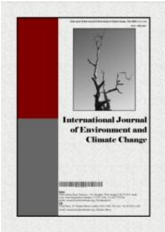

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Can Wet Aggregate Stability and Texture Regulate Organic Carbon Stock in Alluvial Soils of East Champaran (Bihar)?

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Authors' contributions

This work was carried out in collaboration among all authors. Author VK designed the study, performed the statistical analysis. Author RL managed the analyses of the study and author DN wrote the protocol and wrote the first draft of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: Here in this experiment, the investigation was done for the relationship among the various soil health parameters i.e., soil organic carbon (SOC), soil texture, and wet aggregate stability (WAS).

Place and Duration of Study: Sample: Collection of soil samples were done from 0-15 cm depth from East Champaran is situated in Bihar and is located at $26^0$38'N and $84^0$54'E in the year 2019-2020.

Methodology: Soil texture: 14g (+/- 0.1g) of sieved soil was added to a 50 ml centrifuge tube holding 42 ml of a dispersant 3% sodium hexametaphosphate solution follwed by 2 hr shaking and 0.053 mm sieved. **Water stable aggregates:** Each 0.25-mm sieve contained 4g of air-dried, 2-mm aggregate soil. Each sample's precise weight was recorded. The soil samples were dispersed for 3 minutes with 100 mL distilled water and then for 10 minutes with a 2 g/L sodium hexametaphosphate solution. Pre-weighed filter sheets were used to filter both solutions. Each filter paper was weighed after being oven-dried at 105°C.

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Soil organic carbon: The amount of soil organic carbon (SOC) was calculated using the Walkley and Black technique (1934).
Results: Wet aggregate stability and soil organic carbon storage were shown to have a strong positive connection. Soil carbon stock in soils of East Champaran varied between 5.27-19.60 Mg ha^{-1} with an average of 12.98 Mg ha^{-1}. WAS ranged from 3.82 to 36.43% with a mean of 16.11%. The results revealed that WAS increased with increase in SOC stock. This experiment also revealed that clay (%) and silt (%) directly affect WAS and hence enhance SOC storage.
Conclusion: So, it can be concluded that WAS and soil texture directly and positively impact SOC storage in soils of East Champaran, Bihar.

Keywords: Wet aggregate stability (WAS); soil organic carbon (SOC); soil texture; relationship.

1. INTRODUCTION

Soil organic carbon (SOC) is the single biggest reservoir of carbon in the worldwide terrestrial carbon cycle [1]. It has a carbon content of approximately 1500 Pg, which is more than the average carbon content of plants and atmospheric reservoirs [2]. Because of its high percentage, even a little change in its concentration may result in a significant rise in CO_2 emissions, affecting global warming [3,4]. SOC mineralization is a crucial process related to the release of fertiliser, soil nutrients, quality improvement, greenhouse gas emissions and, ultimately, food production [5,6,7,8]. Comprehensive study of all the characteristics and variability of SOC mineralization processes are essential to better enhance soil fertility management, climate change mitigation and food safety [5]. Aggregate stability is a soil quality measure that is proportional to the quantity of organic matter present. Soil organic matter gives soil surface aggregates more stability, enabling them to withstand wetness and mechanical stresses from tillage tools and vehicle activity [9,10,11]. Many studies on different soils and climatic conditions have demonstrated a strong relationship between SOC and macro and micro aggregates structural stability (250 mm) [9,12].

It is widely recognized that complete SOC is a dynamic process with many components, and that increasing the amount of carbon sequestered in these components is critical for reducing carbon conversion to greenhouse gases and preventing climate change [5,13]. One of the most significant processes that contributes to the long-term sustainability of SOC and carbon sequestration in soil aggregation [5,14,15,16]. By physically shielding SOC from mineralization, soil aggregates play a significant role in soil fertility maintenance and structure. It is further considered as a key indicator of soil structure development, deterioration, and stabilization [5,15,16]. The quantity of inorganic and organic fertilizers used in agricultural operations has risen in recent decades, increasing the risk of soil depletion, which is linked to unsustainable resource use practices [5,18,19]. Therefore, it is highly recommended to use optimum fertilization methods to enhance soil quality, soil C sequestration, and agronomic efficiency [5,19,20]. The main objective of this study was to investigate whether aggregate stabilization along with soil texture plays a significant role in managing SOC storage.

