Journal of the Indian Society of Soil Science, Vol. 66, No. 4, pp 370-380 (2018)
DOI: 10.5958/0974-0228.2018.00046.4

Effect of Incubation Duration of Incorporated Organics on Saturated Hydraulic Conductivity, Aggregate Stability and Sorptivity of Alluvial and Red-Laterite Soils

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Improvement in soil hydro-physical properties is a pre-requisite for maintaining soil quality and sustaining agricultural productivity. The objective of this study was to see the effect of degree of decomposition of farmyard manure (FYM) and vermicompost on aggregation indices *viz*., water stable aggregate (WSA), mean weight diameter (MWD) and aggregate stability (AS), and water transmission properties namely, saturated hydraulic conductivity (Ks) and sorptivity (S) of two contrasting soils (red-laterite and alluvial soils). Soils were incubated with FYM and vermicompost @ 20 t ha^{-1} for 60 days at field capacity moisture content under laboratory condition and analyzed at 0, 20, 40 and 60 days of incubation (DOI) for hydro-physical and soil organic carbon (SOC) content. Results indicated that the influence of organics was more predominant in red-laterite soil having more iron and aluminium oxides and lower clay content than alluvial soil. Upon incubation, the organic treated red-laterite and alluvial soils increased 73 and 15 per cent SOC, 16 and 13 per cent micro-porosity, 119 and 412 per cent Ks, 25 and 19 per cent WSA, 45 and 11 per cent MWD and 31 and 26 per cent S, respectively. Similarly, vermicompost and FYM treated soils increased 44 and 43 per cent SOC, 17 and 11 per cent micro-porosity, 622 and 239 per cent Ks, 31 and 13 per cent WSA, 33 and 24 per cent MWD and 46 and 11 per cent S. Bulk density (BD) varied from 1.54 to 1.38 and 1.31 to 1.24 Mg m^{-3}, respectively for red-laterite and alluvial soils during the entire incubation period with a strong negative relationship (r = -0.97, $p< 0.001$) with micro-porosity. Strong positive correlations between WSA and SOC (r = 0.58, $p < 0.01$), MWD and SOC (r = 0.74, $p < 0.001$) and AS and SOC (r = 0.73, $p < 0.001$) were observed indicating that the AS would increase 3.8 per cent with the increase in SOC by 1% in both soils. Sorptivity was positively and significantly related to SOC (r = 0.55, $p<0.01$) and micro-porosity (r = 0.51, $p<0.01$), however, had a negative relationship with BD (r = -0.51, $p<0.01$). Vermicompost had shown better results in structural as well as hydro-physical properties as compared with FYM in both soils.

Key words: Farmyard manure, vermicompost, water stable aggregate, mean weight diameter, soil organic carbon, micro-porosity

Incorporation of organics like farmyard manure (FYM) or composts in agricultural soils is a common practice to add or sustain soil organic matter (SOM) content which on decomposition improves soil physical properties and helps in soil restoration (Smith *et al*. 1993; Aggelides and Londra 2000; Pagliai *et al*. 2004). Organic substances improve soil aggregation, reduce soil compaction and surface crusting, increase carbon sequestration and nutrient availability, and enhance infiltration and water holding capacity (Ohu *et al.* 2009). Addition of SOM increases aggregate cohesion through the bonding of mineral and soil particles by organic polymers or through the physical enmeshment of particles by fine roots or fungi, and reduces the wettability of individual aggregates, which in turn, reduces slaking pressures of aggregates subjected to rapid wetting (Tisdall and Oades 1982; Chenu *et al*. 2000; Zaher *et al*. 2005). However, the processes involving influence of SOM on intensity of soil aggregation process is not well understood.

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The products of SOM decomposition bind soil primary particles into aggregates physically and chemically, and this in turn, increases stability of the aggregates limiting their breakdown during wetting process (Le Bissonnais 1996). The overall aggregate stability in the soil is very dependent on stable microaggregates. It is important to the development of stable macroaggregates. In turn, the formation of macroaggregates is thought to play a major role in the development of the stable microaggregates as the macroaggregates provide an environment for the accumulation of the polysaccharides and humic materials to stabilise the microaggregates (Oades 1984). Hence, the processes and mechanisms of aggregate stability are complex (Angers and Carter 1996). The stability and hydraulic behaviour of a soil when exposed to disaggregating stresses depend on the strength of the cohesive forces holding the particles together and the magnitude of the net effect of disaggregation forces in operation. These are contingent on intrinsic soil factors such as SOM content, clay content and mineralogy, oxide content, and cationic composition (Barzegar *et al.* 1997; Wuddivira *et al.* 2006). There is a general trend for aggregate stability to increase with increasing levels of SOM (Carter 1992; Haynes 2000). The amount and type of SOM, the effects of the organic materials on plant growth, the nutrient levels of the organic materials and the type of soil has a large influence on the aggregate stability (Krull *et al*. 2004; Quilty and Cattle 2011).

