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Some Tillage-Induced Differences in the Macroaggregates-Size Fraction

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Tillage is one of the most significant management applications that determine properties of the soil aggregates. The effects of three tillage systems on organic carbon and extractable potassium contents of macroaggregates were studied. In the years 2003 and 2004, the soil samples were taken from an experimental pot that has been carried out for four years in a loam soil (typic Xerofluvent). Treatments consisted of three planting systems (chisel plowing, chisel plowing and disc harrowing and chisel plowing and combine harrowing) under the rotation system (sunflower/barley/hungarian vetch and triticale) with three replications. Samples were sieved to separate the five macroaggregate size fractions (8–4.76, 4.76–2, 2–1, 1–0.5, and 0.5–0.25 mm). The differences in the organic carbon and extractable potassium contents of the macroaggregate size fractions were most significant and were independent of the tillage systems. The greatest organic carbon contents were in the > 2 mm macroaggregate size fractions. Extractable potassium content generally increased as macroaggregate size increased. Both mean organic carbon and extractable potassium contents were the greatest in the chisel plowing, the contents of macroaggregate size fractions would not fully show differences among tillage treatments.

Key Words: Organic carbon, Potassium, Aggregate.

INTRODUCTION

It is a subject of research how soil management affects organic carbon content and quality allows determining soil productivity levels and soil behaviour against degradation processes. Soil aggregation is significantly linked with changes in soil organic matter quality and quantity. The aggregate-size distribution has been successfully used to investigate the changes caused in soil properties by different tillage systems and management practices[1–3]. On the other hand, some soil properties are dependent more on the amount of organic matter accumulated in different size fractions.

Ashman *et al.*[4] investigated how variations in aggregate fractionation procedures influence the chemical and biological properties of different sized soil aggregates. On the other hand, organic matter in size fractions of soils as a function of climate, soil texture and management was studied by Hevia *et al.*[5]

Filho *et al.*[6] reported that the greatest quantities of organic carbon in which treatments consisted of two planting systems (conventional and no tillage), under three crop rotations, were found in the > 2 mm aggregate size class, which had a value 23% higher than the other classes.

The amount of soil macroaggregates increases when the particulate organic matter increases. Nutrient availability largely depends on the mineralization rates of particulate organic matter[7].

Our underlying hypothesis was that the some properties of macroaggregate size fractions would better show the difference among tillage treatments. We have not found any difference for organic matter and some plant nutrients among tillage treatments on the < 2 mm soil samples[8]. In addition, the effects of secondary tillage on macroaggregate composition are less documented. The objective of this study is to determine the influence of tillage practices on some properties of macroaggregate size fractions in a dryland in the passage zone between the coastal belt and the continental climate of Central Anatolia, Turkey.

EXPERIMENTAL

The experiment was started in the year 2001 at the University of Suleyman Demirel, Agricultural Faculty Farm (37°50′31″N, 30°32′09″E), near Isparta, Turkey, on a loam soil (typic xerofluvent). The experimental site has an elevation of 1015 m above sea level and a slope of 1%. The soil parent material is medium textured, calcareous, alluvial material. The experimental soil has xeric soil moisture regime and mesic soil temperature regime[9]. The main characteristics of experimental soil (0–20 cm) are: 6.55 g kg^{-1} organic carbon; 223 g kg^{-1} clay; 438 g kg^{-1} silt; 339 g kg^{-1} sand; 7.84 pH; 1 : 1 soil : water and cation exchange capacity of 29.29 mol kg^{-1}. According to the long-term data (1931–1980), the mean annual precipitation of the region is 600.4 mm and the mean annual temperature is 12.1°C.[10]

