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Changes in Some Chemical and Physical Properties of a Sandy Clay Loam Soil During the Decomposition of Hazelnut Husk

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Hazelnut husk was applied at the rates of 0 (control), 2, 4 and 6 % to a sandy clay loam soil in order to investigate effect of hazelnut husk on some chemical and physical soil properties during its mineralization period for 16 weeks. Experiment was conducted at 4 different incubation periods (1, 4, 8 and 16 weeks) under the same laboratory conditions. Hazelnut husk treatments increased organic carbon content, electrical conductivity, aggregate stability, volumetric water content, total porosity and lowered bulk density of the soil over the control treatment. During the 16 weeks incubation period, organic carbon content for hazelnut husk treatments decreased while the electrical conductivity values of the soil increased. Organic carbon content gave a significant negative relationship (-0.984**) with electrical conductivity value. Mean bulk density of the soil significantly decreased from 1.25 g cm^{-3} for control to 1.05 g cm^{-3} for 6 % hazelnut husk treatment. Increases in the mean porosity and the mean volumetric water content for 6 % hazelnut husk rate over the control were 14.3 and 26.2 %, respectively. The highest aggregate stability was determined with 6 % of hazelnut husk application rate in the eight week. Aggregation in soils slowed down after eight weeks and disaggregation occurred for all application rates in the last incubation period due to possibility of more substrate demands of bacteria and bacterial attack on products which bind soil particles together.

Key Words: Hazelnut husk, Organic carbon, Electrical conductivity, Aggregate stability, Bulk density, Sandy clay loam.

INTRODUCTION

The role of plant residues to soil structure improvement through a variety of mechanisms are influenced by the amount and quality of the residue[1]. Aggregation is an indicator of soil structure[2] resulting from the arrangement of particles, flocculation and cementation[3]. Soil organic carbon can strongly influence aggregation processes and in turn is influenced by the type of plant residues or organic amendments and their decomposition rate and products. The effect of organic carbon on aggregation depends on soil textural class, with strongest effects generally being in coarse textured soils[4]. Benefits of organic amendments have been associated with desirable soil microbial, chemical and physical properties including higher plant available water holding capacity and lower bulk density[5].

Soil structural stability is influenced by microorganisms in two major ways: i) by the mechanical binding of soil particles together and ii) by the production of effective binding agents either by synthesis or through the decomposition of organic materials[6,7]. Roberson *et al.*[8] reported that polysaccharides due to high organic carbon content can be an important factor affecting soil aggregation. In a study of Martens[1], addition of different organic residues to a Webster soil (2% w/w) resulted in a rapid, transient increase in aggregate mean weight diameters (MWD) when incubated for 9 d with residues of low phenolic acid content (alfalfa, canola and clover). Soil organic carbon after 84 d was related to the MWD (r = 0.82) suggesting that transient aggregate stability initiated by microbial decomposition of the carbohydrate and amino acids contents of the residue. Bossuyt *et al.*[9] reported that after 14 d of incubation, aggregation, microbial respiration and total microbial biomass were not significantly different between the low-quality (C/N: 108) and high-quality (C/N: 19.7) residue treatment. They found that after 14 d of incubation maximum aggregation for soil sieved at field capacity was reached and fungal biomass was higher for the low-quality residue treatment compared to the high-quality residue treatment. They concluded that macroaggregate formation was positively influenced by fungal activity but was not significantly influenced by residue quality or bacterial activity.

Hazelnut is one of the most important products in the Black Sea region of Turkey with a yield of around 630.000 tons per year[10]. There are large quantities of hazelnut husk available as an organic waste in this region each year. Soil erosion is a serious problem in the natural and agricultural environment in this region and has been linked with degraded soil physical properties[11]. Using organic wastes as a soil amendment might provide an economical means of disposal of these materials. The objective of this study was to investigate the changes in some chemical properties such as, organic carbon content and electrical conductivity and some physical properties such as bulk density, volumetric water content and aggregate stability of a sandy clay loam soil during the mineralization of hazelnut husk.

