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Effects of short-term amendments of farmyard manure on some soil properties in the Mediterranean region - Turkey

Erdem Yilmaz [1*] and Zeki Alagöz [2]

[1] *Kumluca Vocational High School, Akdeniz University, 07350 Antalya, Turkey.* [2] *Department of Soil Science, Faculty of Agriculture, Akdeniz University, 07058 Antalya, Turkey. *e-mail: erdemyilmaz@akdeniz.edu.tr*

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Abstract

Organic materials play a critical role in sustainability in the arid and semi-arid regions. Despite this importance, there is little predictive understanding for the management of organic inputs in arid and semi-arid agroecosystems. It is now widely recognized that SOM plays an important role in soil chemical (pH, base saturation, salinity and CEC changes) and physical (bulk density, stabilization of soil structure and aggregate formation) properties. In this study, the influences of farmyard manure (FYM) applications on some physical and chemical properties of the soil were investigated. This study was conducted between October 2000 and April 2001 in greenhouse as a pot experiment with a Lithic Rhodoxeralf. Treatments included four rates of FYM as follows on a dry weight basis: 0, 10, 20 and 40 t ha^{-1}. After seven months incubation period, soil organic matter (SOM) contents, total nitrogen (N), soil pH, electrical conductivity (EC), cation exchange capacity (CEC), base saturation (BS) and bulk density (BD) were determined. The effect of FYM applications on SOM, total N, pH, EC, CEC and BD were found to be significant ($p<0.001$), however, the effect of FYM on BS was not significant. The use of FYM led to an apparent increase, especially in intermediate and high doses, in SOM, total N, pH, EC and CEC but to a slightly decrease in BD. The use of FYM can contribute to enhancing the level of organic matter in Lithic Rhodoxeralf, which is particularly poor in organic matter under greenhouse condition.

Key words: Fertility, Lithic Rhodoxeralf, organic matter, soil physics.

Introduction

The loss of soil organic matter (SOM) increases the possibility of erosion by wind and water, decreases overall soil quality or fertility, and ultimately reduces agricultural soil sustainability. Organic materials are important soil additives, particularly in semiarid regions (such as Turkey) where there is low input of organic materials.

Use of organic matter in arid and semi-arid regions, where soil organic matter (SOM) content is rather low, will contribute to enrich the soil with SOM. The gradual and rapid decrease in SOM content in soils under intensive agriculture practices, especially in those having hot climates, may lead to the deterioration of their chemical and physical properties [1]. However, the positive effects of organic matter (OM) on soil properties depend on the amount and also the composition of OM [3]. In degraded lands, both soil organic C and N are lost, and N can become the limiting nutrient in recovery process [2].

Soil physical and chemical characteristics are affected by soil amendment and production system [4]. The use of organic soil amendments has been associated with desirable soil properties including higher plant available water holding capacity, pH and CEC and lower bulk density, and can foster beneficial microorganisms [5]. Soil organic matter has a less direct, but nonetheless important effect on nutrient supply through its influence on cation exchange capacity [6]. The effect of farmyard manure (FYM) on cation exchange capacity (CEC) of the soil was significant, and the highest rates of FYM have also increased soil organic carbon and potentially mineralizable nitrogen [7]. In addition, soil surface (0-15 cm) pH significantly increased with beef cattle manure [8].

Organic resources play a dominant role in soil properties through their short-term effects on nutrient supply and longer-term contribution to soil organic matter (SOM) formation [9]. Nutrient management in organic systems is based on fertility building leys to fix atmospheric nitrogen (N), combined with recycling of nutrients via bulky organic materials, such as farmyard manure (FYM) and crop residues, with only limited inputs of permitted fertilizers [10]. One of the central assumptions of organic soil management is that it leads to an increase in levels of SOM, resulting from large inputs of organic matter from leys and animal manure [11].

