Jour. Agric. Physics, Vol. 8, pp. 5-10 (2008)

Influence of Water Regimes on Soil Sorptivity and Nature and Availability of Organic Matter in Inceptisol

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ABSTRACT

Sorptivity was determined for soils coming under three different moisture regimes namely; non irrigated uplands, irrigated cultivated and water logged from Raghunathpur village of Jagatsinghpur district of Orissa for two different seasons. The study was carried out in laboratory at room temperature in plexiglass columns. Physico-chemical parameters like pH, ,E.C., saturated moisture content, texture, organic C had also been determined. Cumulative infiltration was highest in non-irrigated upland soil and lowest in water logged soil. The highest sorptivity of 4.0-4.5 mmmin$^{-1/2}$ was found in non-irrigated upland soil and lowest in water inundated soil (1.0-1.5 mmmin$^{-1/2}$). Organic C content of all the three soils were low (<1%), E.C. values were also low. Saturated moisture was however high in water logged soil. The relationships between sorptivity and clay, pH, E.C., porosity and humic acid were significant, exponential and negative.

Key words: Infiltration, soil sorptivity, humic acid, fulvic acid

Introduction

The ability of a soil to absorb water during infiltration is called sorptivity. Theoretically, Philip (1957) has established that, in absence of gravity effect, the amount of water absorbed during infiltration is proportional to the square root of time (t) i.e., I = St ½ where S is a constant and is called sorptivity, I is cumulative infiltration. Sorptivity, S= $(\theta_o-\theta_i)(D/\pi)^{1/2}$, where D is weighted mean diffusivity, θ_i is initial soil water content, θ_o is saturated wetness and t is time. Sorptivity is defined only in relation to a fixed initial state θ_i and an imposed boundary condition θ_o. This is true for t > 0. Typical values of the steady infiltration rate for sandy and silty soils, loams and clayey soils are 10-20 mm h^{-1}, 5-10 mm h^{-1} and 1-5 mm h^{-1} (Hillel, 1980). Study conducted by Harden and Scruggs (2003) showed that in the lower slopes of Andes (Equador) infiltration rates ranged from 6 to 206 mm h^{-1}, 16 to 117 mm h^{-1} in the southern Appalachians and 0-106 mm h^{-1} in Luquillo Mountains (Puerto Rico) at forest sites. Soils under sal forest, chrysopogon and cropland have less water drop penetration time and therefore are classified as wettable. However soils under eucalyptus plantation and panicum stand showed considerable hydrophobicity. This is considered as being caused by differences in organic matter composition rather than amount of organic carbon (Mandal and Jayaprakash, 2009). Soils containing a large amount of hydrophobic materials such as plant litter, residue and microbial by-products may become water repellent or less wettable (Doerr *et al*., 1996; Bisdom *et al*., 1993). These are generally thought to be present as a coating on soil particles or aggregates (Bisdom *et al*., 1993). The accumulation of hydrophobic waxes on soil particles humic acid and /or fulvic acid soil coatings and other long-chained organic compounds on or between soil particles are all accepted as factors contributing to this negative impact phenomenon (Franco *et al*., 2000; Karnok *et al*., 1993). Wettability of soil is greatly influenced by nature of decomposed organic materials (Singh and Das, 1992). Topography and rainfall are the main factors which determine a soil would be water logged or not. Information on the influence of different fractions of organic material such as humic acid, fulvic acid and humin on soil wettability/repellency resulting in water logging is meagre. Present investigation was therefore carried out to study the effect of three different water regimes on the composition of soil organic matter and to study the effect of different fractions of organic matter towards water repellency /soil wettability particularly in a seasonally water logged soil.