2. EXPERIMENTAL DETAILS

2.1 Description of the Site, the Experimental Setup, and Soil Sampling

East Champaran is geographically located in Bihar between 26^{0}38'N and 84^{0}54'E at an elevation of 62 m above sea level (m a.s.l.). The area is characterized by a Hot Subhumid (moist) climate, with hot, humid summers and mild winters. The yearly average rainfall is 1,202 mm. The major soil types are: Udifluvents, Haplaquents, Paleustalfs alluvial with silty to sandy loam texture, and calcareous nodules (kankar).

Soil samples were collected at 0-15 cm soil depth, air-dried for 6 days, passed through a 2 mm sieve, and kept for analysis of wet aggregate stability (WAS), soil texture, and SOC.

2.2 Assessment of Soil Texture

14g (+/- 0.1g) of sieved soil was added to a 50ml centrifuge tube holding 42 ml of a dispersant 3% sodium hexametaphosphate solution. To completely disperse soil into suspension, it was continuously agitated for 2 hours on a shaker. The whole contents were sieved onto a 0.053mm sieve assembly over a plastic funnel above a 1L beaker. The sand that has accumulated on top of the sieve is collected in a metal container and put aside.

Silt and clay particles were collected in a 1L beaker and stirred to re-suspension before being allowed to settle for 2 hours. Before measuring dry weight, both the sand and silt fraction cans were dried at 105°C to a consistent weight. Percent sand, silt, and clay were then calculated as follows:

Sand % = (mass of oven dry sand/ mass of original sample) x 100%
Silt % = (mass of oven dry silt / mass of original sample) x 100%
Clay % = 100 - (Sand % + Silt %)

2.3 Assessment of Wet Stable Aggregate

Each 0.25-mm sieve contained 4g of air-dried, 2-mm aggregate soil. Initially, each sample's precise weight was recorded. Each soil sample was duplicated two times, for a total of four samples per eight-sieve batch. The soil samples were dispersed for 3 minutes with 100mL distilled water and then for 10 minutes with a 2g/L sodium hexametaphosphate solution in an Eijkelkamp unit. Pre-weighed filter sheets were used to filter both solutions. Each filter paper was weighed after being oven-dried at 105°C.

% stable aggregate was calculated using the following equation:

% stable aggregates=

$$\frac{\text{Weight of soil in dispersing solution}}{\text{Weight of soil in dispersing solution + weight of soil in water}}$$

2.4 Assessment of Soil Organic Carbon, Soil Organic Matter, and Soil Organic Carbon Stock

SOC was calculated using the Walkley and Black technique (1934). The calculated SOC was then multiplied with Von Bemlen factor (1.724) to determine soil organic matter (SOM). SOC stock was calculated by multiplying area (m^2), bulk density (Mg m^{-3}), soil depth (m), and SOC (percent).

2.5 Statistical Analysis

Statistical analyses were done using SPSS software version 16.0.

3. RESULTS AND DISCUSSION

3.1 Soil Organic Carbon (Soc) and Soil Organic Matter (Som) Content

The soil system regulates plant growth in the terrestrial ecosystem [21]. SOM and SOC play a vital role in good plant growth and soil health.

SOM is one of the sources and sink of SOC. SOC in these studied soil samples of East Champaran varied between 0.24-0.99 % with a mean of 0.66 %. SOM ranged from 0.46 to 1.71 % with a mean of 1.13 % (Fig. 1). The data of SOC and SOM revealed that increase in SOC improves SOM content. Both SOM and SOC were positively correlated. One of the most important elements affecting soil stability is organic matter [9,22,23,24]. The topsoil layer was found to be more stable than deeper ones, with the difference related to the former's greater SOC content [9,25].

3.2 Wet Aggregate Stability and Soil Organic Carbon Stock

Soil carbon stock in soils of East Champaran varied between 5.27-19.60 Mg ha^{-1} with an average of 12.98 Mg ha^{-1}. Wet aggregate stability varied between 3.82-36.43 % with a mean of 16.11 % (Fig. 2). WAS increased with increasing in SOC. Aggregate protects SOM by physical disconnection [26,27].

