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Changes of soil hydraulic properties during the decomposition of organic waste in a coarse textured soil

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ABSTRACT

Hazelnut husk (HH) used as an organic waste was incorporated into a sandy clay loam soil with the rates of 0 (control), 2, 4 and 6% in order to investigate the changes of hydraulic properties, outflow electrical conductivity during the mineralization period for 16 weeks. Changes in soil physical properties and microbiological activity were determined at five different incubation periods (1, 2, 4, 8 and 16 weeks) under the greenhouse conditions. HH application increased organic carbon (OC) content and basal soil respiration (BSR) in soil. Soil OC content had significant positive relations with ECs, F and significant negative relations with Vp, BD values. Basal soil respiration had significant positive relations with ECs, OC, AS and F. Outflow ECo showed significant negative correlations with Ks and Vp. Organic waste application into soil increased ECs, BSR, and F, but decreased Vp values. While the percentage of EC in bulk soil increased with HH application over the control, EC in outflow decreased at the end of the incubation. According to the path analyses results, BSR as an indicator of microbial activity in soil had the highest direct effect on Ks (44.16%) and ECo (51.84%). The highest indirect effects on soil hydraulic properties were usually determined via OC and BSR. Increasing ECs at 16th week of the incubation showed that decomposition products from HH might be fixed by micro aggregates. Electrical conductivity in 5 pore volumes outflow decreased with increasing Vp values.

1. Introduction

Intensive agricultural practices cause to soil degradation through the loss of soil organic matter and decline of soil structure (Usowics and Lipiec, 2009; Busscher and Bauer, 2003; Dexter, 2004). Agricultural wastes are important to improve soil physical, chemical and biological properties as organic soil conditioners (Candemir and Gülser, 2010; Gülser and Candemir, 2015, Demir and Gülser, 2015). Soil structure is one of the most important soil physical factors with controlling or modulating the flow and retention of water, solutes, gases and biota in agricultural and natural ecosystems (Lal, 1991; Young et al., 1998). Aggregation is an indicator of soil structure and results from the rearrangement of particles, flocculation and cementation (Six et al., 2000; Gülser, 2006). Organic residues contribute to the development of soil structure with a binding agent in the formation of aggregates. The soil organic carbon has a greater effect on aggregation especially in coarse textured soils (Bronick and Lal, 2005). The application of organic wastes to soils reduces bulk density, increases total pore space, mineralization, available nutrient elements and electrical conductivity of soils and also increase microbial activity (Anikwe, 2000; Eigenberg et al., 2002).

Hazelnut is one of the most important agricultural products with a yield of around 630.000 tons per year in the Black Sea Region of Turkey. Large quantity of hazelnut husk as an agricultural waste material is available in the region. Benefits of organic soil conditioners to soil have been related with desirable soil microbial, chemical and physical properties including higher plant available nutrients, water holding capacity and lower bulk density (Doran, 1995). The objective of this study was to investigate possible uses of hazelnut husk (HH) as a soil conditioner to improve soil structure and its effects on hydraulic properties of a sandy clay loam soil by increasing soil microbial activity.

2. Materials and methods

A sandy clay loam textured soil was air-dried in a laboratory and sieved through 2 mm screens. Some soil properties (Table 1) were analyzed as follows; particle size distribution by hydrometer method (Day, 1965), soil reaction (pH, 1:1 (w:v) soil:water suspension) by pH meter, electrical conductivity ($EC_{25\ ^\circ C}$) in the same soil suspension by EC meter, exchangeable cations by ammonia acetate extraction (Kacar, 1994). The results can be summarized as; the textural class of soil is sandy clay loam, slightly alkaline in pH, low in organic matter content, non-saline according to EC value (Soil Survey Staff., 1993).

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Table 1
Some physical and chemical properties of the soil.

Sand, %	52.09	Organic matter, %	0.52
Silt, %	26.11	Ca, me/100 g	37.68
Clay, %	21.80	Mg, me/100 g	17.97
$EC_{25\ °C}$, dS/m^{-1}	0.74	K, me/100 g	0.51
pH (1:1)	7.60	Na, me/100 g	0.55

Hazelnut husk (HH) was obtained from a hazelnut orchard in Samsun, Turkey. Some properties of HH were determined according to the Kacar (1984). Hazelnut husk had 49.49% organic C, 0.96% total N, 51.31 C:N ratio, 5.00 pH and 6.05 dS/m EC in saturation extract. After HH was ground and sieved into less than 4 mm fractions, it was incorporated to the soil sample at 0, 2, 4 and 6 wt%. The experiment was carried out in a completely randomized plot design with three replicates. Mixtures of HH with soil were packed into 500 g of 60 pots, moistened near the field capacity and incubated for 1, 2, 4, 8 and 16 weeks at 25 ± 5 °C under a laboratory condition for aggregate stability (AS), basal soil respiration (BSR) and electrical conductivity (ECs) measurements. After each incubation period, disturbed pots were set aside and not used anymore. Soil respiration rate was determined according to Isermayer (1952) by measuring CO_2 produced without adding glucose at 22 °C. CO_2 production was explained as mg CO_2 100 g^{-1} oven dry soil at the end of the 24 hours incubation period after each soil sampling.

