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Soil Salinity, Infiltration and Organic Matter Status under Different Landforms in Coastal West Bengal

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Sorptivity was determined from soils of three different landforms, namely, non-cultivated deltaic (NCD), mud flat (MUD) and depressed low land (DL) under Gosaba Block of coastal West Bengal. The area covers approximately 4 km^2 and soil samples were collected during the dry season (Feb. - March) of 2018. A horizontal infiltration study was carried out in the laboratory in plexiglass columns packed with soil for determining the infiltration and sorptivity parameters. Physicochemical parameters like pH$_2$, EC$_2$, saturated moisture content, texture, organic C were determined. The humic components of organic matter, namely, humic acid and fulvic acid, were also separated out to study their effect, if any, on soil sorptivity. Steady state cumulative infiltration was the highest (50-55 mm) in NCD soil and lowest (18-20 mm) in DL soil. The highest sorptivity of 3.1-3.5 mm min$^{-½}$ was found in NCD soil and lowest in DL soil (1.0-1.1 mm min$^{-1/2}$). Organic C content of all soils were medium to high (0.50-1.20 %) and EC$_2$ values were also low (< 4 dSm^{-1}) in most of the soils except DL soil which had an EC$_2$ value of 4-5.8 dS m^{-1}. Saturated moisture content was highest in DL soil. The NCD soils contained higher fraction of fulvic acid (0.10-0.12%) which enhanced infiltration, whereas DL soils contained greater fraction of insoluble humic acid (0.27-0.31%) and exhibited less cumulative infiltration. MUD soils showed intermediate values. The relationships between sorptivity and clay, pH, EC, porosity and humic acid were significant (r = -0.90, -0.86, -0.86, -0.87 and -0.90, respectively), exponential and negative. Percentage fulvic acid was positively correlated (r = +0.94) with sorptivity.**

(***Key words:*** *Fulvi acid, Humic acid, Infiltration, Salinity, Sorptivity*)

Soil organic matter (SOM) contains almost all essential plant nutrients and plays a pivotal role in crop production. For sustainable utilization of soil resources, SOM should be maintained at a threshold level (Jenny and Raychaudhuri, 1960). The status of SOM of tropical countries like India is generally much below the threshold levels (Goswami, 1998). The soil salinity and cropping behaviour under different landforms also have an important influence on soil organic matter (Malik *et al*., 1979).

The water that falls in the form of precipitation may either flow over the land eventually reaching streams, lakes, rivers and oceans or infiltrate through the soil surface, into the soil profile. Runoff water that flows over land causes erosion, flooding as well as degradation of water quality. Infiltration is one of the major components of the hydrologic cycle and is the only source of water that helps to sustain the growth of vegetation. Infiltrated water is filtered by the soil which removes many contaminants through physical, chemical and biological processes. It also replenishes the ground water supply to wells, springs and streams. Soil infiltration and sorptivity are also affected by different components of SOM like humic acid, fulvic acid and humin. Intensification of agriculture along with the adoption of multiple cropping systems and energy intensive cultivation practices, especially excessive tillage and imbalanced use of chemical fertilizers have a negative influence on SOM (Kaleem, 1996). Hence for an efficient management of SOM, it is necessary to study the influence of agricultural impact, soil salinity and cropping sequence on organic matter availability.A study on the influence of salinity on organic matter in tidal wetlands showed that salinity was strongly and negatively correlated with soil organic matter content (Morrissey *et al*., 2014). In coastal West Bengal the major crop cultivated is rice particularly during the *kharif* season. In *rabi* season due to lack of good quality water there is limited cultivation of rice and vegetables. The productivity of crop is also seriously affected by soil salinity during this season. Therefore, the aim of

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this study was to determine soil sorptivity in relation to salinity and organic matter content so that amelioration measures can be taken to improve soil sorptivity.

MATERIALS AND METHODS

Soil samples were collected from three different villages of Gosaba Block (22° 09′ - 22°10′ N and 88°47′ - 88°48′ E) of South 24 Parganas district of West Bengal (India) coming under three different landforms namely, non-cultivated deltaic (NCD), mudflat (MUD) and depressed lowland (DL). Soil samples were collected from three different locations (replications) and three different depths (0-20, 20-40, 40-60 cm) under each landform during the dry season in the month of February-March, 2018. The soil samples were air dried, processed and made to pass through 2 mm sieve. For studying the horizontal infiltration and sorptivity, the soil was packed into plexi glass columns in the laboratory. The columns were prepared placing plexiglass segments (0.01 m height and 32 in number) one over another. These were filled as uniformly as possible with soil sample at a bulk density of 1.2 Mg m^{-3}. Columns were placed horizontally on a wooden stand and water was introduced to the inlet end from marriotte tube from the diffusivity measuring cylinder.

