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Changes in physical conditions of a coarse textured soil by addition of organic wastes

Melis Cercioglu [a,*], Bülent Okur [b], Sezai Delibacak [b], Ali Riza Ongun [b]

[a] Dumlupinar University, Vocational College of Simav, Department of Organic Farming, Simav, Kutahya, Turkey
[b] Ege University, Faculty of Agriculture, Department of Soil Science and Plant Nutrition, Bornova, Izmir, Turkey

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Abstract

Effects of composted tobacco waste, chicken manure and bio-humus applied during a period of three years on a coarse textured soil (Typic Xerofluvent) at Agriculture Faculty's Research and Practise Farmyard of Ege University located on Menemen plain (Izmir, Turkey) on soil physical properties were studied. The experiment was arranged in a randomized block design on 16 plots with four replications. Each plot size was 5x3 m^2. Composted tobacco waste (CTW) from cigarette industry and chicken manure (CM) and bio-humus (BH) from plant residuals were applied at rates of 50 t ha^{-1}, 4 t ha^{-1}, 10 t ha^{-1}, respectively. Inorganic fertilizers (N-P-K) are also added with chicken manure and bio-humus plots. Tobacco wastes obtained from cigarette industry were used after composting. The addition of organic wastes resulted in a significant ($p \leq 0.05$) decrease in bulk density (BD); increase in porosity (PO), field capacity (FC), wilting point (WP), available water content (AWC) and structure stability index (SSI) of soil samples when compared to the control.

Keywords: Bio-humus, chicken manure, composted tobacco waste, soil physical conditions.

Introduction

Mineral fertilization provides readily available nutrients for plant growth; however, it does not contribute to improve soil physical condition. Organic matter inputs through organic amendment, in addition to supplying nutrients, improve soil aggregation and stimulate microbial diversity and activity (Shiralipour et al., 1992; Carpenter-Boggs et al., 2000). Applications of manure increase soil organic matter content and this results in increased water holding capacity, porosity, infiltration capacity, hydraulic conductivity and water-stable aggregation and decreased bulk density and surface crusting (Haynes and Naidu, 1998).

The addition of agricultural wastes with high organic matter content to soil is a well-known environmental and agricultural practice for maintaining characteristics of soil in terms of reclaiming degraded soils and supplying plant nutrients (Aggelides and Londra, 2000). Tobacco dust, as a waste product contains high levels of organic nitrogen and organic matter. In this order, it is a good organic material to be mainly used for composting (Gostkowska et al., 1996). The application of plant residues to soil is considered a good management practice because it stimulates soil microbial growth and activity, with the subsequent mineralization of plant nutrients (Eriksen, 2005; Randhawa et al., 2005), and increases soil fertility and quality (Doran et al., 1988).

Agbede et al. (2008), were found that a decrease in soil bulk density by applying chicken manure (rates of 7.5 t ha^{-1}) in a 3-year field experiment. Celik et al. (2004), were analyzed that the compost (made from plant

* Corresponding author.
Dumlupinar University, Vocational College of Simav, Department of Organic Farming, Simav, 43500 Kutahya, Turkey
Tel.: +90 274 5137250 Fax : +90 274 5135316 E-mail address: meliscercioglu@hotmail.com
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residues) and farm manure treatments resulted in the highest values in both field capacity and available water content. Soil structure stability is influenced by microorganism in two major ways: by the mechanical binding of soil particles together, and by the production of effective binding agents either by synthesis or through the decomposition of organic materials (Oades, 1984; Zaller, 2007). Improved soil moisture associated with poultry manure is attributable to mulcing effect of organic matter and improved moisture retention and water acceptance as a result of improved soil structure and macro porosity (Aluko and Oyedele, 2005). Adesodun et al. (2005) had found that application of poultry manure to soil increased soil aggregate stability.

The objective of the present study was to evaluate changes in physical conditions of the soil by addition of composted tobacco waste (CTW), chicken manure (CM) and bio-humus (BH).