Undisturbed soil samples from the pots were taken using the cylinders having 4.5 cm inside diameter and 5 cm length for measurements of saturated hydraulic conductivity (Ks). At the end of the each incubation period, aggregate stability according to Kemper and Rosenau (1986), saturated hydraulic conductivity by constant head method (US Salinity Lab. Sta., 1954) were determined. During the hydraulic conductivity measurements, the hydraulic gradient was approximately the same for all columns (1.80 ± 0.15 cm), pore water velocity (Vp) estimated from the flow rate dividing by cross-sectional area of pores, outflow electrical conductivity (ECo) in 5 pore volumes of outflow from soil columns were also determined. Bulk density of the each soil core was determined according to Blake (1965). Volumetric water content (θ) and total porosity (F) were estimated from the following equations; θ = gravimetric water content (g H_2O/g soil at the sampling time) × soil bulk density (g/cm^3) and F = [1 − (soil bulk density (g/cm^3) / 2.65 (soil particle density, g/cm^3))], respectively.

The correlations among the results and statistical analysis of experimental data were accomplished by standard analysis of variance and pairs of mean values compared by least significant difference (LSD) using the SAS software package (SAS Institute, 1988). Path coefficients, direct and indirect effects of soil properties on hydraulic properties were determined with path analysis using TARIST (1994) statistics program.

Table 2
Effect of hazelnut husk application on bulk density, total porosity and hydraulic conductivity.

Hazelnut husk doses	Incubation periods 1st week	2nd week	4th week	8th week	16th week	Mean value
Bulk density (BD), g/cm^3						
0 (control)	1.24	1.24	1.24	1.25	1.24	1.24
2%	1.11	1.16	1.17	1.16	1.18	1.15
4%	1.09	1.11	1.15	1.15	1.16	1.13
6%	1.03	0.96	1.05	1.05	1.07	1.03
Total porosity (F)						
0 (control)	0.53	0.53	0.53	0.53	0.53	0.53
2%	0.58	0.56	0.56	0.56	0.55	0.56
4%	0.59	0.58	0.56	0.56	0.56	0.57
6%	0.61	0.64	0.60	0.61	0.60	0.61
Saturated hydraulic conductivity (Ks), cm/h						
0 (control)	34.10	33.32	32.60	31.40	25.60	31.40
2%	18.40	17.61	16.80	37.50	41.60	26.38
4%	11.20	19.02	20.50	40.80	41.10	26.52
6%	7.60	22.01	33.90	48.90	46.40	31.76

3. Results

Organic C content of sandy clay loam soil increased in all application rates of HH compared with the control treatment (Fig. 1A). During the decomposition of HH in soil by microorganisms, OC contents of soil samples in all treatments decreased from 1st week to 16th week of incubation period. On the other hand, basal soil respiration in all HH treatments generally increased from 1st week to 16th week of incubation period over the control (Fig. 1B). There was a significant positive correlation between OC and BSR (0.864 at $P < 0.01$). A significant correlation (0.856 at $P < 0.01$) between BSR and total porosity in this study confirms that CO_2 production correlates directly with aerobic respiration and hence aerobic biological activity (Hue and Liu, 1995; Gülser and Erdoğan, 2008). The decrease in OC content of the soil samples may be attributed to the increasing population of microorganisms which utilize decomposable hazelnut husk both as a source of food and energy (Chefetz et al., 1998).

Hazelnut husk application decreased the soil bulk density over the control (Table 2). The lowest bulk density was determined with 6% dose of HH in all incubation periods. Decreases in bulk density caused increases in total porosity values (Table 2). HH applications also increased aggregate stability values over the control at the end of the all incubation periods, except 2% and 4% rates of HH in 16th week (Fig. 2A). Dexter (1988) reported that application of organic matter to soils results in lower bulk density due to its low bulk density and ability to increase soil aggregate stability.

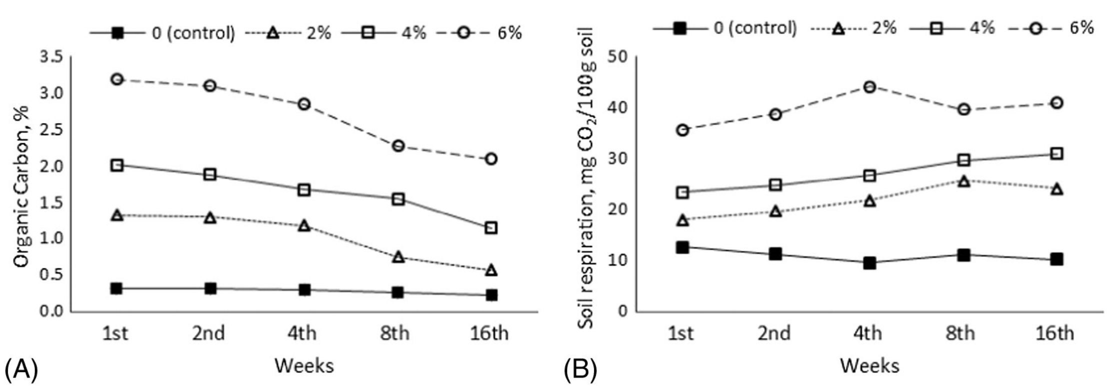

Fig. 1. Effect of hazelnut husk application on soil organic carbon (A) and soil respiration rate (B).