Under the conditions of horizontal infiltration, there is no gravitational component and the cumulative infiltration is given by Philip (1957)

$$I = St^{½} \qquad \ldots(1)$$

where, S is sorptivity, I is cumulative infiltration and t is the time.

The sorptivity (S) is given by the relation

$$S= (\theta_0 - \theta_i)(\check{D}/\pi)^{1/2} \qquad \ldots(2)$$

where, Ď is weighted mean diffusivity, θ_i is initial soil water content, θ_o is saturated wetness and t is time.

Soil water diffusivity, D(θ) was calculated by using the following formula (Bruce and Klute, 1956)

$$D(\theta)=-1/2\ t.dx/d\theta + \int x d\theta \qquad \ldots(3)$$

where, t is time; x is distance; the definite integral is solved between initial wetness (θ_i) and final wetness (θ_o).

The weighted mean diffusivity was calculated according to Crank's (1956) formula:

$$\check{D}= \frac{1.66}{(\theta_0 - \theta_i)+^{5/3}} + \int D(\theta)\,(\theta_0 - \theta_i)^{2/3}\, d\theta \qquad \ldots(4)$$

where, Ď is weighted mean diffusivity, θ_i is initial moisture content, $\theta_0$is saturated moisture content and D(θ) is soil-water diffusivity.

The soil samples were also analysed for physicochemical characteristics like texture, pH, EC, organic C, etc. following the standard procedures as described by Black (1965) and Jackson (1973). Particle size analysiswas done using a Buoycous hydrometer (Day and Forsythe, 1957). The organic carbon was estimated by wet oxidation method (Walkley and Black, 1934); pH_2 and electrical conductivity (EC_2) were measured in 1:2 soil water ratio (Jackson, 1973). The saturated water content of the soils was determined by using Keen's box (Piper, 1950). The humic acid and fulvic acid fractions of organic matter were separated following the procedure of Kononova (1966). Relationship between sorptivity and other soil parameters were also studied by carrying our correlation analysis and test of significance at both 5 and 1 % level of significance (Gomez and Gomez, 1984).

RESULTS AND DISCUSSIONS

Soil physicochemical properties

The physicochemical properties of the soils are presented in Table 1. The texture of MUD and DL soils was clay, with a clay content of 46-47 % in the surface layer (Table 1). Clay content in NCD soil at surface (0-20 cm) was 24% and sandy clay loam in texture. In the 20-40 cm and 40-60 cm soil layer for DL soils clay content did not differ much (48-50 %, clay). In the present study, organic carbon content for all landforms decreased with soil depth (Table 1) and organic carbon content of DL soils (0.50-0.62%) were less than that of MUD (0.64-1.02%) and NCD (0.51-1.20%) soils. All the soils were medium to high in organic C content (0.50-1.20 %). Organic C content of coarse soils are usually lower than clayey soils (Zinn *et al*., 2005) for all depths. In this study organic carbon content was higher in NCD soils than other soils irrespective of soil texture. This may be due to more C sequestration in NCD soils. The NCD and MUD surface soils were slightly acidic to neutral in soil reaction (pH 5.0 to 7.7). EC values for NCD soils were low (2.0-2.1 dS m^{-1}) and relatively high for DL and MUD soils (2.0-5.8 dS m^{-1}). The saturation moisture content (θ_s, porosity) of different layers did not vary much because of their similar textural content (Table 1). The highest porosity or saturation water

Table 1. Physicochemical characteristics of Gosaba soil

Name of soil	Particle size (%)			Textural class	Org C (%)	pH_2	EC_2 (dS m^{-1})	θ_s (m^3m^{-3})
	S	Si	C					
0-20 cm								
NCD	18	58	24	SCl	1.20	5.0	2.1	0.66
MUD	34	20	46	C	1.02	5.6	2.0	0.63
DL	26	27	47	C	0.62	7.4	4.2	0.67
20-40cm								
NCD	24	48	28	Cl	1.10	6.2	2.0	0.66
MUD	40	20	40	SiC	0.64	7.7	5.8	0.63
DL	18	34	48	C	0.54	7.6	4.6	0.63
40-60cm								
NCD	13	24	63	Cl	0.51	5.9	2.0	0.63
MUD	32	24	44	SC	0.64	7.5	3.8	0.64
DL	24	16	50	C	0.50	7.4	4.9	0.68

S: sand, Si: Silt, C: clay, and l: loam; NCD: non-cultivated deltaic, MUD: mudflat/mangrove, DL: depressed low land

content was found in DL soil (0.63-0.68 cm^3cm^{-3}) and the lowest was in MUD soil (0.63-0.64 cm^3cm^{-3}).