Material and Methods

Experimental layout and treatments

The study was carried out from 2009 to 2011 at Agriculture Faculty's Research and Practice Farmyard of Ege University (Menemen, Izmir, Turkey) on a Xerofluvent soil. The main characteristics of the soil in 20 cm surface layer were: sand 55.28%, silt 36% and clay 8.72%, organic matter 1.11 g kg^{-1}, total N 0.07 g kg^{-1}, pH 7.62 and total soluble salt content 0.046 g kg^{-1}. The general properties of the soil are shown in Table 1.

Table 1. Initial soil properties

Clay (%)	Silt (%)	Sand (%)	$CaCO_3$ (g kg^{-1})	BD (g cm^{-3})	PO (%)	FC (%)	WP (%)	AWC (%)
8.72	36	55.28	4.70	1.46	50.66	17.77	10.26	7.51

(BD: Bulk density, PO: Porosity, FC: Field capacity, WP: Wilting Point, AWC: Available water content).

The organic wastes applied were a composted tobacco waste (CTW), chicken manure (CM) and bio-humus (BH). Their general properties are reported in Table 2. Tobacco wastes were obtained from cigarette industry used after composting period. Composting of tobacco waste was performed outdoor under a roof. The moisture content of the compost was analyzed approximetly 55% by weighing the material regularly and adding water when necessary. Aeration was made by manual turning during the composting. After 3 months, when the temperature of the compost decreased to the ambient level, composting was completed. Both of BH (composted plant residues) and CM were gathered from organic manure industry for this research. All doses of organic wastes were determined by researching recent studies, recommendations from producers of materials and plant nutrient removal by corn from soil.

Table 2. Organic wastes features

Parameter	CTW	CM	BH
pH	9.18	8.60	7.88
EC (ds m^{-1})	49.5	54.5	9.20
OM (g kg^{-1})	33.6	44.9	46.5
C/N	22.41	25.84	29.35
$CaCO_3$ (g kg^{-1})	7.06	12	26
Total N (g kg^{-1})	0.87	1.01	0.92
Available P (mg kg^{-1})	2770	3470	2050
Total K (mg kg^{-1})	19486	21985	6995
Total Ca (mg kg^{-1})	74440	94424	117656
Total Mg (mg kg^{-1})	635	12000	9200
Total Na (mg kg^{-1})	794.8	5663	993.5

(CTW:Composted tobacco waste, CM:Chicken manure, BH:Bio-humus)

The experimental layout was a randomized complete block with a total amount of 16 plots, with each plot measuring 5mx3m.

Four treatments were used (four replicates per treatment):

(1) CTW, 50 t ha^{-1}

(2) CM, 4 t ha^{-1}+300 kg ha^{-1} NPK

(3) BH, 10 t ha^{-1}+ 300 kg ha^{-1} NPK

(4) C, control soil (no organic amendment)

Soil measurements

The soil (Typic Xerofluvent) was a sandy loam taken from an experiment field of Ege University, Faculty of Agriculture, within 0-20 cm of the surface. During the research, undisturbed and disturbed soil samples were collected from each plot on 21 April 2009, 20 May 2010, 16 June 2011 (planting period) and 23 October 2009, 30 October 2010, 21 October 2011 (harvest period). The samples were air-dried and passed through 2 and 8 mm sieves. Particle-size distribution was determined according to Bouyoucos (1951). Bulk density was determined from undisturbed soil samples that were taken by using a steel cylinder of 100 cm^3 volume (Black, 1965). Soil testing cylinder (Soil Survey Staff, 1972), structure stability index and aggregation percentage were calculated by formula (U.S. Soil Survey Staff, 1951). Porosity was determined according to Danielson and Sutherland (1986). Field capacity, wilting point, and available water content were determined using disturbed soil samples sieved through a 2-mm-mesh utensil (U.S. Salinity Laboratory Staff, 1954). Total salt, organic matter concentration, calcium carbonate and pH were all determined according to Page et al., (1982).