This experiment revealed that soils with the highest aggregate stability are characterized by more SOC stock. A possible explanation of this result could be attributed to soil organic matter content and quality. Binding agents, which are typically polysaccharides derived from exocellular mucilages and root exudates, situated between aggregates may create an active pool [26,28], resulting in significant SOC storage. In high aggregate stability soils, fresh plant residues, as well as various faunal and microbial residues, which constitute alternate pools of easily accessible SOM to decomposers [26,28], are more likely to be found than in low aggregate stability soils. Plant organic residue, as well as microbial and microfaunal waste, including fungal hyphae in various stages of decomposition, make up the light fractions [29,30] According to the soil aggregation hierarchal model, there are efficient stabilizing agents for soil macroaggregates [10]. The increased microbial activity led these light fraction materials to disintegrate preferentially and they are primarily associated with macro-aggregates which played a major role in aggregate stability [29].

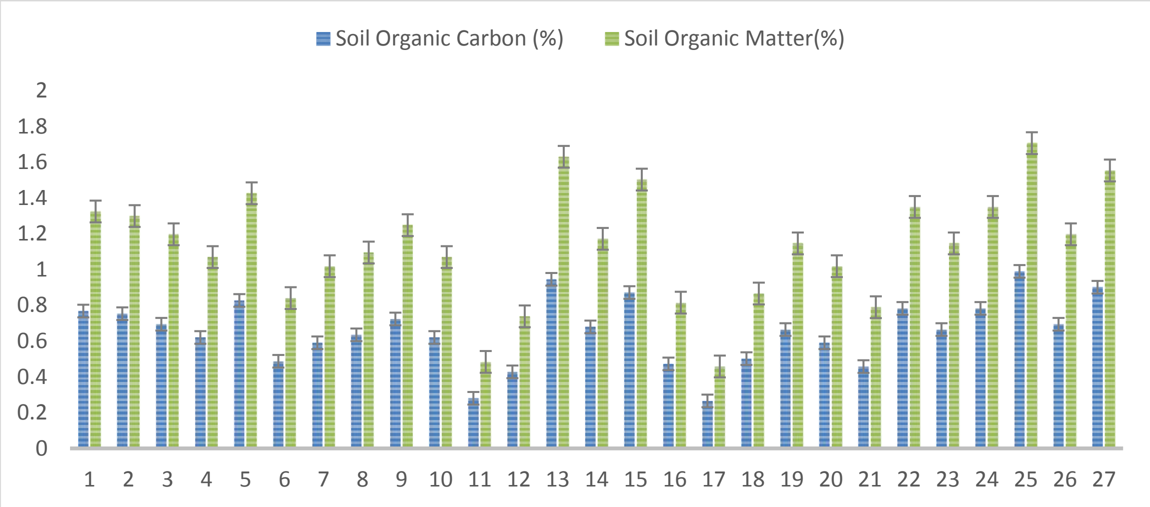

Fig. 1. Level of soil organic matter (SOM) and soil organic carbon (SOC) in soils of East Champaran

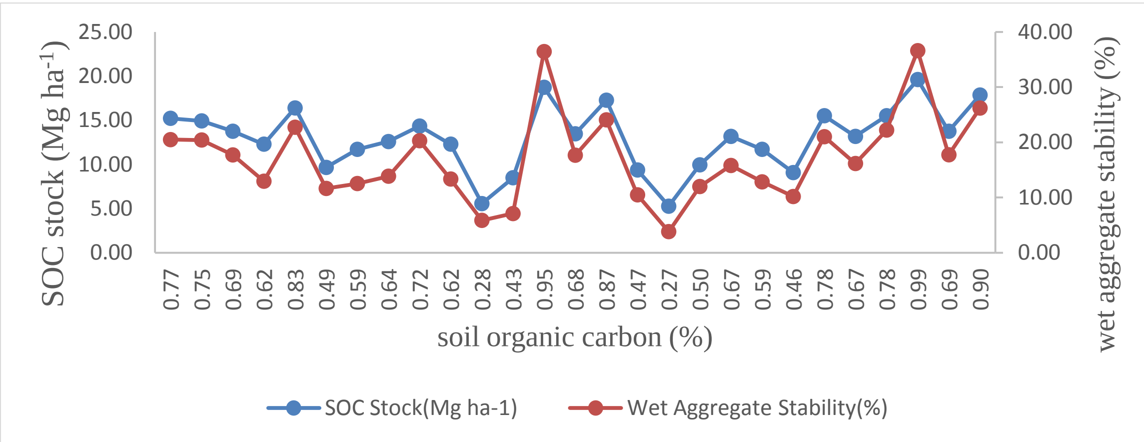

Fig. 2. Relationship between soil organic carbon stock and wet aggregate stability (%)