There is a 3-yr rotation system including sunflower (*Helianthus annuus* L.), hybrid Vinimix, barley (*Hordeum vulgare* L.), variety Tokak and a mixture of Hungarian vetch (*Vicia pannonica Crantz*) and triticale, variety Tathcak 97 (3 + 1 rate) in randomized plots (3 × 50 m) with three replicates in the experiment. The experimental site had been under cereal-follow cropping system until the year 2000 before the experiment was started in the year 2001. The tillage treatments were chisel (C), chisel and disc harrow (CD), and chisel and combine harrow (CH). All plots were chiselled to a depth of 25 cm in February 2001, September 2001, September 2002 and November 2003. Disc harrow and combine harrow treatments for CD and CH tillage were applied to a depth of 10 cm on April 2001, November 2001, October 2002 and April 2004 just prior to plantings. Hungarian vetch and triticale mixture was sown at 63 kg ha^{-1} in rows 14.5 and 13 cm aparts, respectively, by mounted type planting machines in 2002. Second sunflower crop in the rotation in 2004 was planted with 75 cm inter row and 35 cm intra row distances using a pneumatic planting machine. Sunflower seeding rate was 38000 kernels ha^{-1}. Fertilizer was used to be 250 kg ha^{-1} DAP (18–46) for sunflower and not used for Hungarian vetch + triticale mixture. Weeds were controlled for only sunflower using hoe machine and hand hoe. For a more detailed description regarding experiment, see Bayhan *et al.*[11].

Soil samples of about 2 kg were collected randomly using a spade within each plot from the 0–20 cm depth after harvesting of Hungarian vetch and Triticale mixture and sunflower on June 2003 and August 2004, respectively. Samples were put in a closed plastic container and stored in the refrigerator at 4°C until analysis. Moist clods larger than 8 mm in soil samples were broken into aggregates to pass through the 8 mm sieve for laboratory determination of dry-aggregate-size distribution. After air drying, about 1 kg of soil samples was separated using a dry-wet sieve machine (Retsch, Model: AS 200) with a series of five sieves (4.76, 2, 1, 0.5, 0.25 mm) at 80 amplitude for 20 min. Organic carbon (OC) was determined by modified Walkley-Black method for aggregates on each sieve[12]. Extractable potassium (EK) contents of aggregates were determined by ammonium acetate method[13]. The experimental data were statistically analyzed with SPSS 10.0 for Windows package program.

RESULTS AND DISCUSSION

The statistical analysis of the results indicates that the effect of year on organic carbon and extractable potassium of macroaggregates was significant ($P < 0.001$), when all aggregate size fractions were considered (Table-1). The mean organic carbon and extractable potassium contents in the year 2003 were higher than those in the year 2004. Organic carbon contents were unaffected by tillage systems, but extractable potassium had changed ($P < 0.05$). The mean extractable potassium contents of macroaggregates in chisel treatment were higher than those in CD and CH treatments. The mean organic carbon and extractable potassium contents regarding aggregate size fractions showed significant differences ($P < 0.001$). The highest contents for organic carbon and extractable potassium were found for 4.76–2 mm and 1–0.5 mm aggregate size fractions, respectively (Table-2). The mean organic carbon contents differed between all aggregate size fractions except for aggregates < 1 mm ($P < 0.05$). The mean extractable potassium contents of macroaggregates increased gradually from 8–4.76 mm to 1–0.5 mm, and then decreased in 0.5–0.25 mm aggregate size class.

Interactive effects of year × tillage and tillage × aggregate size class were not significant. The three way interaction of year × tillage × aggregate size class also was not significant. But, the year × aggregate size class interaction was significant ($P < 0.001$) for organic carbon contents (Table-1). The cause of interactive effect was a difference in 4.76–2 mm aggregate size class. While the mean organic carbon contents in 2004 decreased for the other aggregate size fractions, there is an increase in 4.76–2 mm aggregate size class.

Changes of the mean extractable potassium contents of macroaggregates from 2003–2004 in this study were in accordance with the contents of the soil samples taken from the depth of 0–20 cm in the 2001–2003 experiment years[8]. These results can be explained by the not using fertilizer included potassium along four years of the experiment and the using of plants. Cultivation operations (hoe and ridger) accelerated organic matter mineralization for sunflower in 2004 may explain the decline in the quantity of organic carbon. It has frequently been pointed out[14, 15] that conservation tillage systems is effective in increasing organic carbon content.

TABLE-1
SUMMARY OF STATISTICAL ANALYSIS OF ORGANIC CARBON AND EXTRACTABLE POTASSIUM OF AGGREGATE SIZE FRACTIONS AS INFLUENCED DIFFERENT TILLAGE SYSTEMS

Source of variation	df	Mean square	
		Organic carbon	Extractable potassium
Year (Y)	1	6.829†	9.645.6†
Tillage (T)	2	0.483^{ns}	1841.0*
Aggregate size fraction (A)	4	2.893†	2542.5†
Y × T	2	0.287^{ns}	1577.3^{ns}
Y × A	4	2.605†	140.5^{ns}
T × A	8	0.195^{ns}	40.0^{ns}
Y × T × A	8	0.415^{ns}	14.3^{ns}

^{ns}Not significant.
*Significant at P = 0.05.
†Significant at P = 0.001.

