggested for agricultural soils, even at 8% application rates (Arthur et al., 2012; Postel and Starke, 1990; Rhoades et al., 1992).

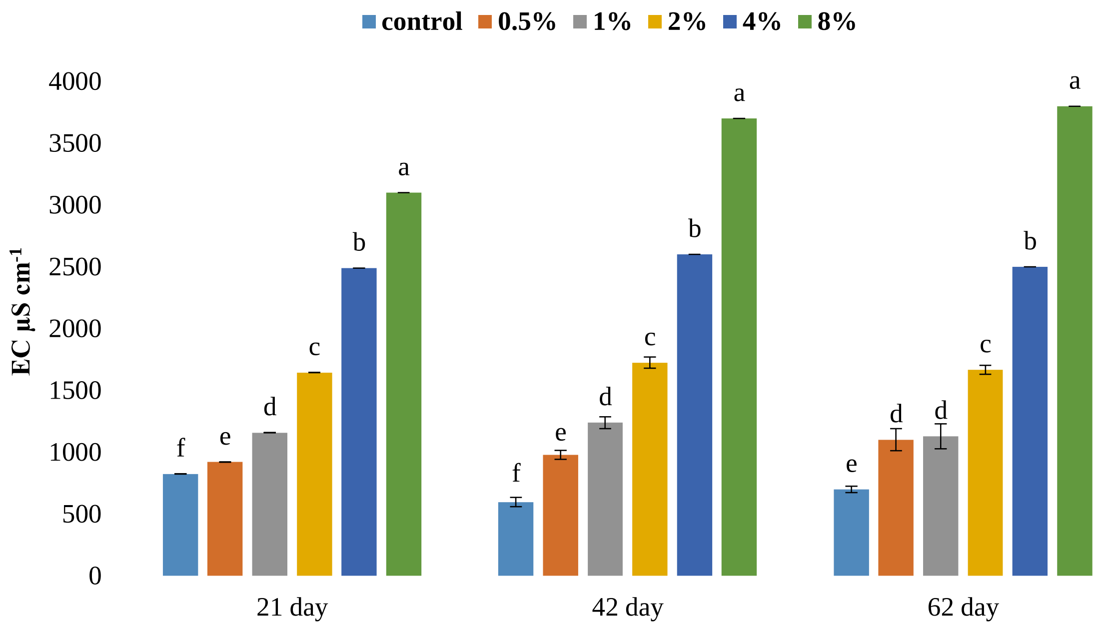

Fig 3. Effects of different rates of SMC applications on soil EC, Error bars indicate least significant difference (P<0.05). For additional information regarding results of one way ANOVA LSD test. 0.5, 1, 2, 4 and 8% SMC

4.4 Soil organic carbon (SOC)

The effects of SMC on SOC values of the soil are shown in Fig. 4. The SOC values significantly increased SMC application. Investigation performed at incubation periods revealed that soil SOC existentially increased in response to the increment in SMC dose, and the strongest effect were obtained with the doses 4% and 8%, where differences in SOC values, depending on incubation periods and rates of SMC was noticed. SOC content of soil increased with the increasing amendment rates of SMC (Fig 4). In general, SOC content values in experiments increase with the increase of amendment rates of organic materials. Soil organic carbon is known to play important roles in the maintenance, as well as improvement of many soil properties, and thus, its concentration is often cited as one of the major indicators for sustaining soil productivity. Increases in soil organic carbon contents can be achieved by adding spent mushroom compost application (Courtney and Mullen, 2008; Medina et al., 2012).