Water movement in the soil is largely related to aggregate stability, the rate of movement being higher with higher aggregate stability (Wakindiki and Ben-Hur 2002). Lado *et al.* (2004) found that the saturated hydraulic conductivity (Ks) of the soil with high SOM content was higher than that with low SOM content and the difference in Ks between the two soils was explained to be due to the structural degradation. Organic matter or soil organic carbon (SOC) may also be responsible for the differences in repellency of soil aggregates and hence the sorptivity is reduced by water repellency. It may stabilize aggregates during fast wetting and increase wettability (opposite to repellency) of soil (Eynard *et al*. 2006; Raut *et al*. 2012). Organic matter, aggregate stability and water movement in the soils are therefore closely related. However, there is little evidence to show if the intensity of decomposition of SOM affects aggregate stability, sorptivity and Ks. The red-laterite and alluvial, two contrasting soils in respect of their mode of formation and mineralogy (Ghosh *et al*. 1974) are found in the humid tropics of eastern India. Owing to variable rainfall and multiple cropping throughout the year, the SOM poor soils are continuously subjected to the dispersal action of water. Building up of intra-aggregate pressure as a result of entrapped air during rapid wetting makes these soils vulnerable to erosion, compaction, crusting and other related problems. The major challenge in these soils is to achieve and maintain an open aggregated structure to ensure adequate water movement and infiltration, and sustain it under continued wetting and raindrop impact in rainy season as well as to check erosion. Though soil aggregate formation and stabilization are linked to SOM dynamics, very limited efforts were made to understand their interaction in these soils. We hypothesised that the intensity of decomposition of FYM and vermicompost in red-laterite and alluvial soils alters the Ks within a short time through incubation, by affecting the aggregate stability and alteration in porosity, depending on their soil texture. Therefore, the objective of this study was to determine the effect of degree of decomposition of incorporated FYM and vermicompost on aggregate stability, Ks and sorptivity of red-laterite and alluvial soils.

Materials and Methods

Site description and characteristics of soils and organics used

Soil samples were collected from the top soil layer (0-20 cm) of two soil orders from the agricultural farm fields namely, Alfisol in red-laterite soils at Sriniketan, West Bengal (23° N, 87° E) and Inceptisol in alluvial soils at Jaguli, West Bengal (22° N, 88° E). The two sites had contrasting soil forming processes (Ghosh *et al*. 1974) with different mineralogy and falls within the hot, humid subtropical region of eastern India. The experimental sites receive an average annual rainfall of approximately 1480 mm and experience mean annual minimum and maximum temperatures of 12.5 and 36.2 ºC, respectively. Rice–mustard-fallow and rice-wheat-fallow are the commonly practiced cropping system in red-laterite and alluvial soils, respectively. The soils of the two experimental sites were sandy loam (Vertic Ochraqualfs) and clay loam (Aeric Haplaquepts) of red-laterite and Gangetic alluvium origin, respectively. Detailed soil characteristics were determined at the initiation of the experiment and presented in table 1. It was observed that the red-laterite and alluvial soils were neutral in pH (6.9 and 7.2), non-saline (EC 0.41 dS m^{-1}), low to medium in SOC (5.7 and 6.7 g kg^{-1})

Table 1. Some physical and chemical characteristics of the studied soils and organics used

Parameter	Soil		Organics	
	Red-laterite	Alluvial	FYM	Vermicompost
Taxonomic name	Vertic Ochraqualfs	Aeric Haplaquepts		
Soil order	Alfisol	Inceptisol		
Sand (%)	69.7	39.7		
Silt (%)	13.0	31.0		
Clay (%)	17.3	29.3		
Textural class	Sandy loam	Clay loam		
Bulk density (Mg m^{-3})	1.53	1.32		
Saturated hyd. conductivity (cm h^{-1})	1.01	0.68		
Water holding capacity (%)	25.9	34.3		
Moisture content at θ_{fc} (cm^3 cm^{-3})	0.22	0.32	0.83	0.84
pH	6.88	7.16	6.86	6.54
ECe (dS m^{-1})	0.41	0.41	2.84	2.63
SOC (g kg^{-1})	24.8	50.7	33.42	24.4
Total N (%)	0.034	0.036	0.55	0.82
Free Fe and Al oxides (%)	3.65	1.08	0.23	0.16
Exch. Ca^{2+} [cmol(p^+)kg^{-1}]	10.4	14.1	4.32	3.16
Exch. Mg^{2+} [cmol(p^+)kg^{-1}]	2.54	12.0	1.11	1.20
C:N			60.8	29.7
Polyphenol (%)			1.13	1.19
Lignin (%)			17.6	23.5
Cellulose (%)			25.8	28.7

and total N (0.034 and 0.036%) with variable free Fe and Al oxides (3.65 and 0.88%) and exchangeable Ca^{2+} and Mg^{2+}. The chemical characteristics of the organics (FYM and vermicompost) were also depicted in table 1. The pH of FYM and vermicompost were 6.86 and 6.54, non-saline (EC 2.84 and 2.63 dS m^{-1}) with variable SOC (16 and 13%) content, respectively. The biochemical composition of the organics was also determined following the methods described by Rahn *et al*. (1999).