Infiltration and Sorptivity

The highest steady state cumulative infiltration (5.1 cm) was observed from the non cultivated deltaic (NCD) soil followed by mudflat (MUD) soil (3.2 cm) and depressed low land soil (DL) soil (2.0 cm) (Fig. 1). In 50 minutes time only 1.4 cm water infiltrated in DL soil while for the same period 3.5 cm water infiltrated in NCD soil and 2.4 cm in MUD soil. The cumulative infiltration of NCD soils was about 2.3 times higher than that of DL soils. This result may be due to the difference in soil texture and cultivation practices in three different soils (Ghildyal and Tripathi, 1987; Hallet *et al.*, 2004; Singh and Bhargava, 1993).

The water content of air dried soil before initiation of infiltration (θ_i), final water content (θ_s) and gain in water content are presented in Table 2. The water content in soils before initiation of infiltration varied from 0.02-0.03 cm^3 cm^{-3} in MUD and 0.03-0.04 cm^3 cm^{-3} in DL soils, whereas the values were 0.02-0.04 cm^3 cm^{-3} in NCD soils. Sorptivity was the highest (3.1-3.5 mm $min^{-1/2}$) in NCD soil, followed by 2.1-2.5 mm $min^{-1/2}$ in MUD soil and 1.0-1.1 mm $min^{-1/2}$ in DL soils. Sorptivity values differed significantly for three different landforms for different depths as evident from the slope of the cumulative infiltration versus square root of time relationship curves (Fig. 2). The slope of NCD soils in the present study was higher than the MUD and DL soils. The cumulative infiltration of NCD soils was about 2.5 times higher than that of DL soils. Significant and negative relationships were observed between sorptivity and clay, pH, EC, porosity and humic acid (r = -0.90*, -0.86**, -0.86*, -0.87* and -0.90*, respectively) (Table 3). A strong relationship between percentage

Table 2. Water content of soil samples, gain in water content and sorptivity

Name of soil	θ_i	θ_s	θ_s - θ_i	Sorptivity (mm $min^{-1/2}$)
0-20 cm				
NCD	0.02	0.40	0.38	3.5
MUD	0.02	0.36	0.34	2.5
DL	0.03	0.44	0.41	1.1
20-40cm				
CD	0.04	0.41	0.37	3.3
MUD	0.03	0.36	0.33	2.3
DL	0.04	0.43	0.39	1.0
40-60cm				
CD	0.04	0.41	0.37	3.1
MUD	0.03	0.41	0.38	2.1
DL	0.04	0.44	0.40	1.0

NCD: cultivated deltaic, MUD: mudflat/mangrove, DL: depressed low land; $F_{2,6}$> F tab (1%); CD = 1.0; T_1 = 9.9, T_2 = 6.9, T_3 = 3.1

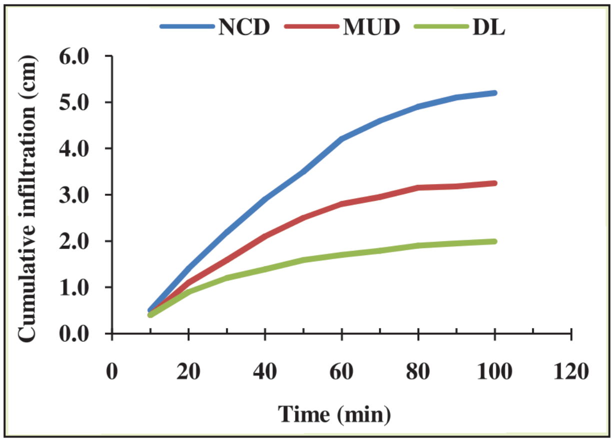

Fig. 1. Cumulative infiltration vs time curve for different soils

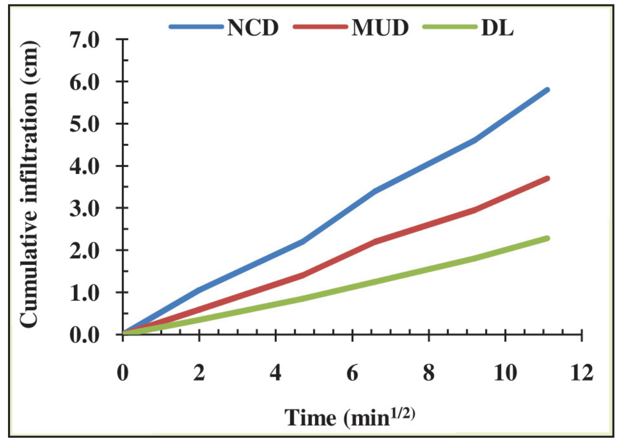

Fig. 2. Cumulative infiltration as a function of square root of time

fulvic acid and sorptivity (S) (r = +0.94**) was found. These results are in agreement with the findings of Singh and Kundu (2001) who reported similar relationships for Odisha soils (Inceptisols).