The management of organic wastes is an important aspect in the physical and chemical properties of soil. These practices influence microbial activities, soil properties, nutrient availability and crop yield [12]. These systems sustain soil quality and productivity by maximizing nutrient (C and N) cycling, microbial population and activities and soil aggregation [13].

Soil organic matter (SOM) or soil organic carbon (SOC) concentrations are often cited as major indicators of soil quality or fertility. However, only few studies have attempted to discuss minimum or maximum threshold values of SOC. For example, the relationships between SOC in the uppermost 15 cm and soil productivity, an upper threshold of SOC existed, beyond which no further increases in productivity were achieved [14].

The objective of this paper was to determine the role of FYM on some soil properties, with specific emphasis on soil organic matter (SOM), total N, soil pH, electrical conductivity (EC), cation exchange capacity (CEC), base saturation (BS) and bulk density (BD) in a Lithic Rhodoxeralf soil.

Materials and Methods

Soil sample was collected from the 0-25 cm of A-Horizon of a Lithic Rhodoxeralf [15] at the campus of Akdeniz University. Solid farmyard manure (FYM) was obtained from smallholders. Selected physicochemical properties of soil and analytical composition of the organic material are given in Tables 1 and 2, respectively.

Table 1. Selected physicochemical properties of soil.

pH	6.79
EC (dS m^{-1})	1.00
$CaCO_3$ g kg^{-1}	14.3
OM g kg^{-1}	19.0
BS* g kg^{-1}	633.1
CEC** cmol kg^{-1}	32.17
Ca^{2+} cmol kg^{-1}	17.40
Mg^{2+} cmol kg^{-1}	0.88
K^{+} cmol kg^{-1}	1.77
Na^{+} cmol kg^{-1}	0.31
Sand (2–0.05 mm) g kg^{-1}	159
Silt (0.05–0.002 mm) g kg^{-1}	377
Clay (<0.002 mm) g kg^{-1}	464
Texture	Clay
Bulk density (Mg m^{-3})	1.0
Field capacity g kg^{-1}	40

* Base saturation ** Cation exchange capacity.

Table 2. Analytical compositions of the FYM.

pH	8.81
OM g kg^{-1}	48.58
N g kg^{-1}	11.8
C g kg^{-1}	282.4
C:N	23.93
P g kg^{-1}	8.3
K g kg^{-1}	9.0
Ca g kg^{-1}	7.1
Mg g kg^{-1}	9.8
Fe (mg kg^{-1})	2524.6
Mn (mg kg^{-1})	276.2
Zn (mg kg^{-1})	112.0
Cu (mg kg^{-1})	27.8

The study was carried out in a completely randomized plot design with three replications and conducted under greenhouse conditions as a pot experiment between October 2000 and April 2001. A total of 3500 g air-dried and sieved (4 mm) soil samples mixed with organic matter were placed in each pot (height 15 cm × length 50 cm × depth 11 cm) on the 5 cm thick layer of rough sand placed at the bottom of pots. On a dry weight basis, four levels of organic amendment (0, 10, 20 and 40 t ha^{-1}) were applied to soil and then incubated for seven months. During the incubation period, the soil moisture level in the pots was maintained at 50-75% of field capacity.

The pipette method was used for texture analysis [16]. Soil field capacity was measured by using direct determining method [17], and bulk density was measured using the cylinder method [18]. Soil pH was measured in a 1:2.5 (soil: water) aqueous extract [19], and the soluble total salt content was calculated in the saturation extract set out by Bower and Wilcox [20]. Calcium carbonate ($CaCO_3$) content of soil was measured with a Scheibler calcimeter [21]. Exchangeable Na^+, K^+, Ca^{2+} and Mg^{2+} were determined by extraction with 1 N ammonium acetate (CH_3COONH_4) and measured with an atomic absorption spectrophotometer [22]. Cation exchange capacity (CEC) was measured using 1 N ammonium acetate (CH_3COONH_4) method [23]. Base saturation was calculated by exchangeable bases (Na^+, K^+, Ca^{2+} and Mg^{2+}) divided by total CEC value. Extractable P (with $NaHCO_3$) was determined using the Olsen method [24]. Extractable Fe^{2+}, Zn^{2+}, Mn^{2+} and Cu^{2+} were determined using the DTPA extraction method and the atomic absorption spectrophotometry [25].