Materials and Methods

Soil samples were collected for two different seasons from three different depths (0-15, 15-30, 30-45cm) from Raghunathpur village (Lat. 20°30'-20°33' N; Long. 86°30'-86°32' E) of Jagatsinghpur district coming under three different moisture regimes namely irrigated cultivated (I.C.), non irrigated upland (N.I.U.) and waterlogged (W.L.). The seasons for collections are June- July, 2007 (before rice cultivation) and Jan-Feb., 2008 (after rice cultivation). The area is mostly mono cropped (rice). Soil samples were collected from three different points (three replications) for soils of each moisture regimes. Sorptivities were studied in plexiglass columns. Weighted mean diffusivity was calculated according to Crank's (1956) formula : $D = 1.66/(\theta_o-\theta_i)^{5/3} \int D(\theta)\ (\theta_o-\theta_i)^{2/3}\ d\theta$ where D is weighted mean diffusivity, θ_i is initial moisture content, θ_o is saturated moisture content $D(\theta)$ is soil water diffusivity. Physicochemical characteristics like soil texture, pH, EC, organic C etc. were also studied. Cumulative infiltration was plotted as a function of time. The physicochemical characteristics of the soils were determined by using Black (1965) and Jackson (1973) methods. Particle size analysis was done using a Buoycous hydrometer. Organic carbon was determined by Walkley and Black method, pH and electrical conductivity (EC) were measured in 1: 2 soil : water ratio. 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 by following the procedures described by Kononova (1966). Cumulative infiltration was plotted as a function of time. Relationship between sorptivity and other soil parameters were also determined.

Results and Discussions

The highest cumulative infiltration was observed in NIU soil followed by irrigated cultivated (I.C.) soil and seasonally water logged soil (W.L.). This can be verified from the slope of the curves (Fig. 1 and 2). In 50 minutes time only 5-13 mm water infiltrated in W.L. soil. Whereas for the same period 40-90 mm water infiltrated in N.I.U. soil. Infiltration in I.C. soil was medium (20-23 mm). The seasonal variation of cumulative infiltration may be associated with the cultivation practices i.e., root activity apart from the variations due to soil texture (Ghildyal and Tripathi, 1987). During rice cultivation all these soils are puddled. High clay content facilitates puddling resulting in the decrease in non-capillary pore spaces which in turn decreases infiltration (Fig. 1 and 3). Irrigated cultivated (I.C.) and water logged (W.L.) soils were clay, with a clay content of 69-83% in the surface layer (Table 1 and 2). Clay content in non irrigated upland soil (N.I.U.) varied from 21-35% and were of the sandy clay loam type. In the 15-30cm and 30-45 cm soil layer for I.C. and W.L. soils clay

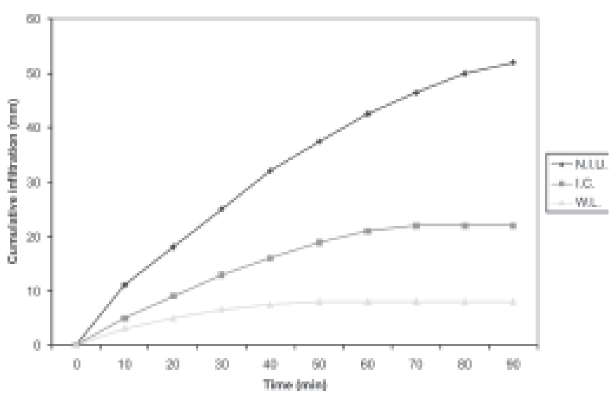

Fig. 1. Cumulative infiltration as a function of time for soils of three moisture regimes (1st)

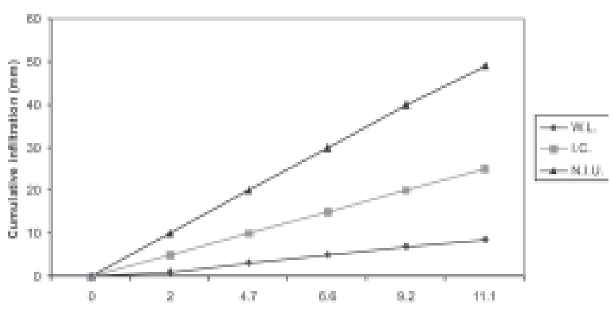

Fig. 2. Cumulative infiltration as a function of square root of time for soils of three moisture regimes (1st)