EXPERIMENTAL

The sandy clay loam soil used in this study was sampled around Kurupelit Creek (41º 21' N, 36º 11' E) in Samsun, Turkey. Soil samples were air-dried in a laboratory and sieved through 2 mm screens. Particle size distribution determined by the hydrometer method[12], pH (1:1), electrical conductivity (1:1), exchangeable cations determined by the ammonia acetate extraction method and organic matter content determined by the modified Walkley-Black method[13] are shown in Table-1. The soil is a non-saline[14] slightly alkaline sandy clay loam, relatively low in organic matter.

TABLE-1
SOME PHYSICAL AND CHEMICAL PROPERTIES OF THE SOIL

Sand (%)	52.09	Organic matter (%)	0.52
Silt (%)	26.11	NH_4-OAc extractable cations	
Clay (%)	21.80	Ca (me/100 g)	37.68
Texture class	SCL	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 was obtained from hazelnut orchards in Terme, Samsun, Turkey. Some properties of hazelnut husk were determined according to the methods of Kacar[15] (Table-2). To determine the water holding capacity (WHC) [16], hazelnut husk was dried for 24 h at 105°C and then submerged in water and left for 12 h. WHC was calculated from the equation: WHC = (Wet mass × 100)/dry mass.

TABLE-2
SOME PROPERTIES OF THE HAZELNUT HUSK USED

Organic carbon (%)	Organic matter (%)	Nitrogen (%)	Carbon : nitrogen	$EC_{25°C}$ (dS m^{-1})	pH (saturated extract)	Water holding capacity (%)
49.49	85.33	0.96	51.31	6.05	5.00	467.7

After hazelnut husk was grounded and sieved into less than 4 mm fractions, it was incorporated into soil admixtures at rates of 0, 2, 4 and 6% by weight. The experiment was carried out in a completely randomized plot design with three replicates. Mixtures put into 500 g pots were moistened to the water content at field capacity and incubated in a laboratory at 25 ± 5°C for 1, 4, 8 and 16 weeks. At the end of each incubation period, three pots for each treatment were selected from total 48 pots for soil sampling and were not used again. Aggregate stability was determined on soil samples taken from the pots at the end of each incubation period using a wet sieving method[17]. The equivalent of 40 g of oven dried soil aggregates was placed on a sieve with 0.25 mm opening. The sieve was lowered to the water surface and the soil sample allowed wetting by capillarity for 5 min. The Yoder apparatus had a vertical stroke of 45 mm and was operated for 5 min at a speed of 37 cycle min^{-1}. The fractions left on the sieve at the end of sieving were oven dried at 105ºC to constant mass. Aggregate stability was expressed as a percentage of the total sieved samples. Corrections for sand content in calculations were made after the fractions were dispersed chemically. Volumetric water content (θ) was calculated from: θ = gravimetric water content (g H_2O/g soil at the sampling time) × soil bulk density (g/cm^3). Total porosity (F) was estimated from: F = [1–(soil bulk density (g/cm^3)/2.65 (soil particle density, g/cm^3))].

Statistical analysis of experimental data was accomplished by standard analysis of variance and pairs of mean values compared by least significant difference (LSD) using the SAS software package[18]. The correlations among the results were also estimated according to Steel and Torrie[19].

RESULTS AND DISCUSSION

Increases in hazelnut husk application rates increased organic carbon contents and electrical conductivity values of the soil over the control (Figs. 1 and 2). While the electrical conductivity values increased, organic carbon contents for each hazelnut husk treatment decreased for the following incubation periods due to decomposition of organic matter. The highest organic carbon content (3.19 %) and electrical conductivity value (1.12 dS m^{-1}) were obtained with the highest application rate of 6 % hazelnut husk after the 1st and 16th week, respectively. Application of organic wastes into soil increases microbial activity, nutrient contents and electrical conductivity values of soil[20,21]. It has been reported that electrical conductivity can serve as a measure of soluble nutrients[22] for both cations and anions and is useful in monitoring the mineralization of organic matter in soil[23]. There was a significant negative relationship (-0.984**) between mean organic carbon content and mean electrical conductivity values during the incubation. This indicates that mineralization of hazelnut husk increased soluble nutrient content of the soil.

