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EFFECT OF ORGANIC AMENDMENTS ON DISTRIBUTION, STABILITY AND CARBON CONCENTRATION OF SOIL AGGREGATES

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The behavior of different organic manures may vary in soil because of their compositional differences. The basic objective of this study was to examine the fundamental characteristics of the traditional organic manures and their direct effect upon aggregate formation and stability. The organic manures i.e. municipal solid waste compost, farmyard manure and poultry litter were characterized on the basis of total organic carbon, total polysaccharides, microbial biomass carbon, humic and fulvic acid content. A two years field trial was executed by applying each of these manures at four levels i.e. 0, 0.25, 0.50 and 1% of soil organic carbon in a randomized complete block design. Poultry litter dominated in the carbonaceous compounds in its composition and under field conditions its application at 0.25% level significantly enhanced the macro aggregate formation (2-4 and 1-2 mm) which reflected in mean weight diameter (MWD) as 1.48 mm and effective sizes at D10, D30 and D60 (0.0261, 0.099 and 0.732 mm, respectively). The application of MSW compost at 0.25% level significantly improved the MWD of wet aggregates (5.5 mm) and carbon concentration of macro aggregates (2-4, 1-2 and 0.5-1 mm).
Keywords: Aggregate size distribution, aggregate stability, carbon sequestration, organic manures, carbonaceous compounds.

INTRODUCTION

A good soil structure is indicated by the abundance of soil aggregates which has an important role in sustainable agricultural management and soil productivity. As it affects hydraulic conductivity, gases transport within the soil and seed germination, root respiration and eventually plant growth. The different sized fractions of soil aggregates are influenced significantly by both the amount and the composition of organic matter present in the soil (Piccolo, 1996). The degree of soil aggregation and aggregate stability is the result of the interaction between organic and inorganic soil components.

Soil structure degradation occurs mostly due to the decrease in soil organic carbon caused by excessive soil cultivation and soil erosion (Wu *et al*., 2014). Eroded soils have consistently shown lower soil organic carbon and nutrient concentrations in upper profiles than cultivated soils, this is also true for other physical properties such as soil texture and saturated hydraulic conductivity (Heckrath *et al*., 2005).

Soil organic carbon (SOC), includes soil organisms (e.g. microbial biomass), simple organic compounds (e.g. polysaccharides), large and complex humic substances, as well as relatively fresh residue at various stages of decomposition (Weil and Magdoff, 2004). The effect of different composted and un composted products on soil aggregate stability across time scales vary from weeks, months to years after the incorporation (Monnier, 1965). The various components of organic carbon such as microbial biomass carbon, polysaccharides and humic substances play very important role in the aggregate formation mechanism. The polysaccharides are highly complex polymers, consisting of many structural units, and are naturally resistant to decomposition or become resistant through reaction with other soil constituents and serve as binding agents. Microbial biomass carbon is an active form of carbon and it influences aggregate formation and stability. Humic substances account for the largest and most decomposed proportion of soil organic matter (SOM) with chemically complex and ill-defined structure, and act as persistent binding agent for stabilization of aggregates. Stabilization of aggregates by organic matter (Six *et al.*, 2004) and interactions between aggregative factors and aggregate structures is well documented. In most studies, the organic matter additions were characterized by their elemental composition but additional information such as contents of humic and non-humic substances were seldom provided.

In this study we hypothesized that addition of organic sources on equivalent carbon level basis affect the soil aggregate formation differently as composition of materials vary. The objectives of the present study were, to examine the quality (fundamental characteristics) of the traditional organic manures and their direct effect upon formation, stability and carbon contents of different aggregate size fractions (macro and micro) till two years after application.