Experimental details

The collected bulk soil samples were taken to the laboratory in bags and pooled together to make a composite sample for each site and were then allowed to air-dry for 72 h. The air-dried sub-samples of each site were hand crushed, passed through 2-mm sieve and were stored for determination of various physical and chemical properties. Additionally, sieved sample for each site was taken and passed through 5-mm sieve but retained on 2-mm sieve. Samples of organics manures (50 g of ground FYM and vermicompost) were thoroughly mixed with 5 kg soil (@ 20 t ha^{-1}) (2-5 mm sieved) and transferred to a clear plastic bag for incubation. The soil-FYM and soil-vermicompost mixtures were then moistened at field capacity moisture content (θ_{fc}) by adding water (ECe 0.210 dS m^{-1}) in small increments and then placed in black plastic bags and incubated in laboratory condition for 60 days. A control treatment, without adding any organic was also kept for incubation after moistening the soil at filed capacity. The incubation was started in the 2nd week of February and ended in 2nd week of April. During incubation period, the temperature and relative humidity in the laboratory were in the range of 26±2 to 28±2 °C and 68±2 to 72±2%, respectively. A small volume of water was added periodically to keep the soil at θ_{fc}. Sub-samplings were drawn at 0, 20, 40, and 60 days of incubation (DOI) to study the dynamics of pore geometry, aggregation, saturated hydraulic conductivity (Ks), sorptivity, soil water diffusivity and SOC during the decomposition of FYM and vermicompost. The experiment was set up in 4×2×3 factorial complete randomization design with three replications. The treatments consisted of (i) addition of organics (No organics, Control, FYM and vermicompost); (ii) two soils (red-laterite and alluvial); and (iii) four incubation period (0, 20, 40 and 60 days).

Soil analyses

The soil sub-samples were drawn at 0, 20, 40 and 60 DOI, air-dried in shade at room temperature, crushed and passed through 5-mm and 2-mm sieve and analyzed for SOC, aggregate stability, sorptivity and diffusivity. Two sets of six nested sieves with aggregate size classes of 2.0, 1.0, 0.5, 0.25 and 0.1 mm were used for aggregate separation by the wet sieving method as described by Yoder (1936). After correcting coarse material content in all aggregate fractions by dispersion with 0.5% sodium hexametaphosphate and sieving through the same sieve size, the mean weight diameter (MWD) was estimated (van Bavel 1949) using following formula:

$$MWD = \Sigma x_i w_i \quad \ldots(1)$$

where, w_i is the proportion of each aggregate class in relation to whole soil, and x_i is the mean diameter of the class (mm).

The water stable aggregate (WSA) was computed by adding the aggregates of different size fractions (0.25-2 mm), and expressing them as percentage of the total weight of soil taken for analysis. The WSA for each size class was determined as:

$$WSA_i = [(Wa - Wp)/Wo] \times 100 \quad \ldots(2)$$

where, Wa = weight of soil particle on the sieve after wet sieving of size i; Wp = weight of primary particle in size i; Wo = weight of soil aggregates placed on the sieve prior to wet sieving of size i.

Aggregate stability (AS) was calculated following the procedure of Gupta and Dakshinamurti (1980) as given below:

$$AS = [(Wa{>}0.25 - Wp{>}0.25)/ Wp{<}0.25] \quad \ldots(3)$$

where, Wa>0.25 = weight of the per cent soil particle >0.25 mm; Wp>0.25 = weight of the per cent primary particle >0.25 mm; Wp<0.25 = weight of the per cent primary particle <0.25 mm.

The soil water sorptivity (S), obtained from subsampling of the treatments at 0, 20, 40 and 60 days, were determined following the method described by Bruce and Klute (1956) using the Philip's (1957) horizontal infiltration equation as:

$$S = [I/\sqrt{t}] \quad \ldots(4)$$

where, I = cumulative infiltration (cm); t = time (min).