Organic carbon was determined using the modified Walkley-Black method [18], and the organic matter content of the organic material was calculated by multiplying the organic carbon value with 1.72 [26]. The pH value of the organic material was measured in a 1:5 organic matter-water mixture [27]. Nitrogen was determined using the modified Kjeldahl method [28]. The phosphorus content of the organic material was determined using the vanado-molybdo-phosphoric yellow color in the filtrate method attained from nitric-perchloric acid mixture and the wet oxidation method [29]. The amounts of macro and microelements (K^+, Ca^{2+}, Mg^{2+}, Fe^{2+}, Zn^{2+}, Mn^{2+} and Cu^{2+}) in the filtrate after wet oxidation were measured using the atomic absorption spectrophotometry [28].

One-way analysis of variance (ANOVA) was used to compare the effect of CM on some soil properties. The LSD procedure was conducted to compare soil properties means at $p<0.05$ [30].

Results and Discussion

One of the most significant effects of organic matter amendment was the increase in the soil organic matter (SOM) content (Table 3). The FYM amendment significantly increased the total SOM content ($p<0.001$), and the highest values were found in Doses 3, 2 and 1, respectively. Organic matter enrichment was 1.5 times higher with FYM treatment compared to the control treatment. Therefore, the use of FYM may contribute to maintain soil organic matter in high level. Soil type, climate, management, mineral composition, topography, soil biota and the interactions between each of these are modifying factors that will affect the total amount of SOM.

Total organic matter has long been recognized as an important determinant of soil performance. Its influence depends on the amount of organic matter added to the soil, its decomposition rate, and the amount held by the soil. The amount, type, and location of organic matter may be one of the best integrating indicators of many physical, chemical and biological processes [31]. A higher concentration of total SOM is often considered to be an inevitable result of conversion to organic management [32]. Indeed, many authors have measured a higher concentration of total SOM in organically managed soils [33, 34].

Significant differences in total N over control were found. The FYM amendment significantly increased the total N ($p<0.001$), and the highest values were determined in Doses 3, 2 and 1, respectively (Table 3). Total N values in the experiment were found to be linked to the increasing amendment rates of the FYM. It is thought that these results may be due to quick decomposition of the FYM. The FYM has a moderate C:N ratio (23.93:1), and the high N mineralization from the FYM may be attributed to its moderate C:N ratio. The organic matter decomposition rate was believed to be influenced by the organic matter quality, as defined

Table 3. The effect of FYM on some physical and chemical soil properties [1].

Treatment	SOM g kg^{-1}	Total N g kg^{-1}	pH	EC (dS m^{-1})	CEC ($cmol_c$ kg^{-1})	BS g kg^{-1}	BD (g cm^{-3})
Control	19.0d[2]	0.97d	6.79c	1.00b	32.17c	633.1	1.00a
Dose 1	19.9c	1.70c	7.18b	1.03b	32.38c	638.5	0.97a
Dose 2	28.8b	1.82b	7.31a	1.37a	34.76b	641.0	0.93b
Dose 3	29.8a	2.04a	7.34a	1.44a	38.78a	638.8	0.90c
Significance [***]	***	***	***	***	***	NS	***
LSD (%5)	0.06101	0.005954	0.07877	0.08010	0.2709	63.31	0.02244

[1] Values of *n* = 3. [2] The difference between values not shown with the same letter are significant at a p<0.05 level.
[***]: Significance: NS, not significant; *** significant at p<0.001.

by the chemical composition and relative proportions of its constitutive organic compounds [35]. In addition, some authors described the decomposition of organic fertilizers in soil as a function of their quality, mainly their C-to-N ratio [36].