MATERIALS AND METHODS

***Field experiment*:** The study was carried out under field conditions in dry land fallow-wheat rotation for two years (2012-13) at Research Farm of Arid Agriculture University, Rawalpindi. The characteristics of experimental soil are given in Table 1. Three organic amendments i.e. municipal solid waste compost (MSWC), farmyard manure (FYM) and poultry litter (PL) each at four levels i.e. 0, 0.25, 0.50 and 1% of soil organic carbon were applied in a randomized complete block design with four replications (Table 2). The plot size was 25 m^2. The three levels of each organic material were added to soil during fallow period of first experimental year on the basis of their organic carbon content (Table 2). Wheat crop (cv. Chakwal 50) was sown as a test crop each year during November, and seed rate of 150 kg ha^{-1}, urea and diamonium phosphate (DAP) as sources of N and P, respectively were applied.

Table 1. Characteristics of the experimental soils.

Characteristics	Values
Texture	Silty Clay loam
Sand (%)	19
Silt (%)	55
Clay (%)	26
EC (dS m^{-1})	0.31
Soil pH	7.7
Bulk Density (Mg m^{-3})	1.40
Total Organic Carbon (g $100g^{-1}$)	0.60

Table 2. Details of the application of varying levels of different organic amendments.

Levels of SOC (%)	MSW Compost	Farmyard Manure	Poultry Litter
	t ha^{-1}		
0	0	0	0
0.25	62	50	30
0.5	124	100	60
1.0	248	200	120

***Characteristics of the manures*:** The poultry litter had higher contents of almost all types of humic and non-humic substances as compared to other manures (Table 3). But due to the heterogeneity in the transformation rates of different compounds within manures, it is quite impossible to predict the best source suitable for the rehabilitation of structurally degraded soils. But on the basis of the initial status of the manures, it is evident that poultry litter and MSW compost had higher contents of stable forms of carbon such as humic and fulvic acids.

***Analyses of manures*:** Total organic carbon (TOC) in organic amendments was measured by wet digestion method (Nelson and Somers, 1982) with a little modification of reducing the sample weight to 0.25 g instead of 1 g, due to high amount of carbon present in the manure samples. Total polysaccharide contents (TPC) were extracted from 1g of manure samples by adding 20 mL distilled water, keeping at 80°C for 24 hours and then centrifugation at ambient temperature for 25 minutes. The TPC contents of the supernatant were measured colorimetrically (Dubois, 1956). Microbial biomass carbon (MBC) was estimated by the fumigation extraction method using a 0.025 M solution of K_2SO_4 (Vance *et al.*, 1987). Organic carbon fractions were measured by extracting humic acid and fulvic acid with NaOH and HCl. The concentration of these fractions was estimated colorimetrically against carbon standards (Swift, 1996).

Table 3. Concentration of different humic and non-humic substances in the manures.

Manures	Farmyard manure	Municipal solid waste compost	Poultry litter
Humic acid (g kg^{-1})	8.67	14.08	14.97
Fulvic acid (g kg^{-1})	9.96	4.90	25.22
Total polysaccharides (mg kg^{-1})	1.58	2.06	3.28
Total organic carbon (g kg^{-1})	100.70	80.60	158.60
Microbial biomass carbon (g kg^{-1})	1.71	3.07	37.20

***Soil analyses*:** The textural analysis of soil was carried out using hydrometer method (Gee and Bauder, 1986). Bulk density was measured using the core sampler (Blake and Hartge, 1986). Soil moisture content was measured gravimetrically (Gardner *et al*., 1991). Aggregate size distribution was determined by sieving 750 g of soil through sieves of 8, 4, 2, 1, 0.5, 0.25 and 0.05 mm sizes for 5 minutes (Chepil, 1962) using the sieve shaker (Octagon D200, Endecotts Limited, London). Aggregate stability was determined by wet sieving of each aggregate fraction obtained from dry sieving in wet sieving apparatus (Eijkelkamp Agrisearch Equipment, The Netherlands). Each aggregate fraction was sieved against water through their respective sieves of 4, 2, 1, 0.5, 0.25 and 0.05 mm for 3 minutes. Aggregate stability percentage was calculated by Kemper's aggregate stability formula (Kemper and Koch, 1966).

