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Effect of integrated nutrient management modules on water stable aggregates and carbon distribution in aggregate size in *Vertisol* of central India

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Abstract
Soil aggregate and organic carbon (OC) are deemed as potent indicators of soil structure and quality. An investigation was carried out with maize crop in *kharif* season during 2015-2016 under long-term interagted nutrient management module and examine its approach on soil organic carbon and aggregation. The soil aggregate formation was separated using a wet sieving method. The large macro-aggregates varied from 3-10 % under different treatments whereas, about 72-82% of aggregate corresponded to small macro-aggregates (0.25–2 mm) followed by micro-aggregates which constituted about 12-17%. Application of organics increased the proportion of small macro-aggregates. The highest content was recorded in T_3, T_4, T_{11} and T_{12}. This is because soil organic matter has been recognized as binding agent of soil particles for the formation of water stable aggregates. It was observed that there was improvement in the percentage of water stable aggregates (>250 mm) due to integrated use of recommended dose of NPK and farmyard manure (FYM). However, the effect was not statistically significant. In general large macro-aggregates contained higher concentration of soil organic carbon than other size fractions. Highest concentration of C (0.79%) in large aggregate size class was recorded in treatment T_{11} where FYM was applied every season. Similarly, application of 5 t of FYM in T_5 along with chemical fertilizer also recorded higher soil carbon concentration. The similar trend was recorded in T_9 and T_{10} also where poultry manure and FYM was applied along with other organic sources of nutrients.

Keywords: soil organic carbon, soil aggregates, integrated nutrient management

Introduction
The effect of manures and fertilizers on crop growth and the soil properties has been studied mostly separately; there is very meager information on a holistic study on the effect of integrated use of chemical fertilizers and farmyard manure on crop growth and soil properties. Here, an attempt has been made to collect information on impact of different INM module on soil and crop productivity. *Vertisols*, which constitutes about 21.4% of the total geographical area of the country, contributes about 12.5% of the total soil organic carbon stock of India (NBSS and LUP, 1988) [16]. The main soil related production constraints in *Vertisols* is attributed to its poor physical properties including formation of wide and deep cracks, high bulk density, low hydraulic narrow range of moisture for field operation. The low content of soil organic carbon in *Vertisols* is one of the major reasons for the deterioration of soil health resulting in low and unsustainable productivity of soybean in this soil. The influence of organic matter on soil biological and physical fertility is well known. Organic matter affects crop growth and yield either directly by supplying nutrients or indirectly by modifying soil physical properties such as stability of aggregates and porosity that can improve the root environment and stimulate plant growth (Darwish *et al*., 1995, Mandal *et al*., 2006; Bandyopadhya *et al*., 2010) [7, 15, 3].
Incorporation of organic matter either in the form of crop residues or farmyard manures has been shown to improve soil structure and water retention capacity (Bhagat and Verma, 1991) [6], increase infiltration rates (Acharya *et al*., 1988) [1], and decrease bulk density (Khaleel *et al*., 1981) [12]. Therefore, any nutrient management practice that can improve organic matter status of soil is important. Neither inorganic nor organic amendments alone can maintain organic matter status of soil and sustain the productivity in the semi-arid tropics (Prasad, 1996) [18]. A judicious and combined use of organic and inorganic sources of nutrients is essential to maintain soil health and to augment the efficiency of nutrients (Lian, 1994) [13].

In long-term fertility experiments in India, decline in soil organic matter is generally implicated as one of the causes for yield stagnation, particularly where N is the only fertilizer, irrespective of cropping system and soil type (Swarup *et al*., 2000) [21]. This eventually leads to deterioration of soil aggregation and net release of carbon from agricultural field to atmosphere. Carbon is a measureable component of soil organic matter. About 58% of the mass of organic matter exists as carbon. Increasing soil organic carbon (SOC) can improve soil health and can help to mitigate climate change. An appropriate management strategy *i.e*., integrated nutrient management system for carbon sequestration can improve soil productivity and crop production as well as help to reduce the atmospheric build-up of carbon dioxide (CO_2). It will also help in the formation of stable soil aggregates and improving the structure, aeration, tilth, moisture-holding capacity and cation exchange capacity of the soil.