All rates of hazelnut husk significantly reduced bulk density when compared with the control (Table-3). The lowest bulk densities were obtained with the highest application dose of hazelnut husk in all incubation periods. Dexter[24] reported that organic matter due to its low density and ability to increase soil aggregation stability results in lower bulk density. The decrease in bulk density is associated with an increase in total porosity (F) (Fig. 3). Incorporating hazelnut husk into soil also increased volumetric water content (θ) (Fig. 4). The highest porosity and the highest volumetric water content were obtained with the highest application rate of hazelnut husk in all incubation periods. There was a significant positive correlation coefficient (0.871**) between total porosity and volumetric water content. Increases in the mean total porosity and the mean volumetric water content over the control were 3.5, 4.1, 7.5 % and 3.2, 4.7, 7.6 %

for the 2, 4 and 6 % hazelnut husk rates, respectively. Mbagwu[25] reported that incorporation of organic waste into the soil at a rate of 10 % increased the total porosity by 23 %.

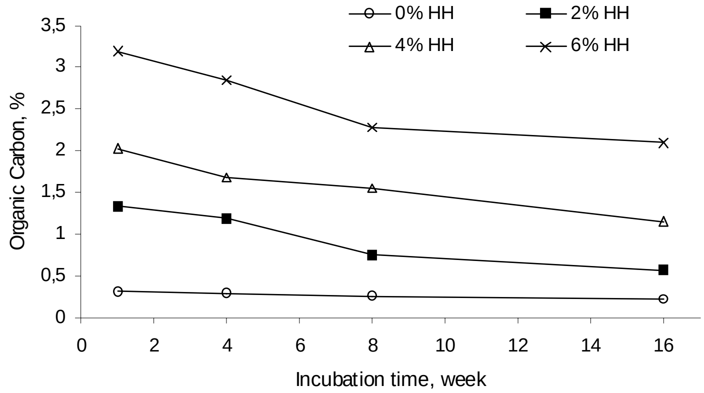

Fig. 1. Effects of HH application doses on organic carbon content in incubation periods

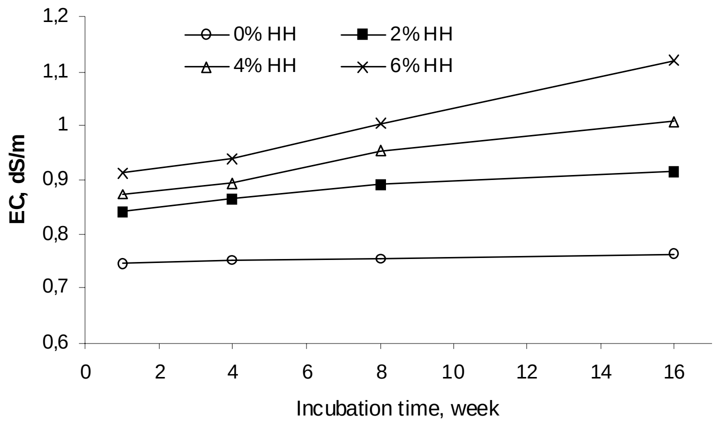

Fig. 2. Effects of HH application doses on electrical conductivity (EC) values in incubation periods

Mean aggregate stability value of 2 % hazelnut husk application rate was not significantly different from mean aggregate stability of control treatment (Table-4). However, 4 and 6 % hazelnut husk applications significantly increased mean aggregate stability over the control. There were significant differences among the mean aggregate stability values for different incubation periods. The mean aggregate stability value significantly increased between weeks 1 and 8, and then significantly decreased between weeks 8 and 16. The mean aggregate stability in week 16 was significantly lower than that in week 4. Aggregate stability of control treatment significantly increased between weeks 1 and 4 due to reorganization of disturbed particles and then decreased between weeks 4 and 16.