(1)

The carbon contents of the different aggregate size fractions after wet sieving and bulk soil was determined by wet digestion method (Walkley, 1947).

***Statistical analysis*:** Mean weight diameters of the separated dry and wet aggregates were calculated by using the equation:

(2)

Where, n is the number of size fractions, d_i is the mean diameter of each size range and w_i is the weight of aggregates in that size range.

Data collected was subjected to two-way analysis of variance (ANOVA) using Randomized Complete Block Design (RCBD) taking levels and manures as factors. The means were separated by Least Significant Difference (LSD) test at 5% level of significance (Steel *et al*., 1997).

RESULTS

***Aggregate size distribution*:** The distribution of different aggregate size classes by the varying levels of different amendments remained non-significant in the first year (2012) of application, but revealed significant differences after second year of the experiment (Table 4). The results of second year (2013) showed that the application of poultry litter at 0.25% SOC level, significantly enhanced the formation of macro aggregates (2-4 mm and 1-2 mm), while the application of farmyard manure at 1% SOC level, improved the formation of 1-2 mm and 0.5-1 mm aggregates with valuable significance. Both of these treatments enhanced the formation of 0.25-0.5 mm aggregates. While, the abundance of micro aggregates (0.05 - 0.25 mm) was found at highest point with the application of MSW compost at 0.25% SOC level. Therefore, these results clearly suggest that the application of farmyard manure (1% SOC) and poultry litter (0.25% SOC) significantly improved the formation of macro aggregates.

The effect of treatments on mean weight diameter (MWD) showed that the application of farmyard manure and poultry litter at 0.25% levels significantly improved the MWD of dry aggregates (1.48 mm) as compared to the control (Table 4). Mean weight diameter values were calculated on the basis of dry aggregate size distribution, so this parameter clearly reflects the overall soil structure development as affected by different amendments.

The data for aggregate size distribution from organic amendments treated plots obtained as described above, are expressed in the form of logarithmic normal distributions as illustrated in Figure 1. A family of three graphs each for both

Table 4. Variation of dry aggregate size distribution as affected by varying levels of the different organic manures.

Aggregate size fractions	4 - 8		2 - 4		1 - 2		0.5 - 1		0.25 - 0.5		0.05 - 0.25		MWD	
	--------------mm--------------													
Treatments	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**
Control	8.5	11.3	9.8	8.1 ^{bc}	7.2	9.5 ^{cd}	10.5	8.2 ^{bc}	16.9	12.4 ^{ab}	27.5	25.1 ^{abc}	1.09	1.20 ^{bcd}
MSWC$^{0.25\% SOC}$	9.6	10.6	9.3	7.4 ^{c}	6.6	8.6 ^{d}	9.6	7.8 ^{cd}	14.8	11.5 ^{abc}	23.8	27.9 ^{a}	1.11	1.12 ^{cd}
MSWC$^{0.5\% SOC}$	10.8	12.2	10.7	9.3 ^{ab}	7.7	10.5 ^{b}	10.7	8.0 ^{cd}	16.6	11.1 ^{bcd}	21.4	24.3 ^{bcd}	1.25	1.30 ^{abc}
MSWC$^{1\% SOC}$	9.0	10.1	9.7	5.9 ^{d}	7.0	7.4 ^{e}	10.0	6.5 ^{e}	15.3	9.9 ^{de}	22.4	27.5 ^{ab}	1.09	1.01 ^{d}
FYM$^{0.25\% SOC}$	9.0	15.9	9.5	8.8 ^{ab}	6.7	9.8 ^{bc}	9.6	7.5 ^{cde}	16.3	9.4 ^{e}	22.4	17.9 ^{f}	1.08	1.48 ^{a}
FYM$^{0.5\% SOC}$	10.2	13.4	10.0	9.0 ^{ab}	6.6	9.3 ^{cd}	9.1	6.9 ^{de}	14.0	10.5 ^{cde}	20.8	21.3 ^{de}	1.16	1.33 ^{ab}
FYM$^{1\% SOC}$	11.7	12.4	11.2	9.2 ^{ab}	7.3	12.0 ^{a}	9.8	9.8 ^{a}	12.9	12.5 ^{a}	16.1	22.5 ^{cd}	1.29	1.35 ^{ab}
PL$^{0.25\% SOC}$	10.9	14.5	10.4	9.4 ^{a}	7.4	12.0 ^{a}	10.7	9.4 ^{ab}	14.7	12.5 ^{a}	13.2	21.4 ^{de}	1.22	1.48 ^{a}
PL$^{0.5\% SOC}$	12.4	14.1	11.5	7.5 ^{c}	7.5	9.2 ^{cd}	10.9	7.1 ^{cde}	14.3	9.2 ^{e}	14.5	18.7 ^{e}	1.35	1.32 ^{ab}
PL$^{1\% SOC}$	12.4	13.6	11.4	8.5 ^{abc}	7.3	10.5 ^{b}	9.9	7.5 ^{cde}	13.8	11.3 $^{a-d}$	16.1	22.1 ^{cde}	1.34	1.36 ^{ab}
ANOVA	NS	NS	NS	S	NS	S	NS	S	NS	S	NS	S	NS	S