Materials and Methods

The details of treatment are given in table 1. Twelve treatment combinations were tested in randomized block design with three replications. The experiment was conducted at ICAR-Indian Institute of Soil Science, Bhopal. The ongoing long-term INM experiment was utilized for fulfilling the objectives of this investigation it was carried out with maize crop in *kharif* season during 2015-2016. The soil samples were collected from 0-15 cm of soil depth and separated into different aggregate-size classes: large macro-aggregate (>2000 µm), small macro-aggregates (2000-250 µm), micro-aggregates (250-53 µm) and silt-plus-clay fraction (<53 µm). The soil aggregate formation was separated using a wet sieving method adapted from Elliott (1986) [8]. An 100-g sub-sample of 4-mm sieved and air dried soil was immersed in water for 5 min on top of a 2000 µm sieve for slaking. Water stable aggregates were isolated manually by moving the sieve up and down 3 cm for 50 times in 2 minute. Aggregate fractions were then transferred to aluminium pans dried in an oven at 50^{o}C for weighing.

Soil Organic carbon (SOC) was estimated by Walkley and Black's (1934) [23] rapid titration method as described by Jackson (1967) [10]. In this method, organic matter is oxidized with chromic acid (potassium dichromate + sulphuric acid). The unconsumed potassium dichromate is back titrated against ferrous sulphate or ferrous ammonium sulphate.

Table 1: Details of treatment

Sl. No.	Maize
T1.Control	No Fertilizer/ Manure
T2.GRD	120- 60- 30
T3. RD dose (STCR)	135-55-50(Target- 5 t maize)
T4.	75% NPK of T3
T5.	75% NPK of T3 +5 t FYM
T6.	75% NPK of T3+ 1 t PM
T7.	75%NPK of T3 + 5 t UC
T8.	75% NPK of T3 +MR
T9.	MR +1 t PM + Gly 2 t/ha
T10.	MR + 5t FYM + Gly. 2 t/ha
T11.	20 t FYM (every season)
T12.	75% NPK of T3 +20 t FYM (once in 4 years)
Year of start	2002/2012
Duration :	Long-term
Expt. Design	R.B.D
Plot Size	20x5 m
No. of Replications	3

Result and Discussion

Water stable aggregates

Soil organic matter accumulation and storage are strongly related to soil aggregation and facilitated by the formation and stabilization of micro-aggregates and macro-aggregates. Aggregate size distribution, in 0-15 cm of soil depth is shown in Table 2 (sand free aggregate size class). Large macro-aggregates varied from 3-10 % about 72-82% of aggregate corresponded to small macro-aggregates (0.25–2 mm). This finding supports the hypothesis that annual addition of manure favoured the formation of macro-aggregates (Sun *et al*., 1995) [20]. Oades (1984) [17] reported that organic matter increased the stability of macro-aggregates through the binding of the soil mineral particles by polysaccharides. This was followed by micro-aggregates which constitutes about 12-17%. Application of organics increased the proportion of small macro-aggregates. The highest content was recorded in T_3, T_4, T_{11} and T_{12}. This is because soil organic matter has long been recognized as playing an important role in the formation of water stable aggregates as binding agent of soil particles (Tisdall and Oades, 1982) [22]. The organic matter stabilizes the aggregates by forming and strengthening bonds among clay domains and between quartz particles and clay domains (Emerson, 1977) [9]. The proportion of large macro-aggregates is the most important fraction to evaluate the effect of management practices on soil aggregation, because it exerts a strong influence on the mean weight diameter, a comprehensive index for evaluating soil aggregation (Jiao *et al*., 2006; Razafimbelo *et al*., 2008) [11, 19]. Majumdar *et al*. (2010) [14] also reported that long-term fertilization mainly contributes to the formation of small macro-aggregates. It was observed that there was improvement in the percentage of water stable aggregates (>250 mm) due to integrated use of recommended dose of NPK and farmyard manure (FYM). However, the effect was not statistically significant. This finding is in agreement Benbi *et al*. (1998) [5]. Acharya *et al.* (1988) [2] also reported beneficial effect of the long-term application of balanced rates of chemical fertilizers alone or in combination with organic manures on the improvement of aggregation in *Alfisols*.

Table 2: Effect of different treatment combinations on soil water stable aggregates (%) in 0-15 cm of soil depth.