TABLE-3
EFFECTS OF HAZELNUT HUSK ON BULK DENSITY (g cm^{-3})
DURING THE INCUBATION PERIODS

Hazelnut husk doses (%)	Incubation Period, week				Mean (Doses)
	1	4	8	16	
0 (Control)	1.24 ab*	1.24 ab	1.25 a	1.25 ab	1.24 A**
2	1.11 de	1.17 cd	1.16 cd	1.17 cd	1.15 B
4	1.09 ef	1.15 cd	1.15 cd	1.16 cd	1.14 B
6	1.03 f	1.05 ef	1.04 f	1.06 ef	1.05 C
Mean (IP)	1.12 B**	1.15 A	1.15 A	1.16 A	

*Interaction values followed by different letters are significantly different at P = 1 %, **Mean values within the row and column followed by different capital letters are significantly different at P = 1%. (LSD values; Incubation period (IP) and Doses (D) = 0.03; Interaction IP × D = 0.06)

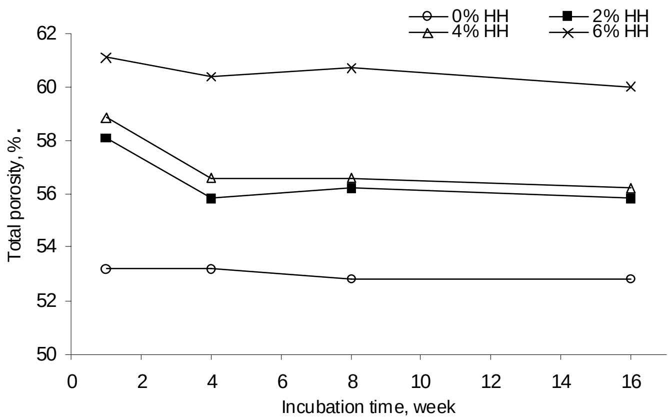

Fig. 3. Effects of hazelnut husk application doses on total porosity in incubation periods

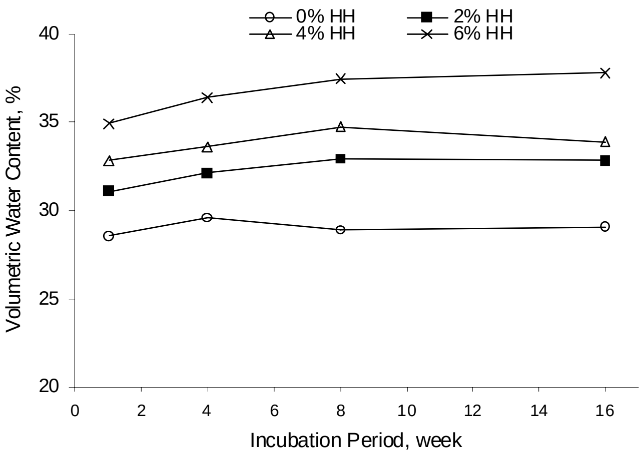

Fig. 4. Effects of hazelnut husk application doses on volumetric water content in incubation periods.