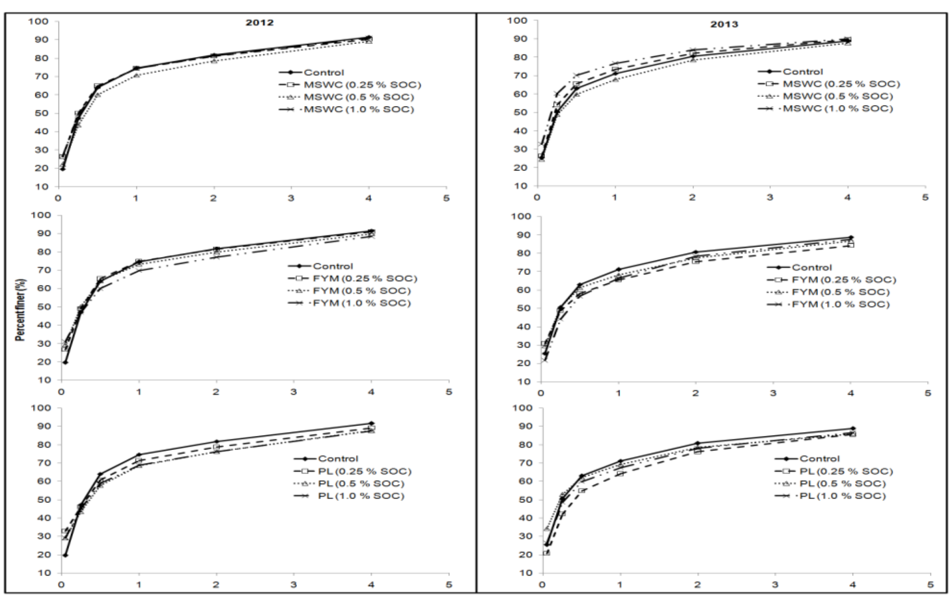

Figure 1. Log-normal distribution of aggregate size distribution data obtained from the application of varying levels of different organic amendments in 2012 (Left) and 2013 (Right).

experimental years (left and right) is shown which represents the changes in aggregate structure due to the varying levels of different organic materials. The logarithmic models derived from these plots were used to compute the effective size at different values of percent finer (Table 5). These effective sizes actually presented the cut marks below which the finer aggregates (%) lies. The effective size or diameter of soil aggregates at 10% (D10), 30% (D 30) and 60% (D 60) suggest that the application of poultry litter at 0.25% SOC level performed significantly better with the values of 0.0261, 0.099 and 0.732 mm, respectively.