The mean extractable potassium content ranking from highest to lowest was C > CH > CD (Table-2), indicating that the quantity of potassium decreased as tillage operations increased. The higher mean organic carbon content with C compared with CH and CD might have been due to slower organic matter mineralization rate. Tillage operations affect rates of organic matter mineralization because tillage alters soil moisture, air and temperature conditions; it also increases weathering and ultimately controls nutrient availability. Also, the mean potassium quantity based on dry matter of plants (2001 and 2003) in this experiment was lower in C treatment than those in CH and CD treatments[8]. According to Mullins *et al.*[16], poor early-season growth with lower soil temperatures in reduced tillage systems has been attributed to poor root development, slower organic matter mineralization rates and low nutrient availability.

The larger concentration of organic matter associated with macroaggregates > 2 mm was due to the greater accumulation of decomposed crop residues, which contributed to the formation of larger aggregates and its protection within these large aggregates. Filho *et al.*[6] found that organic carbon contents were 1.34–1.64% for aggregates > 2 mm, while these were 1.08–1.41% for 0.25–2 mm aggregates. It was emphasized that the larger quantities of organic carbon were associated with increases in aggregate size. Smaller aggregates also have greater quantities of persistent, humidified organic matter.

TABLE-2

EFFECTS OF TILLAGE ON ORGANIC CARBON AND EXTRACTABLE POTASSIUM CONTENTS OF MACROAGGREGATE SIZE FRACTIONS

	Organic Carbon (g kg^{-1})					
	8–4.76 mm	4.76–2 mm	2–1 mm	1–0.5 mm	0.5–0.25 mm	Mean
2003						
C	6.58 ± 0.65*	6.59 ± 0.89	6.64 ± 0.40	6.27 ± 0.39	6.02 ± 0.48	6.42 ± 0.56
CD	6.02 ± 0.35	6.15 ± 0.50	6.53 ± 0.63	7.02 ± 0.19	6.07 ± 0.57	6.36 ± 0.56
CH	6.43 ± 0.26	7.02 ± 1.07	6.50 ± 0.35	5.72 ± 0.49	6.31 ± 0.31	6.40 ± 0.62
Mean	6.33 ± 0.49ab	6.53 ± 0.77ab	6.57 ± 0.42ab	6.42 ± 0.63ab	6.11 ± 0.43abc	6.39 ± 0.56^{a}
2004						
C	6.58 ± 0.40	6.88 ± 1.05	4.89 ± 0.63	5.66 ± 0.82	6.21 ± 0.90	6.04 ± 0.99
CD	6.17 ± 0.26	6.75 ± 0.98	4.60 ± 0.32	4.87 ± 0.59	5.63 ± 0.55	5.60 ± 0.97
CH	6.13 ± 0.49	7.06 ± 0.73	4.90 ± 0.49	5.36 ± 1.29	5.27 ± 0.62	5.74 ± 1.00
Mean	6.31 ± 0.39ab	6.87 ± 0.83a	4.78 ± 0.45d	5.29 ± 0.81cd	5.76 ± 0.73bc	5.80 ± 0.98^{b}
Mean						
C	6.58 ± 0.48	6.73 ± 0.88	5.77 ± 1.07	5.97 ± 0.67	6.11 ± 0.65	6.23 ± 0.81
CD	6.09 ± 0.29	6.45 ± 0.77	5.57 ± 1.15	5.95 ± 1.24	5.85 ± 0.56	5.98 ± 0.87
CH	6.28 ± 0.36	7.04 ± 0.75	5.70 ± 0.99	5.54 ± 0.82	5.79 ± 0.72	6.07 ± 0.87
Mean	6.32 ± 0.42^{ab}	6.70 ± 0.79^{a}	5.67 ± 1.01^{c}	5.85 ± 0.91^{bc}	5.93 ± 0.61^{bc}	6.10 ± 0.84
	Extractable potassium (mg kg^{-1})					
	8–4.76 mm	4.76–2 mm	2–1 mm	1–0.5 mm	0.5–0. 25 mm	Mean
2003						
C	549.1 ± 44.6	552.5 ± 39.4	558.7 ± 33.3	565.9 ± 44.5	571.6 ± 43.5	559.6 ± 35.9
CD	513.3 ± 25.5	519.8 ± 12.7	536.2 ± 16.9	542.0 ± 21.2	539.3 ± 14.8	530.1 ± 19.8
CH	527.6 ± 28.4	530.6 ± 22.5	544.8 ± 28.2	551.1 ± 21.0	549.4 ± 20.1	540.7 ± 20.8
Mean	530.3 ± 33.8	534.8 ± 28.2	546.8 ± 24.9	553.2 ± 29.7	553.9 ± 29.9	543.8 ± 29.6^{a}
2004						
C	496.1 ± 15.0	513.2 ± 16.4	526.8 ± 9.0	534.7 ± 13.4	531.2 ± 20.3	520.4 ± 19.5
CD	495.6 ± 6.9	506.5 ± 4.9	529.4 ± 14.4	536.3 ± 15.5	524.7 ± 16.2	518.5 ± 18.9
CH	504.9 ± 10.8	518.6 ± 12.9	529.0 ± 16.3	540.5 ± 23.1	528.9 ± 11.7	524.4 ± 17.2
Mean	498.1 ± 10.6	512.0 ± 11.6	528.3 ± 11.1	536.7 ± 14.2	528.2 ± 14.9	520.7 ± 18.4^{b}
Mean						
C	522.6 ± 41.6	532.9 ± 34.5	542.8 ± 27.9	550.3 ± 34.0	551.4 ± 37.6	540.0 ± 34.7^{a}
CD	504.5 ± 19.3	513.2 ± 11.3	532.8 ± 14.5	539.1 ± 16.9	532.0 ± 16.0	524.3 ± 19.9^{b}
CH	516.2 ± 21.9	524.6 ± 16.5	536.9 ± 20.9	545.8 ± 19.0	539.2 ± 17.9	532.5 ± 20.4^{ab}
Mean	514.2 ± 29.4^{b}	523.4 ± 23.9^{ab}	537.6 ± 20.9^{ab}	545.0 ± 24.0^{a}	541.1 ± 26.4^{a}	532.2 ± 27.1

