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# Effect of manure on organic carbon content and fractal dimensions of aggregates

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## Abstract

Effects of farmyard manure treatments on some soil structural parameters such as, aggregate stability (AS), geometric mean weight (GMWD) and mean weight (MWD) diameters, fragmentation (D) and mass ($D_m$) fractal dimensions, bulk density (BD) and organic C (OC) contents of aggregates were determined in a clay soil. Application of 67 Mg ha$^{-1}$ farmyard manure to Vertic Haplustoll soil decreased AS 12.14% compared with the control. Manure treatment increased the proportion of microaggregates in the fractions <1.00 mm in size and decreased the proportion of macroaggregates in the fractions >1.00 mm in size. While OC contents of aggregates increased between 22.8% and 123.4%, BD values decreased between 0.8% and 16.6% with the manure treatment. Fragmentation (D) and mass ($D_m$) fractal dimensions were increased with decreasing numbers of macroaggregates of the clay soil. GMWD (1.16 mm) and MWD (1.86 mm) obtained in the manure treatment were lower than that in the control treatment (1.20 mm and 1.95 mm, respectively). Although OC content of the aggregates increased with the manure treatment, the number of macroaggregates of clay soil decreased with decreasing AS..

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## Introduction

Agricultural productivity and environmental protection mostly depend on soil management practices. Loss of soil organic matter due to intensive or inappropriate agricultural practices can destroy soil structure and decrease availability of soil nutrients (Busscher and Bauer, 2003; Bronick and Lal, 2005). Addition of agricultural wastes to soil helps maintaining soil organic matter, reclaiming degraded soils and supplying plant nutrients (Aggelides and Londra, 2000). Soil organic carbon can strongly influence aggregation processes, and in turn is influenced by the types of plant residues or organic amendments used and by their decomposition rate and products (Bronick and Lal, 2005). Application of manure to soil increase soil organic matter content, soil available macronutrients, water holding capacity, porosity, infiltration capacity, hydraulic conductivity, water stable aggregation, and decrease bulk density and surface crusting (Khaleel et al., 1981; Haynes and Naidu, 1998; Matsi et al., 2003). The mean weight diameter (MWD) indicates aggregate size distributions obtained by mechanical sieving (Van Bavel, 1949), and has an important variation under different cropping and tillage practices (Kushwaha et al., 2001). Many investigators have recently used the fractal parameters; fragmentation fractal dimension (D) and mass fractal dimension ($D_m$), as indices to evaluate the influences of cropping practices and wetting treatments on the size distribution of water-stable aggregates (Martinez-Mena et al. 1999; Gülser, 2006). Six et al. (2000) reported that macro and

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micro aggregate proportions in the soil and water stable aggregate size distribution are directly related to the intensity of disruption and rapidly respond to the changes in soil management practices. Therefore, the objective of this study is to investigate the effect of manure on organic carbon contents of aggregates and some soil structural parameters in a clay soil.

## Material and Methods

A field experiment was conducted at the Experimen
University, Samsun in Nowember, 2001. Farmyard manure (FM) was incorporated within 0 - 15 cm Vertic Haplustoll soil depth as 67 Mg $ha^{-1}$ with three replications in a randomized plot design. The FM had 15.62% organic C, 1.95% total N, 7.98 C:N ratio, 1.08% Na, 1.97% K, 6.58% Ca, 0.94% Mg and 7.12 pH. After 8 months of FM application, soil samples were taken middle of the plots. Some chemical and physical characteristics of the soil were determined in soil samples as follows; particle size distribution by hydrometer method, bulk density (BD) by undisturbed soil core method (Demiralay, 1993), soil pH, 1:1 (w:v) soil:water suspension by pH meter, electrical conductivity ($EC_{25°C}$) in the same suspension by EC meter, organic C content by Walkley-Black method and exchangeable cations by ammonia acetate extraction (Kacar, 1994). According to the soil physical and chemical properties given in Table 1, the results can be summarized as; the textural class is clay, none saline, neutral in pH, high in organic matter (Soil Survey Staff, 1993).