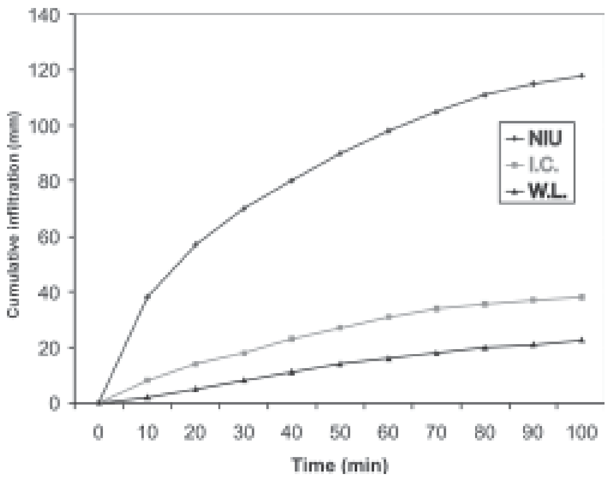

Fig. 3. Cumulative infiltration as a function of time for soils of three moisture regime (2nd season)

content did not differ much (clayey). All three soils were low in organic matter content (<1%) except surface layer of I.C. soil (1-1.33%). The highest porosity or saturation water content was found in W.L. soil (0.60-0.69 cm^3cm^{-3}) and lowest was in N.I.U. (0.37-0.46 cm^3cm^{-3}). The relatively high porosity value of 15-30 cm layer of N.I.U. soil was associated with more clay content.

Water content of air dried soil before initiation of infiltration (θ_i), final water content (θ_0) and water gain during infiltration (θ_0-θ_i) are presented in Table 2 and 4. Average water content in soils after infiltration varied from 0.45-0.60 cm^3cm^{-3} in I.C. and 0.47-0.60 cm^3cm^{-3} in W.L. soils , whereas values were 0.28-0.35 cm^3cm^{-3} in N.I.U.

Table 1. Physicochemical characteristics of Raghunathpur soil (1st season)

Name of soil	Particle size (%)			Tex	Org C	pH	EC	θ_0
	S	Si	C	class	(%)		(dS/m)	(cm^3cm^{-3})
				0-15cm				
NIU	69	10	21	Scl	0.31	5.2	0.05	0.46
IC	13	18	69	C	1.03	5.4	0.07	0.64
WL	9	8	83	C	0.95	5.6	0.08	0.69
				15-30cm				
NIU	51	12	37	Sc	0.22	5.6	0.06	0.49
IC	1	22	77	C	0.72	5.9	0.08	0.64
WL	1	20	79	C	0.73	6.0	0.09	0.69
				30-45 cm				
NIU	71	8	21	Scl	0.36	5.7	0.05	0.47
IC	27	4	69	C	0.56	6.0	0.08	0.57
WL	21	6	73	C	0.56	6.5	0.09	0.63

S: sand, Si :Silt , C: clay, and l: loam; NIU: non-irrigated upland, IC: irrigated cultivated, WL: water logged.

Table 2. Physicochemical characteristics of Raghunathpur soil (2nd season)

Name of soil	Particle size (%)			Tex	Org C	pH	EC	θ_0
	S	Si	C	class	(%)		(dS/m)	(cm^3cm^{-3})
				0-15cm				
NIU	63	2	35	Scl	0.68	5.0	0.05	0.37
IC	27	2	71	C	1.33	5.8	0.07	0.57
WL	21	4	75	C	0.95	6.0	0.08	0.60
				15-30cm				
NIU	71	8	21	Scl	0.54	6.5	0.04	0.38
IC	27	4	69	C	0.95	6.6	0.07	0.59
WL	29	2	69	C	0.96	6.7	0.07	0.61
				30-45 cm				
NIU	79	2	19	Sl	0.40	5.9	0.05	0.47
IC	27	4	69	C	0.90	6.0	0.08	0.57
WL	21	6	73	C	0.90	6.7	0.11	0.59

S: sand, Si: Silt , C: clay, and l: loam; NIU: non-irrigated upland, IC: irrigated cultivated, WL: water logged.