Treatment	Large macro-aggregate (> 2mm)	Small Macro-aggregate (2-0.25 mm)	Micro-aggregate (0.25-0.053mm)	Silt +Clay (<0.053 mm)
T_1	3.59	68.02	14.44	2.95
T_2	4.66	75.62	16.48	3.24
T_3	3.67	81.37	11.04	3.92
T_4	4.18	78.35	14.10	3.37
T_5	10.38	71.07	13.74	4.80
T_6	5.75	77.13	14.37	2.76
T_7	10.08	71.81	15.37	2.74
T_8	5.88	75.88	14.39	3.85
T_9	8.12	74.55	13.10	4.23
T_{10}	9.47	72.57	15.14	2.82
T_{11}	7.46	78.15	13.97	3.43
T_{12}	5.72	78.56	11.71	4.01
CD	NS	NS	NS	NS

Carbon distribution in aggregate size class

Carbon content of different aggregate size fractions are shown in table 3. In general, large macro-aggregates contained higher concentration of soil organic carbon than other size fractions. Highest concentration of C (0.79%) in large aggregate size class was recorded in treatment T_{11} where FYM was applied every season. Similarly, application of 5 t of FYM in T_5 along with chemical fertilizer also recorded higher soil carbon concentration. The similar trend was recorded in T_9 and T_{10} also where poultry manure and FYM was applied along with other organic sources of nutrients. This clearly shows that application of organics in any form helps in build up of carbon in large macro-aggregate size class. Benbi and Senapati (2010) [4] also reported that continuous application of rice straw and farm-yard manure (FYM) either alone or in conjunction with inorganic fertilizers improved macro-aggregate associated C in rice-wheat cropping on a sandy loam soil after 7 years of cropping. They further reported that macro-aggregates had higher C and N concentration as compared to micro-aggregates.

Table 3: Effect of different treatment combinations on C concentration in different aggregate size class

Treatment	>2mm	> 0.25 mm	> 0.053 mm	<< 0.053 mm	Mean
T1	0.466	0.437	0.412	0.340	0.41
T2	0.478	0.451	0.426	0.385	0.44
T3	0.560	0.463	0.450	0.417	0.47
T4	0.473	0.450	0.428	0.391	0.44
T5	0.767	0.490	0.462	0.446	0.54
T6	0.583	0.474	0.458	0.365	0.47
T7	0.533	0.483	0.469	0.364	0.46
T8	0.533	0.457	0.430	0.370	0.45
T9	0.717	0.534	0.447	0.373	0.52
T10	0.723	0.501	0.470	0.353	0.51
T11	0.786	0.573	0.487	0.414	0.56
T12	0.512	0.494	0.460	0.340	0.45
CD (P=0.05)	NS	NS	NS	NS	NS

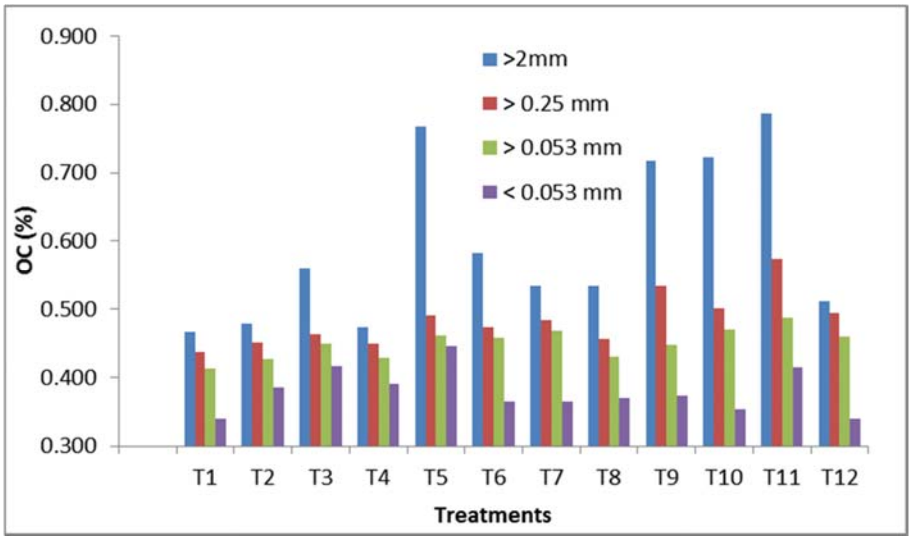

Fig 1: C distribution in aggregate size class

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