Statistical Analysis

The experimental design was arranged three factors and mixed-level factorial randomized block. Table 3 shows the design. Analysis of variance (ANOVA) was performed by general linear model using SPSS 17.0 for Windows and Minitab 16. The means were separated by Duncan test, considering a significance level of $p \leq 0.05$ throughout the study.

Table 3. Mixed-level experimental design

Factor	Parameter	Level 1	Level 2	Level 3	Level 4
A	Year	2009	2010	2011	-
B	Sampling	I	II	-	-
C	Treatment	1	2	3	4

[Treatments 1:Composted tobacco waste, CTW (50 t ha^{-1}); 2: Chicken manure, CM (4 t ha^{-1}) + NPK (300 kg ha^{-1}); 3: Bio-humus, BH (10 t ha^{-1})+ NPK (300 kg ha^{-1}); 4: Control, C (Duncan test, $p \leq 0.05$)].

Results

Changes in physical conditions of soil samples

By the additions of organic wastes, physical properties of soil samples were analyzed statistically significant when compared with the control (Table 4, 5, 6). All the applications were ensured a significant ($p \leq 0.05$) decrease on bulk density by the treatments of CTW, CM and BH according to the control plots. The lowest bulk density was analyzed last year of the experiment by the treatment of CM as 1.04 g cm^{-3}.

Addition of CTW, CM and BH were increased total porosity of soil samples averagely (first and second soil samples) in three planting seasons, respectively. Maximum porosity values were found last year of the study by application of CM compared to the control plots. Mbagwu (1989), noted that organic wastes incorporated into the soil at the rate of 10% increased the total porosity by 23%. Marinari et al. (2000), also found that total soil porosity increased with organic fertilizers and compost, depending on the amount of materials applied.

The water holding capacity of soils at field capacity (FC), wilting point (WP) and available water content (AWC) were significantly ($p \leq 0.05$) effected by additions of organic wastes. Plots amended with bio-humus resulted in the highest values in FC each year of experiment. FC values varied as 21.89%, 21.65% and 20.28% in BH treated soil samples according to years respectively. The highest wilting point (WP) results of each year were analyzed in CM plots. By addition of CM, wilting point (WP) was determined as high as 11.49% in 2010 (Table 5). AWC values varied between 7.35% and 10.72%. First year of experiment, the maximum AWC was determined in CTW treated soil samples (Table 4). On the other hand, second and third year of experiment the maximum AWC values were found in BH treated soil samples (Table 5 and Table 6).

Table 4. Changes in physical conditions of soil by addition of organic wastes in 2009

Treatments ($t\ ha^{-1}$)	BD ($g\ cm^{-3}$)	PO (%)	FC (%)	WP (%)	AWC (%)	SSI (%)
1	1.20	51.08	21.76	11.03	10.72	21.65
2	1.22	50.41	21.66	11.20	10.46	22.36
3	1.19	51.37	21.89	11.18	10.70	17.77
4	1.39	45.63	18.85	9.16	9.68	15.53

BD: bulk density, PO: porosity, FC: field capacity, WP: wilting point, AWC: available water content, SSI: structure stability index. Treatments [1] Composted tobacco waste (50 $t\ ha^{-1}$); [2] Chicken manure (4 $t\ ha^{-1}$) + NPK (300 $kg\ ha^{-1}$); [3] Bio-humus (10 $t\ ha^{-1}$)+ NPK (300 $kg\ ha^{-1}$); [4] Control. (Duncan test, $p \leq 0.05$).