Organic amendments used in soil reclamation emanate from a variety of sources, including agriculture, forestry, and urban areas. Of those generated by agriculture, livestock manure from various species is the most prevalent. Other amendments derived from agriculture include crop residues and spent mushroom compost. The rate of decomposition of organic amendments and soil organic carbon remains over a long-term vary with the intrinsic quality of the amendment (Lashermes et al., 2009; Novara et al., 2015). Carbon in organic amendments was originally fixed by plants through photosynthesis (Larney and Angers, 2012). Soil organic carbon increases due to high organic carbon (Oo et al., 2015), soil biological activity, and/or the root depth effect (Parras-Alcántara et al., 2015). Soil organic matter content is one of the most important soil quality indicators of soil recovery (Mahmoud and Abd El-Kader, 2015; Parras-Alcántara et al., 2015; Pulido Moncada et al., 2015) and it is a good sign for soil quality (Gelaw et al., 2015). The quality of soil organic matter, soil structure, the microbial activity, and the rainfall intensity are, in fact, important parameters that should be evaluated and correlated to assess the fate of carbon during transportation (Novara et al., 2016). Similar results were reported by a few other studies (Arthur et al., 2011; Curtin and Mullen, 2007; Yazdanpanah et al., 2016).

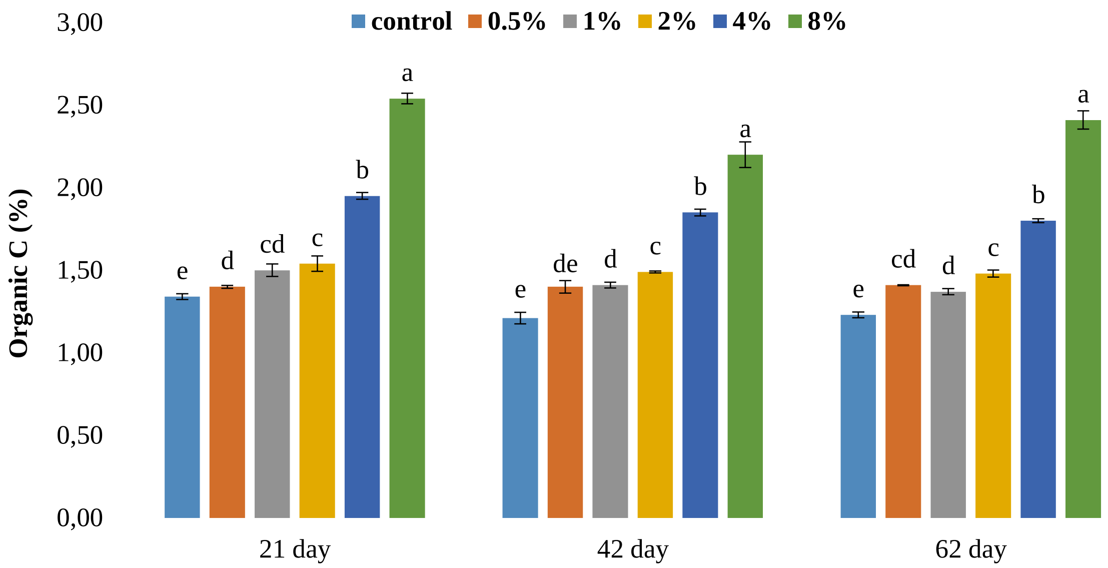

Fig 4. Effects of different rates of SMC applications on soil organic carbon, Error bars indicate least significant difference (P<0.05). For additional information regarding results of one way ANOVA LSD test. 0.5, 1, 2, 4 and 8% SMC

4.5 Total nitrogen (N)

The effects of SMC on total nitrogen values of the soil are shown in Fig. 5. The total nitrogen values significantly increased with respect to elevated SMC application. According to the investigations at 21, 42, and 62 days, one could note 0.5, 1, and 2% applications, which resulted in significant increase, and the strongest effect obtained with the doses of 4% and 8%. The nitrogen content of the soil was closely dependent on the amendment rates of the SMC. In general, the total nitrogen content of soil increased with increasing amendment rates of SMC. Nitrogen content of the soil showed a significant increase, depending on the rate of SMC amendments and suggesting that the incubation period was sufficient for nitrogen mobilization of the materials applied. With regards to the nitrogen dynamics in the soil, the addition of the SMC produced, in general, an increase in the organic N concentration throughout the experiment, especially in comparison to the control soil (Medina et al., 2012). It is believed that physical, chemical and biological properties of SMC (especially C/N mineralization level and decomposition) may play roles in the mineralization of nitrogen from organic materials during the incubation periods.