Soil pH determined after the FYM amendment is given in Table 3. The FYM amendment significantly increased the pH (p<0.001), and the highest values were evaluated in Doses 2 and 3, and also they were found to be similar amendment. Soil pH has an important role in controlling the chemical reactions taking place in soil. In general, pH values between 6 and 7.5 are considered to be optimum for general crop growth. Site specific interpretations for soil quality will depend on specific land use and crop tolerance [37]. Some authors have measured higher soil pH as a result of organic management, while others showed lower pH in organic systems [38-40].

The electrical conductivity (EC) indicated that the amendment significantly increased ion concentration in soil (p<0.001) which is essential for plant growth. The highest values of EC were determined in Doses 2 and 3, and also they were found to be similar (Table 3). The electrical conductivity (EC) of soil-water mixtures indicates the amount of salts present in the soil. All soils contain some salts, which are essential for plant growth. However, excess salts hinder plant growth by affecting the soil-water balance. The high EC values determined in this experiment may be explained by the decomposition of the larger organic fragments and their intermediates or end product of FYM during incubation periods. EC values of the soils treated with the FYM were lower than 4 dS m^{-1}, the traditional value above which soils present a salinization hazard [41].

As expected, the data of the experiment indicated that there was significant increase (p<0.001) for CEC in the soil for all doses, and the highest value was attained from Dose 3, and CEC increased to 38.78 $cmol_c$ kg^{-1} (Table 3). It is thought that this is a result of presence of humified organic materials as a component of soil CEC and higher soil pH may also create negative charge in these soils increasing the CEC [42, 31]. Generally, SOM is responsible for 25-90% of the total CEC of surface horizons of mineral soils [43]. Though the statistical significance was determined in CEC, the base saturation of soil (BS) was not significantly affected by FYM amendment which was applied to different doses (Table 3).

The effect of FYM amendments on soil bulk density (BD) was detected after the incubation period (Table 3). The bulk density of soil (BD) was significantly decreased (p<0.001), and the highest value was obtained from Dose 3 within the all treatment levels. Generally, soil bulk density values in the experiment were found to be linked to the increasing amendment rates of the FYM. Intensive field crop production can cause the physical quality of agricultural soils to decline [44]. Bulk density is a dynamic property that varies with the structural condition of the soil. This condition can be altered by cultivation, trampling by animals, agricultural machinery and weather, i.e. raindrop impact [45]. Compacted soil layers have high bulk densities, restricting root growth and inhibiting the movement of air and water through the soil. The lower critical density range from about 1.2 to 1.6 Mg m^{-3} for soil silt + clay, while the upper critical densities ranged from about 1.4 to 1.8 Mg m^{-3}, respectively [46]. Comparable upper critical limits were proposed by Veihmeyer and Hendrickson, who found that root extension in clayey soils could stop completely at bulk densities ≥1.5-1.6 Mg m^{-3} and in loamy and sandy soils at densities ≥1.6-1.8 Mg m^{-3} [47]. The recommended bulk densities for constructed urban landscaping soils, on the other hand, range within 1.1-1.4 Mg m^{-3}, depending on the texture of the mineral component, the type and amount of amendments added and the intended land use [48].

Conclusions

In our study, differences in chemical and physical properties of the soil were related to amount of the organic material added. Increasing doses of FYM had a significant effect on some of the soil properties in the experiment. Soil properties were enhanced in terms of SOM, total N, pH, EC, CEC and BD. The use of FYM may contribute to enhancing the level of organic matter in Lithic Rhodoxeralf, which is particularly poor in organic matter under greenhouse condition. In addition, soil organic matter has to be replenished through periodic additions of FYM for maintaining soil productivity. From this point of view, FYM can be considered as an organic material to be used to improve soil physical and chemical properties in arid and semiarid regions.

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