***Aggregate stability*:** Every aggregate size class showed improvement with different manures and their levels in both years (Table 6). In 2012, the application of poultry litter and MSW compost at 1 % level has significantly improved the aggregate stability of 4-8 mm and 2-4 mm, respectively. The aggregates sized 1-2 mm, were significantly stabilized by the application of poultry litter at 0.5% level, while farmyard manure application at 0.25% and 0.5% levels has significantly improved the stability of 0.5-1 and 0.25-0.5 mm aggregates, respectively. The stability of 0.05-0.25 mm aggregates (micro aggregates) was non-significant. Whereas, in 2013, the application of MSW compost at 0.25%, 1% and 0.5% levels improved the stability of 4-8 mm, 2-4 mm and 1-2 mm (macro aggregates), respectively. The 0.5-1 mm aggregates were also stabilized at significant levels with the application of MSW compost at 1% level. Most of the macro aggregate classes (2-4 mm and 0.5-1 mm) improved their stability significantly by the application of MSW compost at 1% level in second year of application. Therefore, it can be deduced that different levels of MSW compost significantly enhanced macro aggregate (4-8 mm, 2-4 mm and 0.5-1 mm) stability. Similarly, the application of MSW compost at 0.25 % level significantly improved the MWD of wet aggregates (5.5 mm) as compared to the control in the second year (2013) after application.

***Distribution of carbon within soil aggregates and bulk soil*:** The application of farmyard manure (0.5% SOC level) improved the carbon content within 4 - 8 mm aggregate size class in both years (Table 7). The application of 0.25% and 0.5% levels of MSW compost significantly enhanced the carbon concentration within 2-4 mm aggregates in 2012 and

Table 5. Variation in the effective sizes of percent finer as affected by the varying levels of different organic manures.

Treatments	D 60	D 30	D 10
	---------------mm---------------		
Control	0.502^{cd}	0.062^{d}	0.0156^{bc}
MSWC (0.25% SOC)	0.424^{d}	0.053^{e}	0.0132^{d}
MSWC (0.5% SOC)	0.556^{bc}	0.069^{c}	0.0172^{b}
MSWC (1% SOC)	0.304^{e}	0.030^{e}	0.0064^{f}
FYM (0.25% SOC)	0.588^{bc}	0.050^{e}	0.0098^{e}
FYM (0.5% SOC)	0.508^{cd}	0.050^{e}	0.0107^{e}
FYM (1% SOC)	0.644^{ab}	0.091^{b}	0.0245^{a}
PL (0.25% SOC)	0.732^{a}	0.099^{a}	0.0261^{a}
PL (0.5% SOC)	0.443^{d}	0.035^{f}	0.0065^{f}
PL (1% SOC)	0.562^{bc}	0.063^{cd}	0.0148^{cd}

Table 6. Variation of aggregate stability of various fractions and their MWD as affected by varying levels of the different organic manures.