Table 1. Soil physicochemical properties of the experimental field

| | | | |
|---|---|---|---|
| Sand, % | 16.89 | $EC_{25°C}$, mmhos $cm^{-1}$ | 0.69 |
| Silt, % | 20.18 | K, me/100g | 1.12 |
| Clay, % | 62.93 | Na, me/100g | 0.15 |
| Texture class | Clay | Ca, me/100g | 34.00 |
| Organic C, % | 2.46 | Mg, me/100g | 9.44 |
| pH | 7.00 | | |

In the dry sieving, 100 g of air dry soil sample was sieved using a nest of sieves with mesh openings of 4.00, 3.35, 2.00, 1.40, 1.20, 1.00, 0.50, 0.425 and 0.25 mm respectively, and a shaking time of 1 min. Mean weight diameter (MWD) and geometric mean weight diameter (GMWD) were calculated from weights of aggregates retained in each size class with the equations (Hillel, 1982):

$$MWD = \sum_{i=1}^{k} W(i)\, \bar{x}_i \quad (1)$$

$$GMWD = \exp\left(\sum W(i) \log(x_i) | \sum W(i)\right) \quad (2)$$

where W(i) is the proportion of the total dry sample weight, $\bar{x}_i$ is the mean diameter of any particular size range of aggregates separated by sieving and equal to $(x_i + x_{i-1})/2$. Aggregate stability (AS) was determined using a wet sieving method (Kemper and Rosenau, 1986).

According to the model provides fundamental definition for fragmentation fractal dimension by Turcotte (1986), the number-size distribution of fragments is given by

$$N_i = c\, \bar{x}_i^{-D} \quad (3)$$

where $N_i$ is the cumulative number of fragments remaining on the *i*th sieve; $\bar{x}_i$ is the mean size of the fraction on the *i*th sive and equal to $(x_i + x_{i-1})/2$; c is a constant and D is the fragmentation fractal dimension.

D in Eq. (3) was estimated by regressing log $N_i$ against log $\bar{x}_i$ $N_i$ using the aggregate size distribution data obtained after dry sieving.

A mass-based model for the estimation of fractal dimension developed by Tyler and Wheatcraft (1992) is

$$M(x<X)/M_t = (x/XL)^{3-D_m} \quad (4)$$

where M is the mass of aggregates on each sieve from the bottom to the top of the nest of sieves; $M_t$ is the total mass of aggregates; XL is an upper limit on the fractal character of the distribution and $D_m$ is the mass fractal dimension. $D_m$ in Eq. (4) was estimated by regressing log-transforming data obtained after dry sieving.

# Results and Discussion

The mass frequency, organic C content and bulk density of aggregate size distribution are presented in Figures 1, 2 and 3. Application of FM to Vertic Haplustoll soil increased the proportion of micro aggregates in the fractions less than 1.00 mm in size and decreased the proportion of macro aggregates in the fractions greater than 1.00 mm in size. According to the control treatment, the most increase (24.7%) and decrease (-10.1%) percentages in mass of aggregate fractions were found at the fraction size of 0.50-0.425 mm and 4.00-3.35 mm, respectively (Table 2). Organic C content of the different size of aggregates increased by the FM application (Figure 2). Increment in OC content of the different size of aggregates varied between 123.4% in 4.00-3.35 mm size and 22.8% in 0.50-0.425 mm size of fractions. Kushwaha et al. (2001) reported that soil organic C was strongly correlated with soil macroaggregates (>0,3 mm) and the percent increase in the amount of organic carbon in macroaggregates was greater than in microaggregates. In this study, the percent increments in the amount of OC in macroaggregates (>1.00 mm) were similarly greater than in microaggregates. Increasing the amount of OC or organic matter content in soil by FM application decreased the bulk density of the aggregate fractions (Figure 3). Changes in BD values at the fractions smaller than 0.50 mm size were more than that at the fractions greater than 0.50 mm size. The highest (-16.6%) and the lowest (-0.8%) decreases in mass of aggregate fractions were found at the fraction size of 0.50-0.425 mm and 3.35-2.00 mm, respectively (Table 2).