The SOC was estimated following the modified method of Walkley and Black (Tiessen and Moir 1993). Sample of soil (1.0 g) was taken in a digestion tube and digested with a digestion mixture (0.4 *N* $K_2Cr_2O_7$ and 18 *N* H_2SO_4) under 165 °C temperature for 30 min in a digestion chamber. After cooling, it was titrated against 0.2 *N* ferrous ammonium sulphate using O-phenanthroline, ferrous sulphate indicator after the addition of 200 mL of water and 10 mL of orthophosphoric acid. For determination of BD, micro-porosity and Ks, undisturbed soil cores (5 cm diameter and 5 cm height) were collected from the treatments at 0, 20, 40 and 60 DOI. The BD was determined following the method of Blake and Hartge (1986). Micro-porosity was determined from the volumetric water content of the undisturbed soil cores, placed in a wall hanging sintered glass funnel at 100 cm suction of water column. Constant head apparatus, as described by Bandyopadhyay *et al*. (2011) was used to measure Ks following Darcy's equation.

Statistical analysis

Analysis of variance (ANOVA) was performed using factorial completely randomized design (CRD) with three replications. The differences between means of the different treatments were compared by the least significant difference (LSD) at 5% level of significance. Data were analyzed using SPSS software (SPSS Inc. 2008).

Results and Discussion

Soil Organic Carbon

The SOC was found more in alluvial soils than red-laterite soils (Fig. 1) and with increasing days of incubation, the SOC increased up to 40 days for both soils when incubated with organics. The change was much contrasting in red-laterite soil which increased 73 per cent more SOC as compared to alluvial soil (15%) over control. Rapid interaction of applied organics with sandy loam rich red-laterite soil (lower clay content) compared with clay loam rich alluvial soil (higher clay content) might have led to such SOC distribution. Wuddivira *et al*. (2009) and Wakindiki and Yegon (2011) revealed that the effects of the intensity of decomposition of organics were more evident in the lower clay content soil than the higher clay content soil. The SOC level was decreased linearly for alluvial soil after 40 DOI, whereas red-laterite soil reported sharp fall (Fig. 1). The rapid decomposition of added organics by soil microbes and

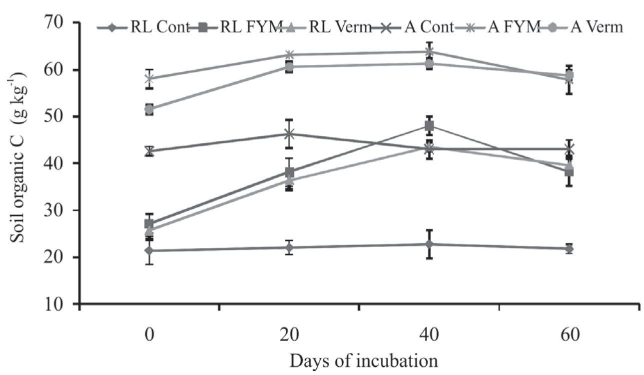

Fig. 1. Soil organic C of two soils as functions of interaction between FYM, vermicompost (Verm) and days of incubation. A, RL and Cont represent alluvial, red-laterite soils and control. Error bar indicates the standard error of mean

Table 2. The F ratios and statistical significance ($p < 0.001$) of effects of soil type (Soil), organics (FYM and vermicompost) and days of incubation (DOI) on soil organic C (SOC), bulk density (BD), micro-porosity (mP), saturated hydraulic conductivity (Ks), water stable aggregate (WSA), mean weight diameter (MWD), aggregate stability (AS) and sorptivity (S)

Source of variation	df*	F ratio							
		SOC	BD	mP	K_S	WSA	MWD	AS	S
DOI	3	225706.83	5.86	NS	166311.29	71.35	35.32	55.36	623.83
DOI × Soil	3	110010.99	NS	NS	597.25	6.21	5.93	43.53	248.15
DOI × Organics	6	4191.28	NS	NS	10702.86	26.47	11.62	21.35	90.36
DOI × Soil × Organics	6	7725.26	NS	NS	3817.77	8.21	5.67	18.00	45.73
Error	18								
Soil	1	6319313.01	388.35	454.42	5863.39	1136.69	5759.29	227.99	392.07
Organics	2	819628.16	51.38	60.69	17981.33	16.97	64.12	98.03	95.10
Soil × Organics	2	211353.91	19.26	23.36	1293.72	58.67	18.35	68.82	29.71
Error	6								

*df = degrees of freedom; NS = non-significant

Table 3. Pearson's correlation coefficient (r) between soil properties

Parameter	SOC	BD	mP	Ks	WSA	MWD	AS
BD	-0.71***						
mP	0.73***	-0.97***					
Ks	0.64***	-0.73***	0.74***				
WSA	0.58**	-0.87***	0.86***	0.70***			
MWD	0.74***	-0.85***	0.83***	0.79***	0.86***		
AS	0.73***	-0.62**	0.63***	0.60**	0.75***	0.65***	
S	0.55**	-0.51**	0.51**	0.39*	0.50**	0.59**	0.39*