Aggregate size fractions	4 - 8		2 - 4		1 - 2		0.5 - 1		0.25 - 0.5		0.05 - 0.25		MWD	
	--------------mm--------------													
Treatments	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**
Control	24.7^{f}	26.8^{bcd}	12.8^{d}	13.3^{d}	16.1^{d}	17.0^{c}	48.7^{e}	43.2^{b}	35.0^{d}	52.0^{b}	42.3	62.2^{cd}	2.6	2.85^{c}
$MSWC^{0.25\% SOC}$	63.9^{ab}	58.9^{a}	24.7^{bcd}	42.8^{a}	23.2^{cd}	15.1^{c}	54.1^{cd}	12.9^{e}	44.0^{cd}	67.5^{a}	50.0	75.8^{ab}	5.5	5.48^{a}
$MSWC^{0.5\% SOC}$	59.8^{bc}	13.9^{d}	18.6^{cd}	35.7^{b}	26.1^{c}	40.3^{a}	52.7^{de}	39.0^{bc}	52.1^{bc}	43.3^{c}	62.3	78.0^{a}	5.2	3.06^{bc}
$MSWC^{1\% SOC}$	66.2^{ab}	22.5^{bcd}	43.4^{a}	46.8^{a}	36.0^{b}	27.8^{b}	51.0^{de}	68.6^{a}	52.7^{bc}	55.4^{b}	63.8	78.7^{a}	6.5	3.98^{abc}
$FYM^{0.25\% SOC}$	39.2^{e}	19.5^{cd}	28.3^{a-d}	18.9^{c}	20.3^{cd}	19.1^{c}	66.4^{a}	36.5^{bc}	53.9^{b}	26.0^{ef}	65.0	56.5^{d}	4.3	2.47^{c}
$FYM^{0.5\% SOC}$	52.3^{cd}	52.1^{ab}	37.9^{ab}	21.8^{c}	25.9^{c}	16.8^{c}	59.0^{bc}	15.5^{e}	67.3^{a}	33.8^{de}	64.2	69.2^{bc}	5.4	4.36^{abc}
$FYM^{1\% SOC}$	59.4^{bc}	17.9^{cd}	20.1^{cd}	23.5^{c}	26.1^{c}	16.9^{c}	48.3^{e}	23.5^{de}	54.3^{b}	37.7^{cd}	79.2	80.8^{a}	5.2	2.45^{c}
$PL^{0.25\% SOC}$	44.8^{de}	20.6^{cd}	32.6^{abc}	18.6^{c}	34.4^{b}	12.7^{c}	54.3^{bcd}	30.0^{cd}	57.7^{b}	73.9^{a}	70.3	65.8^{c}	4.9	2.55^{c}
$PL^{0.5\% SOC}$	49.9^{cde}	48.0^{abc}	19.8^{cd}	34.4^{b}	45.7^{a}	37.9^{a}	54.5^{bcd}	29.1^{cd}	35.2^{d}	22.3^{f}	79.8	65.7^{c}	4.9	4.87^{ab}
$PL^{1\% SOC}$	75.5^{a}	19.9^{cd}	30.2^{abc}	19.5^{c}	40.7^{ab}	19.0^{c}	59.1^{b}	22.4^{de}	54.5^{b}	74.5^{a}	64.8	78.2^{a}	6.8	2.59^{c}
ANOVA	S	S	S	S	S	S	S	S	S	S	NS	S	NS	S

Table 7. Variation of carbon contents of different aggregate size fractions and bulk soil as affected by varying levels of the different organic manures.