C, chisel plowing; CH, chisel plowing, combine harrowing; CD, chisel plowing, disc harrowing.

*±Standard deviation.

[a]Treatments means followed by the same upper case letters in the same column do not differ at the 0.05 level of probability.

[a]Year means followed by the same upper case letters in the same column do not differ at the 0.01 level of probability.

[a]Macroaggregate means followed by the same upper case letters in the same line or column do not differ at the 0.01 level of probability.

[a]Within years means followed by the same lower case letters in the same line or column do not differ at the 0.01% level of probability.

The differences in the mean extractable potassium content among size fractions of macroaggregates were clear. The gradual increases from large aggregates to small aggregates in the mean extractable potassium contents of macroaggregates can be explained by more degraded organic matter in small aggregates than that in large aggregates and by high adsorption capacity of the finer fractions. The results for the mean extractable potassium were in accordance with the data of mean organic carbon. The decline in organic carbon was the highest while the decline for extractable potassium was the lowest, when changes in the mean organic carbon and extractable potassium contents for 2–1 mm and 1–0.5 mm aggregate size fractions from 2003 to 2004 year were considered (Table-2). These aggregate size fractions includes particles which have the size of very coarse sand and coarse sand. Therefore, these results can be attributed to abundance of individual sand particles in these fraction groups. Angers *et al.*[17] also reported that the largest quantities of organic carbon were found in the silt size fraction followed by the clay and sand size fractions.

Our hypothesis cannot be verified on the basis of these results. The interaction effect of tillage × aggregate size fractions was also not significant. The reason of this status could be associated with several factors including low organic carbon and an overall initial weak soil structure of experimental soil that have xeric-soil moisture regime[11]. Consequently, organic carbon and extractable potassium contents of macroaggregate size fractions would not fully show the differences among tillage treatments under dry conditions. Under dry conditions, however, transition time for differences regarding C treatment might be longer than four years. Therefore, the changes in soil properties at long term can provide feasibility of reduced tillage systems.

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