SOC = Soil organic C; BD = Bulk density; mP = Micro-porosity; Ks = Saturated hydraulic conductivity; WSA = Water stable aggregate; MWD = Mean weight diameter; AS = Aggregate stability; S = Sorptivity.
* Significant at $P = 0.05$; ** Significant at $P = 0.01$; *** Significant at $P = 0.001$

decreasing substrate concentration may be the cause of decline in SOC in these soils at different incubation periods. Adesodun *et al*. (2001) reported a similar decrease in SOC concentration with time in a sandy clay loam soil of the humid tropics of Nigeria. Both vermicompost and FYM treated soil increased 44 and 43 per cent more SOC than control upon incubation (Fig. 1). The vermicompost and FYM have more capacity to resist decomposition due to presence of more polysaccharides and lignin type of compounds. Since, the interaction between soil type and treatment, incubation days and treatment and soil type and incubation period were significant, the main effect could not be interpreted independently (Table 2). The triple interaction on SOC suggests that the factors responsible for C accumulation or protection are complex. Strong correlations between SOC and WSA (r = 0.58, $p< 0.01$), MWD (r = 0.74, $p< 0.001$), and AS (r = 0.73, $p< 0.001$) suggested SOC had profound influence on structural properties (Table 3). The results show a strong negative correlation (r = -0.71, $p< 0.001$) between SOC and BD of soil samples.

Bulk Density, Micro-porosity and Soil Hydraulic Conductivity

The dynamics of soil BD has major impact on pore size distribution, level of compaction, aggregate stability and strongly influences soil water movement (Hillel 1980). Soil texture, mineralogy, compaction level and SOM content are reported to control BD of soil (Chaudhari *et al.* 2013). Changes in soil BD in red-laterite and alluvial soil with incubation durations under FYM and vermicompost treatments (Fig. 2) indicated that the BD of both FYM and vermicompost treated red-laterite and alluvial soils decreased with incubation duration. For red-laterite and alluvial soils, the BD varied from 1.54 to 1.38 and 1.31 to 1.24 Mg m^{-3}, respectively, during the entire incubation duration. The control treatments didn't show any significant change in BD for both the soils. Results indicated that the BD of red-laterite soil declined more (0.17 units) than alluvial soil (0.08 units) during the incubation durations, suggesting that pore geometry was changing with organics faster in the red-laterite soil. Faster interaction of organics with sandy loam

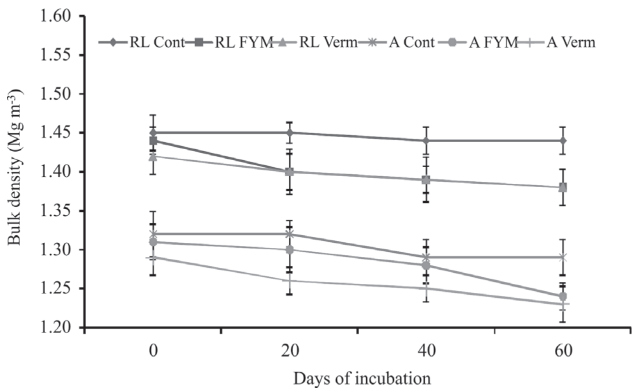

Fig. 2. Bulk density of two soils as functions of interaction between FYM, vermicompost (Verm) and days of incubation. A, RL and Cont represent alluvial, red-laterite soils and control. Error bar indicates the standard error of mean.

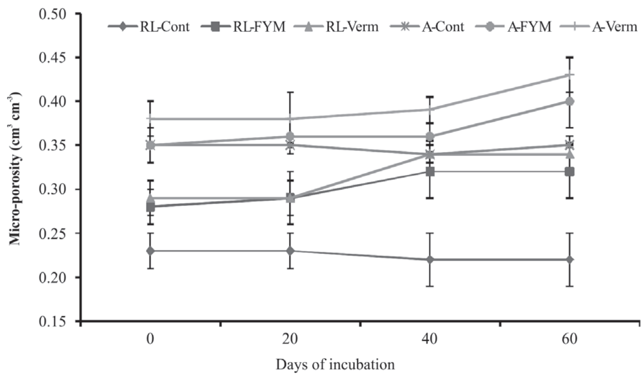

Fig. 3. Soil micro-porosity of two soils as functions of interaction between FYM, vermicompost (Verm) and days of incubation. A, RL and Cont represent alluvial, red-laterite soils and control. Error bar indicates the standard error of mean

than clay loam may favour such contrasting change in pore geometry. The F ratio and statistical significance of the analysis of variance indicated that BD significantly affected by incubation durations, soil type and treatments used (Table 2). Since soil type-treatment interaction was significant, the main effect could not be interpreted independently. The double interaction suggests that organics have a major impact on soil BD values. Strong negative correlation (Table 3) of BD with SOC (r = -0.71, $p < 0.001$) could be attributed to organic matter addition to the soil from time to time, better aggregation and a consequent increase in volume of micro pores (Tiarks *et al.* 1974; Schjonning *et al.* 1994).