Aggregate size fractions	4 - 8		2 - 4		1 - 2		0.5 - 1		0.25 - 0.5		0.05 - 0.25		SOC	
	--------------g $100g^{-1}$--------------													
Treatments	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**	**2012**	**2013**
Control	3.61^{f}	2.9^{e}	5.2^{h}	4.5^{h}	3.6^{g}	4.7^{f}	5.8^{j}	6.5^{g}	5.9^{f}	14.4^{e}	9.6^{f}	18.3^{e}	6.4	7.5
$MSWC^{0.25\%\ SOC}$	16.7^{bc}	15.2^{bc}	26.3^{a}	24.0^{a}	14.3^{b}	11.4^{b}	54.2^{a}	10.7^{e}	11.3^{e}	21.3^{c}	13.8^{e}	25.3^{b}	7.1	8.0
$MSWC^{0.5\%\ SOC}$	17.3^{b}	16.1^{b}	24.4^{a}	25.1^{a}	15.3^{a}	11.1^{b}	33.1^{b}	26.7^{b}	14.1^{d}	10.5^{f}	19.5^{d}	26.4^{ab}	14.0	10.7
$MSWC^{1\%\ SOC}$	15.5^{d}	15.4^{bc}	11.4^{g}	12.6^{g}	10.4^{cd}	8.5^{d}	31.8^{c}	33.8^{a}	15.2^{c}	15.3^{de}	19.3^{d}	25.8^{b}	9.9	9.1
$FYM^{0.25\%\ SOC}$	16.1^{cd}	14.9^{c}	18.7^{cd}	18.2^{cd}	9.6^{d}	7.9^{de}	11.1^{i}	10.5^{e}	14.8^{cd}	8.5^{g}	20.6^{c}	16.2^{f}	12.3	10.0
$FYM^{0.5\%\ SOC}$	19.2^{a}	18.6^{a}	21.8^{b}	22.1^{b}	10.4^{cd}	10.5^{bc}	19.3^{f}	10.1^{ef}	21.3^{a}	11.2^{f}	19.6^{d}	22.1^{c}	10.0	8.9
$FYM^{1\%\ SOC}$	11.9^{e}	13.1^{d}	17.5^{de}	16.6^{de}	7.5^{e}	8.5^{d}	17.7^{g}	9.5^{f}	15.3^{c}	7.5^{h}	26.8^{a}	27.5^{a}	8.5	7.0
$PL^{0.25\%\ SOC}$	15.5^{d}	15.5^{bc}	14.6^{f}	14.9^{f}	6.4^{f}	7.2^{e}	22.4^{d}	14.5^{c}	16.8^{b}	24.1^{b}	22.8^{b}	20.4^{d}	9.4	7.7
$PL^{0.5\%\ SOC}$	16.8^{bc}	15.3^{bc}	20.3^{bc}	19.4^{c}	11.3^{c}	12.5^{a}	20.6^{e}	14.4^{c}	6.8^{f}	15.5^{d}	27.4^{a}	20.1^{d}	9.4	8.3
$PL^{1\%\ SOC}$	16.3^{cd}	15.6^{bc}	16.3^{ef}	15.2^{ef}	10.6^{cd}	10.0^{c}	16.5^{h}	11.7^{d}	15.1^{c}	25.2^{a}	20.6^{c}	26.1^{b}	9.7	8.1
ANOVA	S	S	S	S	S	S	S	S	S	S	S	S	NS	NS

2013 respectively. The organic amendments i.e. MSW compost and poultry litter at the rate of 0.5% level enhanced the carbon content of 1-2 mm aggregates in 2012 and 2013 respectively. In case of 0.5-1 mm sized aggregates, the MSW compost applied at 0.25% and 1% levels increased carbon content significantly in 2012 and 2013, respectively. The application of farmyard manure (0.5% SOC level) and poultry litter (1% SOC level) improved the carbon content within 0.25-0.5 mm aggregate size class in 2012 and 2013, respectively. The poultry litter (0.5% SOC level) and farmyard manure (1% SOC level) application increased carbon contents in micro aggregates (0.05-0.25 mm) significantly in 2012 and 2013, respectively. The soil organic carbon (SOC) was found non-significant in bulk soil samples in both experimental years.

DISCUSSION

It is clearly evident that the poultry litter at 0.25% level application amendment has significantly improved the dry macro aggregate formation, hence improved the soil structure. MSW compost treatments enhanced the formation of micro aggregates but failed to improve the macro aggregation, over two years. Poultry litter has shown the improvement regarding macro aggregate formation which is also reflected in a valuable improvement in MWD and effective sizes. The abundance of different fractions for aggregate formation were enhanced by the application of different organic amendments, which depicts that compositional differences of the manures are playing an effective role in the formation of dry aggregates. All of the three manures were applied on equivalent dose basis with respect to their organic carbon contents. But the variation in results clearly suggest that the organic carbon is not the only driving force for the formation of aggregates but it is the carbonaceous binding agents which act differently in soil. Poultry litter had higher concentration of different carbonaceous compounds relative to other manures (Table 3). Poultry litter had higher microbial biomass carbon and polysaccharide contents which might have increased the microbial activity when applied in soil, and such conditions favors aggregate formation (Six *et al*., 2004). Active carbon fractions like microbial biomass carbon and polysaccharides are more sensitive to the changes in soil quality as compared to whole soil organic matter (Allison *et al*., 2008; Haider *et al*., 2015). It could be the reason that during the two years of field trial, poultry litter performed better as compared to other manures in improving the aggregate formation, and eventually enhancing mean weight diameter (MWD). Organic material addition improves the relative abundance of macro aggregates at the expense of other fractions and also results in higher C in macro aggregate fractions (Das *et al*., 2014). The relationship between mean weight diameters and soil organic matter levels also showed a positive correlation (Sardo *et al*., 2013) because organic matter plays the fundamental role in processing soil particles to form aggregates (Schjonning *et al*., 2012).