Table 3. Water content of soil samples, gain in water content and sorptivity (1st season)

Name of soil	θ_i (cm^3cm^{-3})	θ_0 (cm^3cm^{-3})	θ_0-θ_i (cm^3cm^{-3})	Sorptivity ($mmmin^{-1/2}$)
		0-15cm		
NIU	0.01	0.29	0.28	4.0
IC	0.04	0.47	0.43	2.5
WL	0.05	0.47	0.42	1.59
		15-30cm		
NIU	0.01	0.31	0.30	4.0
IC	0.03	0.53	0.50	2.3
WL	0.04	0.49	0.45	1.3
		30-45cm		
NIU	0.01	0.35	0.34	3.9
IC	0.04	0.60	0.56	2.2
WL	0.04	0.60	0.56	1.2

$F_{2, 6\ (0\text{-}15cm)} > F_{tab\ (1\%)}$; C.D. = 2.7; T_1 = 12, T_2 = 7.5, T_3 = 4.8 (for sorptivity);
$F_{2, 6\ (15\text{-}30\ cm)} > F_{tab\ (1\%)}$; C.D. = 2.5; T_1 = 12, T_2 = 7.0, T_3 = 4.0
$F_{2,6\ (30\text{-}45\ cm)} > F_{tab\ (1\%)}$; C.D. = 2.5; T_1 = 11.5, T_2 = 6.9, T_3 = 4.0

Table 4. Water content of soil samples, gain in water content and sorptivity (2nd season)

Name of soil	θ_i (cm^3cm^{-3})	θ_0 (cm^3cm^{-3})	θ_0-θ_i (cm^3cm^{-3})	Sorptivity ($mmmin^{-1/2}$)
		0-15cm		
NIU	0.01	0.29	0.28	4.5
IC	0.04	0.45	0.41	2.2
WL	0.05	0.49	0.43	1.5
		15-30cm		
NIU	0.02	0.28	0.26	4.0
IC	0.03	0.53	0.5	2.0
WL	0.07	0.57	0.50	1.0
		30-45cm		
NIU	0.01	0.32	0.31	3.9
IC	0.06	0.55	0.49	2.0
WI	0.07	0.60	0.53	1.0

$F_{2, 6\ (0\text{-}15cm)} > F_{tab(1\%)}$; C.D. =2.8; T_1 = 11.7, T_2 = 6.6, T_3 = 3.6 (for sorptivity);
$F_{2, 6\ (15\text{-}30\ cm)} > F_{tab\ (1\%)}$; C.D. =2.5; T_1 = 11.8, T_2 = 6.0, T_3 = 3.6
$F_{2,6\ (30\text{-}45\ cm)} > F_{tab\ (1\%)}$; C.D. =2.6; T_1 = 11.0, T_2 = 6.5, T_3 = 3.5

soils. The gains were higher in I.C. and W.L. soils. Highest sorptivity (3.9-4.5 $mmmin^{-1/2}$) was observed in N.I.U. soil, followed by 2-2.5 mm $min^{-1/2}$ in I.C. soil and 1.0-1.59 $mmmin^{-1/2}$ in W.L. soils. Sorptivity values differ significantly for three different moisture regimes. These can also be verified from the slope of the cumulative infiltration vs. $t^{½}$ relationship (Fig. 2 and 4).

The soil organic matter of histic and mollic epipedons is characterized by a high content of humic acids than that of forest soils. The humic acid to fulvic acid ratio usually decreases with soil depth (Weil, 1993) as is also observed in the present study. The ratio were 6.0 (0-15cm) and 3.7 (15-30cm) for waterlogged soil (Tables 5 and 6). The humic acid (H.A.) and fulvic acid (F.A.) fractions of organic matter in the present study were separated by Kononova (1966) method and given in Tables 5 and 6. Fractionation of organic matter showed that % of H.A. was highest