Decrease in BD improves pore size distribution favouring the smaller pores and specific area of soils (Pagliai *et al.*2004). Significant changes in soil micro pores were observed for both the soils particularly at 40 to 60 DOI (Fig. 3). Upon incubation the red-laterite and alluvial soils produced 16 and 13 per cent higher micro-porosity and vermicompost treated soil as well as FYM treated soil increased 17 and 11 per cent more micro-pores. Incubation durations induced decomposition of organics might have interacted with soil structure creating different pore size distributions, as evidenced by a change in micro porosity in the soil due to application of organics (Bhatia and Shukla 1982; Celik *et al.* 2004; Wuddivira *et al.* 2009). The F ratio and statistical significance of the analysis of variance indicated that micro-porosity was significantly affected (at $p<0.001$) by soil type and organic treatments used (Table 2). However, the main effect could not be interpreted independently as soil type-treatment interaction was significant. Micro-pores were strongly correlated (Table 3) with BD (r = -0.97, $p< 0.001$) and SOC content of soil (r = 0.73, $p< 0.001$), suggesting pores of smaller sizes protect organic substrates against microbial decomposition in soils (Mtambanengwe *et al*. 2008).

Saturated hydraulic conductivity (K_s) is a soil physical indicator to know about the water transmission capacity of the soil which increased with incubation durations (Fig. 4). Incubation of soils to different durations after treating with FYM or vermicompost produced a significant increase in K_s when compared with control treatment. Upon incubation, vermicompost treated as well as FYM treated soils increased 622 and 239 per cent more Ks and the red-laterite and alluvial soils produced 449 and 412 per cent higher Ks (Fig. 4). From F ratio it was revealed that K_s was significantly ($p< 0.001$) affected by soil type, organics incorporation and

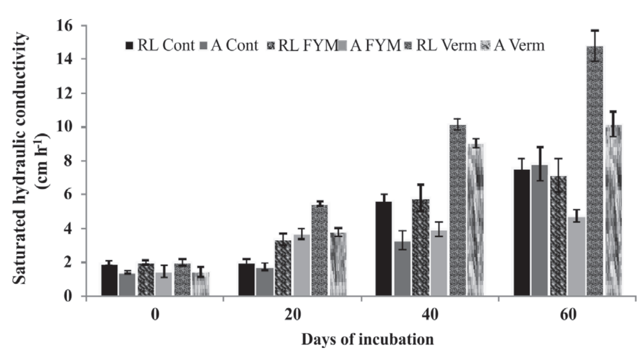

Fig. 4. Saturated hydraulic conductivity of two soils as functions of interaction between FYM, vermicompost (Verm) and days of incubation. A, RL and Cont represent alluvial, red-laterite soils and control. Error bar indicates the standard error of mean

incubation durations (Table 2). However, the triple interaction on K_s suggests that the factors influencing water transmission capacity of these two soils are complex and can't be explained separately. Organics addition increased the K_s due to decrease in BD and a change in pore volume as increased pore volume has a direct influence on K_s of the soil (Flowers and Lal 1998). Lower K_s in alluvial soil may be due to higher clay content that might have slaked and clogged the pores upon incubation durations than red-laterite soil where the intensity of reaction is more due to active charged sites of sesquioxides (Singh and Singh 2007). Higher K_s upon incubation durations in control treatment were also found. Coarse matrix might have played controlling the K_s in controlled treatment rather than the stability of aggregates in red-laterite soil, whereas wetting and slaking of aggregates in alluvial soil might had led to higher K_s in the controlled treatment. Saturated hydraulic conductivity had significant ($p<0.001$) relationship (Table 3) with SOC (r = 0.64), BD (r = -0.73) and micro porosity (r = 0.74) other than with water stable aggregates (r = 0.70) and mean weight diameter (r = 0.79).

Water Stable Aggregates, Mean Weight Diameter and Aggregate Stability

Water stable aggregate (WSA) is an indicator of soil's resistance to dispersion and was increased with incubation durations when treated with FYM and vermicompost as compared to control (Fig. 5). Incorporation of organics had profound influence on WSA of both the soil from 40 to 60 DOI, however, the change was more on red-laterite as compared with alluvial soil. Application of vermicompost and FYM treated soils increased 31 and 13 per cent more WSA; while the red-laterite and alluvial soil increased 25 and 19 per cent higher WSA over control (Fig. 5). Our results corroborate the finding of Wuddivira *et al*. (2009). It could be attributed to the production of microbial polysaccharides that act as binding agents between soil aggregates (Tisdall and Oades 1982). The WSA of red-laterite soil was lower than alluvial soil probably due to higher organic matter as well as clay content in the later. The presence of inherent soil organic carbon, Fe and Al oxides, and applied carbon through FYM and vermicompost influenced on WSA of red-laterite soil while higher clay and Ca^{2+} content in alluvial soil incubated with organics resulted in the release of particle bonding substances that produced more slaking resistance stable aggregates. Calcium may also exert an influence on organo–mineral complexation and its stability at the microaggregate level (Six *et al*. 2004). The organics have the capacity to resist rapid decomposition that facilitates good aggregation, however their biochemical compositions as well as surface area or charge density of soils might be responsible for different WSA of the studied two soils. The interaction of organics was supplementary with sandy loam of red-laterite soil may be due to more Fe and Al oxides with high surface charges (Singh and Singh 2007).