On the contrary, the MSW compost dominantly improved macro aggregate stability which is well correlated with soil organic matter content (Douglas and Goss, 1982). Aggregates larger than 0.25 mm diameter are considered as macro aggregates (Xiao *et al*., 2007). The proportion of water-stable macro aggregates (>1 mm) shows large temporal variation and additional organic matter accumulation in the surface soil provided by manure additions would have led to increased macro aggregation (Angers and Caron, 1998). The varying response by the applied organic sources strengthen the hypothesis that different forms of carbon particularly humic substances are more responsible for aggregate stability of varying fractions rather than total organic carbon.

The carbon distribution within different large sized aggregates was improved by the application of the mature manures as compared to the fresh material like poultry litter in first year of application. The macro aggregate classes (4-8 mm, 2-4 mm and 0.5-1 mm) and micro aggregates (0.05-0.25

mm) improved their carbon contents significantly by the application of farmyard manure and MSW compost (composted materials) at different levels in second year. And it shows that overall the application of mature products helped to retain the carbon contents for longer time as compared to poultry litter. It suggests that mature manures can play effective role in conserving the carbon within the soil aggregates.

The sequestration of carbon within soil aggregates is important for improvement in soil structural properties (Banger *et al*., 2009). The application of composted or un composted organic manures can improve soil aggregation and aggregate associated carbon (Rasool *et al*., 2008). Distribution of carbon within aggregates by manure application increases with the aggregate size (Bhattacharyya *et al*., 2009). Organic manures accumulate within macro aggregates in the form of particulate organic matter (Kong *et al*., 2005) which ensures the presence of stable carbon fractions for enhanced SOC buildup. However, in this case carbon accumulation in macro aggregates and in whole soil mainly depends on the organic carbon concentration in the aggregated silt + clay fractions as compared to the presence of stable or unstable particulate organic matter.

Compost and farmyard manure application significantly increased carbon concentration in soil macro aggregates at the expense of stable micro aggregates. Compost application improves carbon concentration in all aggregate size fractions of loamy sand and sandy loam soils (Liao *et al*., 2006). Silt and clay particles provide various sites for carbon of organic materials having high microbial activity and polysaccharide contents, which accumulate in aggregated silt + clay fractions (Jolivet *et al.*, 2006). Carbon concentration in the un-aggregated fraction may not be stable, and can be greatly affected by management practices. Carbon content in the micro aggregates (0.05-0.25 mm) is likely to play a key role in the formation of macro aggregates. As discussed above, aggregates in the different treatments had significantly improved associated carbon concentrations in the aggregated silt + clay fraction and micro aggregates.

***Conclusion*:** Aggregate formation and stability of different aggregate size fractions improved with the different sources of carbon which proves that soil structure improvement is dependent on the carbonaceous composition of organic sources which act as binding agents for soil particles. An increase in carbon contents of the smaller micro aggregates in the soils amended with mature organic materials like MSW compost and farmyard manure, leads to the formation of micro and macro aggregates. Therefore, the recommendations of organic materials for the rehabilitation of structurally degraded soils should be made after considering the humic and non - humic components of particular organic manure.

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