TABLE-4
EFFECTS OF HAZELNUT HUSK ON AS (%) DURING THE INCUBATION PERIODS

Hazelnut husk doses (%)	Incubation Period, week				Mean (Doses)
	1	4	8	16	
0 (Control)	27.7 h*	59.6 bcd	57.0 cde	54.4 def	49.7 C**
2	28.8 h	61.1 bcd	76.7 a	45.9 fg	53.1 C
4	41.4 g	66.6 b	77.0 a	48.0 efg	58.2 B
6	45.2 fg	76.7 a	79.3 a	65.5 bc	66.7 A
Mean (IP)	35.8 D**	66.0 B	72.5 A	53.4 C	

*Interaction values followed by different letters are significantly different at P = 1 %, **Mean values within the row and column followed by different capital letters are significantly different at P = 1 %. (LSD values; Incubation Period (IP) and Doses (D) = 4.57; Interaction IP × D = 9.51)

Aggregation between weeks 1 and 4 might result from the rearrangement of disturbed particles by the bonding and cementing effects of soil organic carbon, biota, clay, carbonates, organo-metallic compounds or cations[4] such as Fe, Al and Ca. Similarly, aggregate stability values of the hazelnut husk treatments significantly increased between weeks 1 and 8 and then decreased after this period. The highest aggregate stability value (79.3 %) was found with 6 % hazelnut husk application rate at the end of the 8 weeks. The positive relationship between organic carbon and aggregate stability has been reported in various studies[26-28]. Cosentino *et al.*[29] studied the effects of dry-wet cycles on aggregate stability and on its main microbially mediated agents with incubating silty soil cores at 20 ± 0.5°C for 63 d using the following treatments and their combinations: (i) without straw or with straw input (4 g C kg^{-1} soil) and (ii) with or without exposure to 4 dry-wet cycles. They found that the addition of straw stimulated microbial activity and increased the resistance of aggregate stability, enhancing the internal cohesion and hydrophobicity of aggregates. Dry-wet cycles had less impact on aggreagate stability than the addition of straw. There were significant correlations between aggregate stability and organic carbon content in all incubation periods (Table-5). While the electrical conductivity increased between weeks 1 and 8, relationships between aggregate stability and electrical conductivity significantly increased (Table-5). However, more increases in electrical conductivity values between weeks 8 and 16 caused decrease in the relationship between aggregate stability and electrical conductivity. Addition of organic matter into soil causes a rapid stimulation of the soil microflora and this is accompanied by an increase in aggregate stability within a few weeks[9,30]. Microorganisms increase the stability of aggregates as follows i) fungi act mainly by mechanical enmeshment of soil particles[31], ii) bacteria and fungi may exude extracellular polysaccharides which bond the particles and increase interparticle cohesion[32] and also iii) increase the repellency of soil aggregates, presumably by exuding hydrophobic substances[33,34]. It has been reported that soil moisture content directly affects the activity of microorganisms[35]. In our study, there was a significant correlation between aggregate stability and volumetric water content (0.553*). Aggregation stability reached a peak after 8 weeks of incubation and a further 8 weeks of incubation caused a fall in aggregate stability. Microbial activity might have increased after the application of hazelnut husk but it appears that a stage is reached where substrate demands of bacteria and bacterial attack on products which bind soil particles together reduces stability. Many of the soil aggregating substances and microbial products are able to be destroyed by other microorganisms[36].

TABLE-5
RELATIONSHIPS AMONG AS, OC AND EC VALUES
FOR EACH INCUBATION TIME

	Aggregate stability			
Incubation time	1 week	4 weeks	8 weeks	16 weeks
Organic carbon	0.892**	0.933**	0.756**	0.640*
Electrical conductivity	0.783**	0.748**	0.895**	0.366

*correlation is significant at p = 5 %, ** Correlation is significant at p = 1 %.

Conclusion

Incorporating hazelnut husk into a sandy clay loam soil increased soil soluble nutrient contents by mineralization of organic matter and improved soil physical properties by lowering bulk density and increasing total porosity, volumetric water content and aggregate stability. The highest increases in the mean electrical conductivity, total porosity and volumetric water content over the control were determined for the highest 6 % hazelnut husk application rate. Aggregate stability increased until 8th week incubation. Disaggregation occurred for all application rates of hazelnut husk between weeks 8 and 16 due to more substrate demands of bacteria.

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