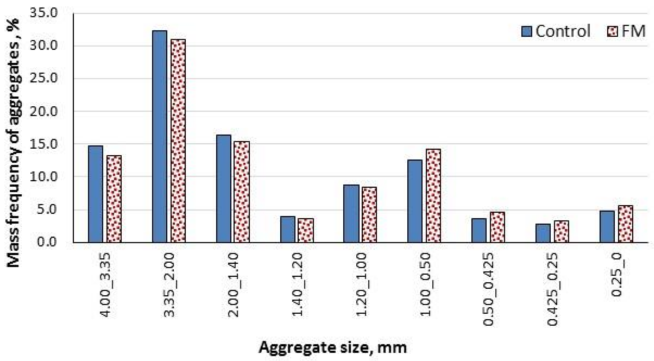


Figure 1. Effect of farmyard manure on mass frequency of aggregates


Figure 2. Effect of farmyard manure on organic C content of aggregates

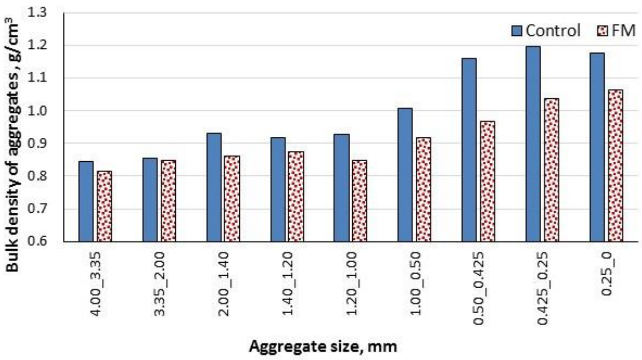


Figure 3. Effect of farmyard manure on bulk density of aggregates.

Effect of FM application on AS, MWD, GMWD, fragmentation (D) and mass (Dm) fractal dimensions were given in Table3. While AS (-12.14%), MWD (-4.95%) and GMWD (-3.36%) decreased by the FM application, D (5.69%) and Dm (3.37%) increased in comparison of the control treatment. It is known that compounds in cattle manure have an important role in buffering soil acidity and increasing the pH of acid soils amended with manure (Whalen et al. 2000). Ghosh et al. (2010) reported that when the manure was applied in to the Vertisol, dispersion index of the soil increased due to its high Na level. In this study, FM having a high Na content (1.08%) increased proportion of smaller aggregate size fractions (less than 1.00 mm) with decreasing AS of clay soil.

Table 2. Changes in mass, organic C and bulk density of aggregate fractions according to the control treatment (%).

| Aggregate size, mm | Fraction Mass | Organic C | Bulk density |
|---|---|---|---|
| 4.00 - 3.35 | -10.1 | 123.4 | -3.5 |
| 3.35 - 2.00 | -4.1 | 97.2 | -0.8 |
| 2.00 - 1.40 | -5.2 | 110.4 | -7.4 |
| 1.40 - 1.20 | -7.0 | 66.8 | -4.7 |
| 1.20 - 1.00 | -3.8 | 55.3 | -8.7 |
| 1.00 - 0.50 | 13.1 | 51.8 | -8.7 |
| 0.50 - 0.425 | 24.7 | 22.8 | -16.6 |
| 0.425 -0.25 | 16.6 | 54.9 | -13.3 |
| 0.250 -_0 | 20.7 | 38.1 | -9.6 |

Table 3. Effect of farmyard manure (FM) application on soil physical properties

| | AS, % | MWD, mm | GMWD, mm | D | Dm |
|---|---|---|---|---|---|
| Control | 68.63 | 1.95 | 1.20 | 2.32 | 2.01 |
| FM | 61.20 | 1.86 | 1.16 | 2.46 | 2.08 |
| % changes | -12.14 | -4.95 | -3.36 | 5.69 | 3.37 |

AS: Aggregate stability, MWD: Mean weight diameter, GMWD: Geometric mean weight diameter, D: fragmentation fractal dimension, Dm: Mass fractal dimension.

FM application decreased MWD and GMWD with increasing the proportion of microaggregates over the control due to dispersion effect of FM. Tyler and Wheatcraft (1992) reported that the fractal behavior of soil particle size is strictly limited to 0 < D < 3. In this study, the values of the both fractal dimensions were less than 3 (Table 3). The value of fractal dimensions increases with increasing fragmentation and higher fractal dimension values indicate a distribution dominated by smaller fragments (Perfect and Kay 1 2006). In this study, the both fractal dimensions increased with increasing proportion of microaggregates or decreasing MWD and GMWD values by the FM application. Gülser (2006) found that mass fractal dimension varied in a narrow range compared to fragmentation fractal dimension, and also both fractal dimensions were negatively correlated with MWD and AS. The percent change in D according to control was larger than that in Dm (Table 3). D and Dm values increased with decreasing AS of clay soil by the dispersion effect of FM.

As a conclusion, although FM application increased OC content of aggregates, it increased proportion of microaggregates (<1.00 mm) with dispersing of macroaggregates. Changes in aggregate size distribution by FM application over the control treatment represented with D very well when comparing with the other physical parameters.

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