Table 1. Descriptive statistics of sand, silt and clay content in soil samples of East Champaran

Descriptive parameters	Sand (%)	Silt (%)	Clay (%)
Mean	19.68 (+2.06)	71.49 (+1.78)	8.83 (+0.83)
Median	16.63	74.27	8.95
Std. Deviation	10.68	9.26	4.33
Variance	114.14	85.76	18.71
Skewness	0.78 (+0.45)	-0.79 (+0.45)	0.49 (+0.45)
Kurtosis	-0.23 (+0.87)	-0.33 (+0.87)	-0.56 (+0.87)
Range	35.42	30.65	15.20
Minimum	6.16	52.46	2.74
Maximum	41.58	83.11	17.94

Table 2. Correlation among SOC (%), SOM (%), Soil Organic Carbon stock, WAS, Sand (%), Silt (%) and Clay (%)

	SOC (%)	SOM (%)	SOC stock (Mg ha^{-1})	WAS (%)	Sand (%)	Silt (%)	Clay (%)
SOC (%)	1						
SOM (%)	1.000**	1					
SOC stock (Mg ha^{-1})	1.000**	1.000**	1				
WAS (%)	0.950**	0.949**	0.949**	1			
Sand (%)	-0.964**	-0.965**	-0.965**	-0.892**	1		
Silt (%)	0.860**	0.864**	0.864**	0.736**	-.916**	1	
Clay (%)	0.541**	0.534**	0.534**	0.627**	-.510**	0.121	1

***Correlation is significant at p < 0.01*

3.3 Descriptive Statistics of Sand, Silt, and Clay Content in Soils of East Champaran

The textural class of studied soil samples was silt loam. The sand % varied between 6.16-41.58 % with a mean of 19.68 while the clay % ranged from 52.46 to 83.11% with a mean of 71.49 (Table 1). The maximum and minimum data of clay were 2.74 and 17.94 respectively with a mean of 8.83. The positive skewness data of sand (0.78) and clay (0.49) revealed that the right side of the distribution has a longer or flatter tail, and also data are fairly symmetrical.

The negative skewness data of silt (-0.79) suggest that the left side distribution is longer or flatter than the tail on the right side. Besides, the negative skewness (-0.79) revealed that the data are highly skewed (Table 1). The negative kurtosis of sand (-0.23), silt (-0.33), and clay (-0.56) revealed that the distribution curve had flattened top than the normal curve and platykurtic distribution is found.

3.4 Correlation among SOC (%), Som (%), SOC Stock, was, Sand (%), Silt (%), and Clay (%) In Soils of East Champaran

The correlation coefficient among SOC (%), SOM (%), SOC Stock, WAS, Sand (%), Silt (%), and Clay (%) was highly significant (Table 2). It was also observed that SOC was positively significant correlated (0.950**) with WAS and negatively significant related (-0.964**) to sand percentage at 0.01 level of significance.

Similarly, SOC stock was significantly correlated with WAS, silt, and clay percent. However, a negative correlation observed between SOC and sand (%). Sand has a negligible contribution towards the SOC stock build-up in the soil. Table 2 displays that WAS has a negative correlation with sand (%) and a positive correlation with both silt (%) and clay (%). The soil silt [31], sand [32], and clay fractions [33] have been identified as having a significant impact on the stability of soil aggregates.

4. CONCLUSION

This study investigated the relationship among WAS, soil texture and SOC: The key findings are as follows:

- WAS was positively significant correlated with SOC stock.

- WAS and SOC stock were accurately proxied by Clay (%), silt (%), SOM.

-SOC stock was substantially greater in soils with the highest stable aggregate stability than that with low aggregate stability.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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