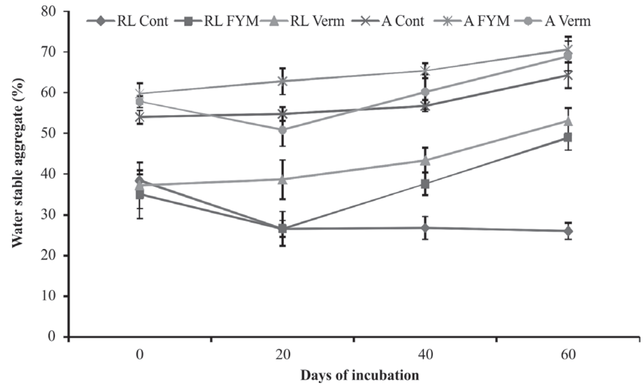

Fig. 5. Water stable aggregate of two soils as functions of interaction between FYM, vermicompost (Verm) and days of incubation. A, RL and Cont represent alluvial, red-laterite soils and control. Error bar indicates the standard error of mean

The MWD gives an estimate of weighted percentage of average sizes of all the aggregates. Changes in MWD with organics incorporation and subsequent incubation durations are shown in fig. 6. Upon incubation application of vermicompost and FYM treated soils increased 33 and 24 per cent more MWD and the red-laterite and alluvial soils increased 45 and 11 per cent higher MWD. Martens (2002) reported the increased MWD values in a silty clay

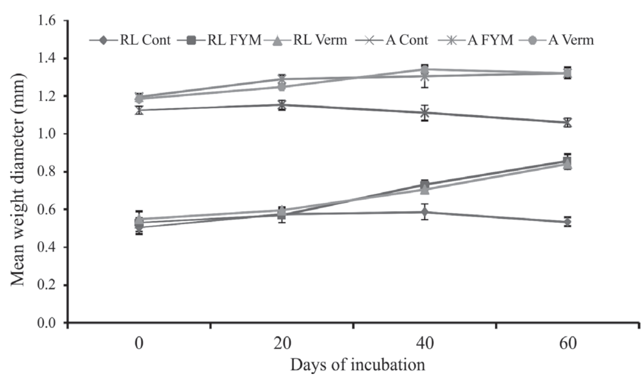

Fig. 6. Mean weight diameter of two soils as functions of interaction between FYM, vermicompost (Verm) and days of incubation. A, RL and Cont represent alluvial, red-laterite soils and control. Error bar indicates the standard error of mean

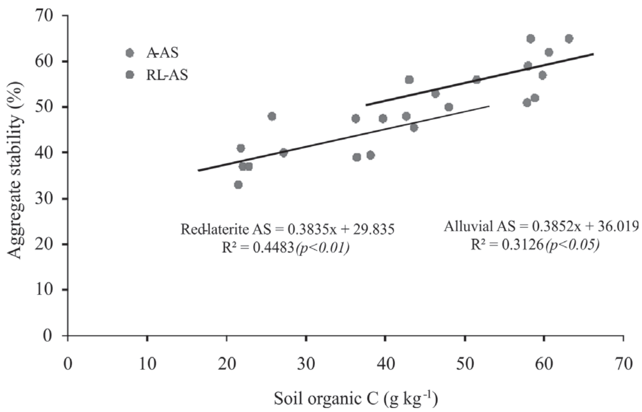

Fig. 7. Aggregate stability of two soils as functions of soil organic C. A, RL and Cont represent alluvial, red-laterite soils and control. Error bar indicates the standard error of mean

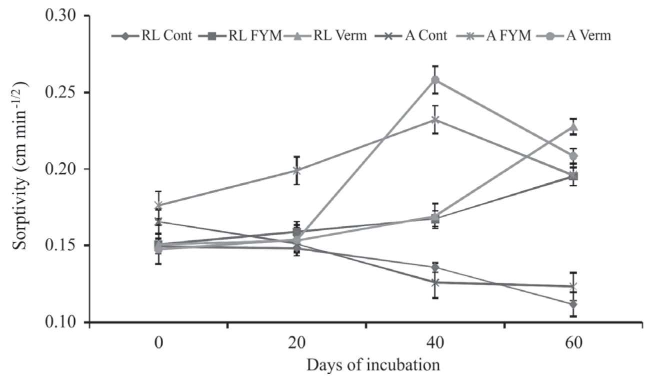

Fig. 8. Sorptivity of two soils as functions of interaction between FYM, vermicompost (Verm) and incubation. A, RL and Cont represent alluvial, red-laterite soils and control. Error bar indicates the standard error of mean