Table 5. Changes in physical conditions of soil by addition of organic wastes in 2010

Treatments ($t\ ha^{-1}$)	BD ($g\ cm^{-3}$)	PO (%)	FC (%)	WP (%)	AWC (%)	SSI (%)
1	1.23	52.46	20.98	11.18	9.80	21.43
2	1.26	51.11	21.19	11.49	9.69	22.46
3	1.24	51.07	21.65	11.26	10.38	20.83
4	1.42	45.88	17.96	9.73	8.23	18.68

BD: bulk density, PO: porosity, FC: field capacity, WP: wilting point, AWC: available water content, SSI: structure stability index. Treatments [1] Composted tobacco waste (50 $t\ ha^{-1}$); [2] Chicken manure (4 $t\ ha^{-1}$) + NPK (300 $kg\ ha^{-1}$); [3] Bio-humus (10 $t\ ha^{-1}$)+ NPK (300 $kg\ ha^{-1}$); [4] Control. (Duncan test, $p \leq 0.05$).

Table 6. Changes in physical conditions of soil by addition of organic wastes in 2011

Treatments ($t\ ha^{-1}$)	BD ($g\ cm^{-3}$)	PO (%)	FC (%)	WP (%)	AWC (%)	SSI (%)
1	1.07	57.65	20.01	10.65	9.36	18.13
2	1.04	59.55	19.99	11.25	8.73	18.37
3	1.09	57.27	20.28	10.66	9.62	17.19
4	1.33	49.85	16.61	9.25	7.35	15.78

BD: bulk density, PO: porosity, FC: field capacity, WP: wilting point, AWC: available water content, SSI: structure stability index. Treatments [1] Composted tobacco waste (50 $t\ ha^{-1}$); [2] Chicken manure (4 $t\ ha^{-1}$) + NPK (300 $kg\ ha^{-1}$); [3] Bio-humus (10 $t\ ha^{-1}$)+ NPK (300 $kg\ ha^{-1}$); [4] Control. (Duncan test, $p \leq 0.05$).

All organic waste treatments were determined statistically significant ($p \leq 0.05$) on structure stability. The highest structure stability values of all years were analyzed that by CM treatment compared with the variation of the control (Table 4, 5, 6).

Discussion

The optimum correlation coefficient can be obtained with statistical model III as seen from the Table 7. For instance, changes in correlation coefficient of structure stability index when studied, it was obtained as 68.58% with model I, 96.34% with model II and 99.90% with model III. In this way, more realiable statistical results were ensured by decreasing error rate. It was observed that the use of organic wastes had a positive impact on physical characteristics of a coarse textured soil because of their high organic matter content which promotes flocculation of particles, the essential condition for the aggregation of soil particles.

In the present study, application of 50 $t\ ha^{-1}$ CTW, 4 $t\ ha^{-1}$ CM and 10 $t\ ha^{-1}$ BH with chemical fertilizers increase soil organic matter content and this results in decreased bulk density the rate of 16.5%; and increased porosity, field capacity, wilting point, available water content and structure stability index as 15.4%, 19.5%, 20.6%, 22.6% and 26.8% as compared to the average of the years and control plots. They can therefore be used at those rates for improving soil physical properties.

Table 7. General evaluation table for results of variance analysis of soil physical properties.

Statistical Model		I			II						III						
		A	**B**	**C**	**A**	**B**	**C**	**A*B**	**A*C**	**B*C**	**A**	**B**	**C**	**A*B**	**A*C**	**B*C**	**A*B*C**
BD	**P**	0.000	0.770	0.000	0.000	0.667	0.000	0.358	0.000	0.000	0.000	0.441	0.000	0.039	0.000	0.000	0.000
	R^2	87.04%			94.03%						98.14%						
PO	**P**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	R^2	77.05%			93.19%						97.82%						
SSI	**P**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	R^2	68.58%			96.34%						99.90%						
FC	**P**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	R^2	89.11%			98.06%						99.87%						
WP	**P**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	R^2	81.41%			94.67%						99.74%						
AWC	**P**	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	R^2	79.17%			93.49%						99.50%						

(**Factors A:** Year, **B:** Sampling **C:** Treatment. **BD**: bulk density, **PO**: porosity, **SSI**: structure stability index **FC**: field capacity, **WP:** wilting point, **AWC**: available water content).

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