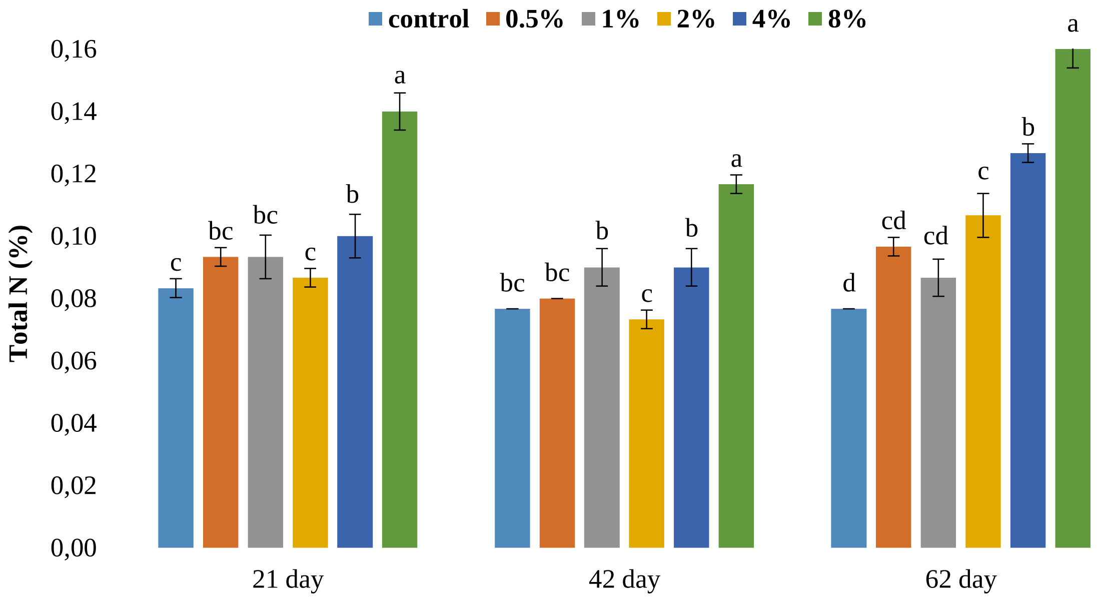

Fig 5. Effects of different rates of SMC applications on total nitrogen, Error bars indicate least significant difference (P<0.05). For additional information regarding results of one way ANOVA LSD test. 0.5, 1, 2, 4 and 8% SMC

5 Conclusions

This study shows that the application spent mushroom compost can improve the stability of the structure of soils. Physical and chemical properties of the soil, such as aggregate stability, soil modulus of rupture, organic carbon, and total nitrogen were improved by SMC amendment. SMC increased soil EC, with all treatments having EC values well below the upper limit of 4000µS cm^{-1}, as suggested for agricultural soils (Arthur et al., 2012; Postel and Starke, 1990; Rhoades et al., 1992). Soil aggregate stability and modulus of rupture were the most dramatically affected by SMC application. The use of spent mushroom compost may contribute to enhancing the level of organic carbon and nitrogen in the soil. In addition, the results show that the spent mushroom compost application is an effective way to improve soil physicochemical properties. This structural improvement has direct benefits for both the farmers of degraded soils as well as mushroom growers who require a safe disposal method for waste products.

Acknowledgements

The authors would you like to thanks Dr. Ali Sabır of Department of Horticulture, Faculty of Agriculture, University of Selçuk for her helpful comments and Hamza Negiş of Department of Soil Science and Plant Nutrition, Faculty of Agriculture, University of Selçuk for helpful laboratory analysis.

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