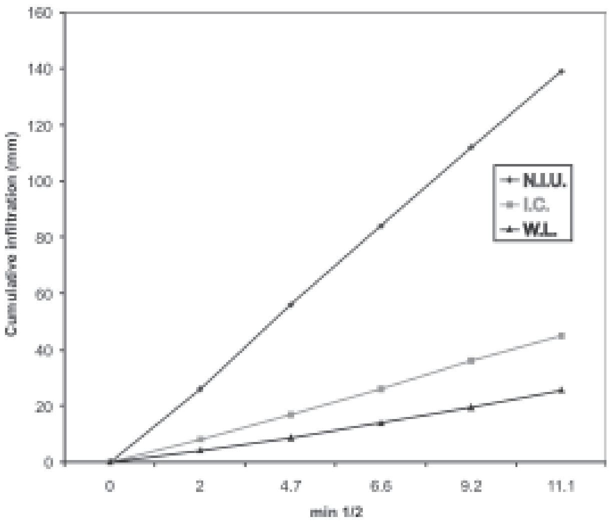

Fig. 4. Cumulative infiltration as a function of square root of time for soils of three moisture regimes (2nd season)

Table 5. Humic acid and fulvic acid in surface soil (0-15 cm) of Raghunathpur (1st season)

Soils	Total organic matter (%)	H.A. (%)	F.A. (%)
I.C.	1.93	0.5	0.12
W.L.	1.68	0.6	0.1
N.I.U.	0.68	0.07	0.2

I.C.: irrigated cultivated, W.L.: water logged , N.I.U.: non irrigated upland

Table 6. Humic acid and fulvic acid content of Raghunathpur soil (15-30cm)

Soils	Total organic matter (%)	H.A. (%)	F.A. (%)
I.C.	1.24	0.45	0.11
W.L.	1.26	0.33	0.09
N.I.U.	0.38	0.06	0.18

I.C.: irrigated cultivated, W.L.: water logged, N.I.U.: non irrigated upland

(0.6%) in W.L. soil and % of F.A. was lowest in the same soil. On the other hand the F.A. fraction was highest in N.I.U. soil. I.C. soils showed intermediate values. Decline in water repellency of soil was due to the presence of water soluble fulvic acid. The N.I.U. soils were having higher fraction of F.A. for which these were more capable of infiltration, where as W.L. soils having greater fraction of insoluble humic acid exhibited less cumulative infiltration.

The relationships between sorptivity and clay, pH, EC, porosity and humic acid were significant, exponential and negative (Table 7). Regression equations showed that sorptivity decreased as the clay content, pH, EC, porosity and humic acid content of the soil increased. These were in agreement with the findings of Singh and Kundu (2001) for Orissa soils.

Conclusions

Cumulative infiltration and sorptivity were higher in non-irrigated upland soil as compared to both irrigated cultivated and waterlogged soil as observed in the laboratory plexi-glass columns. Percentage H.A. was highest (0.6%) in W.L. soil and % of F.A. was lowest in the same soil. On the other hand, the F.A. fraction was highest in N.I.U. soil. I.C. soils showed intermediate values. Though topography and soil texture play an important role in deciding a soil should be waterlogged or not, decline in water repellency of soil in the present study was partially observed to be possibly due to the presence of water soluble fulvic acid. The N.I.U. soils were having higher fraction of F.A. for which these were more capable of infiltration, where as W.L. soils having greater fraction of insoluble humic acid exhibited less cumulative infiltration. The humic acid to

Table 7. Relation between sorptivity (S) and other parameters (x) of soil

Soil parameter	Correlation coefficient (r)	Regression equation
% clay	-0.86 **	$S = 6.0\ e^{-0.02-x}$
pH	-0.70 *	$S = 359.5\ e^{-0.87-x}$
EC (dS / m)	-0.94 **	$S = 18.2\ e^{-28.5-x}$
Porosity ($cm^3\ cm^{-3}$) (saturated water content)	-0.87 **	$S = 31.9\ e^{-4.5-x}$
Humic acid (%)	-0.85 **	$S = 4.3\ e^{-1.7-x}$

*significant at 5% probability level, **significant at 1% probability level.

fulvic acid ratio usually decreases (Weil, 1993) with soil depth as has also been observed in the present study.

Acknowledgements

Authors acknowledge Dr. R.N. Sahoo, Principal Scientist, DWM for his support during conduct of this research.

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