Table 3. Relation between sorptivity (S) and other parameters (X) of soil

Soil parameter	Correlation coefficient (r)	Regression equation
% Clay	-0.90*	$S= 6.2\ e^{-0.03x}$
pH	-0.86**	$S= 6.4\ e^{-0.17x}$
EC (dS/m)	-0.86*	$S= 3.9\ e^{-0.07x}$
Porosity (%)	-0.87*	$S= 80.1\ e^{-6.2x}$
H.A. (%)	-0.90*	$S= 4.1\ e^{-2.31x}$
F.A. (%)	+0.94*	$S= 0.96\ e^{8.9x}$

**Significant at 5% probability level, *significant at 1% probability level; S is sorptivity (mm min $^{-1/2}$)

The humic acid (H.A.) and fulvic acid (F.A.) fractions of organic matter are given in the Table 4. Humus is the major soil organic matter component making up 75-80% of the total (Kononova, 1966). Fractionation of organic matter showed that the fraction of H.A. was the highest (0.31%) in the surface layer of DL soil and the fraction of F.A. was the lowest (0.10%) in the surface layer of the same soil. On the other hand, the F.A. fraction was the highest in NCD soil (0.12%) for which this soil was more capable of infiltration. DL soil with greater fraction of insoluble humic acid exhibited less cumulative infiltration. MUD soils showed intermediate values (0.11%). In the lower soil layers also H.A.% was higher in the DL soils (0.27 to 0.29). The H.A. / F.A. ratio decreased with depth (0.7 to 0.5 for NCD and 3.1 to 3.0 for DL land soils). The decrease of H.A. / F.A. ratio with soil depth was found elsewhere (Weil, 1993; Kononova *et al*. 1961). Presence of humic acid in soil generally decreases volumetric water content of soil and there is decline in water repellency of soil is due to the presence of water soluble fulvic acid (Dyke *et al*., 2009; Singh and Das, 1992).

Soil physico-chemical parameters of three different landforms namely, non-cultivated deltaic (NCD), mud flat (MUD) and depressed low (DL) land were studied in the laboratory. Sorptivity was the highest (3.1-3.5 mm min$^{-1/2}$) in NCD soil, followed by 2.1-2.5 mm min$^{-1/2}$ in MUD soil and 1.0-1.1 mm min$^{-1/2}$ in DL soils. Decrease of soil sorptivity was associated with relatively high soil

Table 4. Humic acid, fulvic acid content of organic matter and their ratio

Name of soil	Total organic matter (%)	H. A. (%)	F. A. (%)	H. A/F. A.
0-20 cm				
NCD	2.1	0.08	0.12	0.7
MUD	1.8	0.18	0.11	1.7
DL	1.1	0.31	0.10	3.1
20-40cm				
CD	1.9	0.08	0.13	0.6
MUD	1.1	0.16	0.10	1.6
DL	0.93	0.29	0.09	3.0
40-60cm				
CD	0.88	0.07	0.11	0.5
MUD	1.1	0.14	0.09	1.5
DL	0.87	0.27	0.09	3.0

salinity and heavy soil textures in the coastal soils. The fraction of H.A. was the highest (0.31%) in the surface layer of DL soil and the fraction of F.A. was the lowest (0.10%) in the surface layer of the same soil. On the other hand, the F.A. fraction was the highest in NCD soil (0.12%) for which these soils were more capable of infiltration. DL soil with greater fraction of insoluble humic acid exhibited less cumulative infiltration. The humic acid-fulvic acid ratio in the present study decreased with soil depth. In soils where cumulative infiltration and sorptivity were low (DL) to intermediate (MUD), adoption of suitable management practices such as deep ploughing, vertical drainage, addition of sand and organic matter is needed. These practices will reduce salinity and improve productivity of the soils. The correction of soil pH and EC, and modification of soil texture with adoption of appropriate amendments will help in improving sorptivity of all the three kinds of soils. This in turn, will improve the productivity of coastal saline soils.

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