loam soil after only nine days under laboratory conditions. Soil aggregate stability (AS) is a crucial soil property indicates the strength of particle bonding within aggregates (Amezketa 1999). Figure 7 indicates that AS was higher in alluvial soil than red-laterite soil and positive and significant relationships were found in between AS and SOC in both the soils. The slope of the curve (Fig. 7) represents the effect of SOC on development of AS and the result revealed that the AS would increase 3.8 per cent with the increase in SOC by 1% in both soils. Red-laterite soil with variable charged sites produced strong inter-particle bond upon application of FYM and vermicompost, while clay content in alluvial soil produced clay-organic bonding that may control AS. A higher coefficient of determination ($R^2 = 0.45$) in red-laterite soil indicated strong association of SOC with Fe and Al oxides as compared with alluvial soil ($R^2 = 0.31$). Changes in biochemical composition of organics and mineralogy of soils may have an effect on the size and stability of aggregates as evident by Piccolo *et al.* (1997) and Lebron *et al*. (2002). Puget *et al*. (1995) also revealed that the type of OM was more critical to structural stability than the net amount of OM. Statistical inference from F ratio (Table 2) indicated that the WSA, MWD and AS were significantly affected by soil type, incubation durations and organics incorporation. The triple interaction on WSA, MWD and AS suggested that the factors influencing the structural stability of the soils are complex. Strong positive correlation (Table 3) between WSA and SOC (r = 0.58, $p < 0.01$), MWD and SOC (r = 0.74, $p < 0.001$) and AS and SOC (r = 0.73, $p < 0.001$), suggested that the aggregation was primarily controlled by SOC concentration in both soils.

Soil Sorptivity

Soil sorptivity indicates the capacity of a soil to absorb water and it actually controls the initial infiltration rate. Incorporation with FYM and vermicompost increased S upon incubation durations in red-laterite and alluvial soils (Fig. 8). Upon incubation application of vermicompost and FYM treated soils increased 46 and 11 per cent more S and the red-laterite and alluvial soils increased 31 and 26 per cent higher sorptivity. The biochemical nature of organics and their interaction with mineral particles for SOC stabilization might be the cause of variability in sorption. The difference in hydrophobic/ hydrophilic moieties of the organics may be responsible for variation in sorptivity (Piccolo and Mbagwu 1999). Lower sorptivity in FYM treated soil as compared with vermicompost treated may be due to water repellency by FYM. Organics incubation and its decomposition in soils had reoriented pore geometry (micro-pores) that controlled the S of water to infiltrate. This is confirmed from the F ratio and level of significance of analysis of variance of triple interactions (Table 2). Sorptivity was positively and significantly related to SOC (r = 0.55, $p<0.01$) and micro-porosity (r = 0.51, $p<0.01$), however, had a negative relationship with BD (r = -0.51, $p<0.01$) (Table 3). Positive correlation between S and WSA (r = 0.50, $p< 0.01$) and AS (r = 0.39, $p< 0.05$) confirmed the influence of slaking on S of soil. Lower values of S in control treatment are indicative of the lower initial infiltration rate due to slaking of structural aggregates without incorporation of organics.

Conclusions

Considering different incubation durations, it was concluded that there was improvement in soil hydraulic and structural parameters under FYM and vermicompost incorporation as evident from higher values of SOC, Ks, %WSA, MWD, AS and S in 40 to 60 days incubation period. Both the organics had a significant effect on coarse textured red-laterite than fine textured alluvial soil. Among the organics, vermicompost had distinct effect in most of the cases on aggravating soil structure and reorienting micro-porosity as compared with the FYM. Soil mineralogy especially clay content, Fe and Al oxides, and nature of organics *viz*., C:N ratio, lignin and polyphenol contents were the influential characteristics upon incubation and structural rejuvenation. SOC present in the added organics is one of the controlling factors for aggregate stability (AS) and it was revealed that the AS would increase 3.8 per cent with the increase in SOC by 1% in both soils. Soil hydraulic parameters, like Ks and S were increased with the increase in aggregation upon incubation with vermicompost in both soils. Incubation of organics at field capacity moisture content can improve structural and hydraulic properties faster in coarse textured soil as compared with fine textured soil. Hence, the application of organics especially vermicompost after structural disintegration could promote particle integration and rejuvenate soil structure and water movement.

Acknowledgement

The first author is grateful to Indian Council of Agricultural Research, New Delhi for providing Junior Research Fellowship.

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Received 2 July 2017; Accepted 12 December 2018