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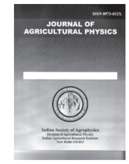

Comparative Study on Soil Water Functional Relationship in Two Texturally Different Inceptisols

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ABSTRACT

Knowledge of the water transmission characteristics in the *vadose zone* is essential for the solution of problems involving irrigation, drainage, water conservation, nutrient and water uptake by crop plants and ground water recharge and pollution. Estimation of such hydrological properties of soil over large agricultural areas by usual laboratory and field procedure are time consuming, labour intensive and cost prohibitive. The method described by Campbell (1974) for the determination of soil hydrological properties like capillary conductivity, hydraulic diffusivity is most common and widely used. The prerequisite of this method is moisture retention curve i.e. (ψ-θ) relationship. Water retention (θ) of the samples at various suctions (ψ) were estimated by using pressure plate apparatus. Using proper relationship as described by Campbell (1974) the $K(\theta)$ and $D(\theta)$ were estimated depth wise for two texturally different soils of IARI farm in New Delhi. At a particular suction, capillary conductivity and soil water diffusivity were generally higher in fine than in coarse textured soils. Continuity of the pores in the fine textured soils might have resulted in the higher values for diffusivity and conductivity observed compared to those for the coarse textured soils.

Key words: Inceptisol, Water retention, Hydraulic conductivity, Diffusivity

Introduction

Water is a scarce, precious and essential resource in agriculture. Efficient use of limited water resources for optimization of crop productivity and proper land and water management, under both irrigated and rainfed farming, requires a thorough understanding of the pertinent hydrological properties, soil water retention characteristics and available water capacity of soils. Dynamics of water in unsaturated soil system can be described by various differential equations derived from the combination of Darcy's law and conservation of mass of principle. Derivations of such equations under varying boundary and initial conditions require knowledge of volumetric water content in soil (θ), soil water suction (ψ), rate at which water flows in the soil (K), soil water diffusivity (D), change in soil water content per unit change in suction (C), and the relationships among them. Direct measurement of unsaturated hydraulic conductivity requires considerable involvement of time, energy and expenditure. Therefore, attempts have been made to calculate the relative unsaturated hydraulic conductivity from the not so-difficult to measure retention curve (Childs and Collis-George,1950; Burdine, 1953; Mualem, 1976).

This study was conducted to evaluate and compare the unsaturated hydraulic conductivity and soil water diffusivity of two texturally different soils found on the farm of Indian Agricultural Research Institute in New Delhi by the very commonly used model of Campbell, 1974.

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Materials and Methods

Samples for water retention study were collected using metal cores of 5-cm diameter from 0-15, 15-30, 30-60, 60-90, and 90-120 cm soil depth from two places within the two textured soil areas of IARI. Water retention (θ) of the samples at various suctions (ψ) was estimated by using pressure plate apparatus (Richards, 1965) and are presented in Figure 1(a) and 1(b). The soil samples were analyzed for pH (Jackson, 1973), EC (Richards, 1954), organic carbon (Walkley and Black, 1934) and mechanical composition (Bouyoucos, 1962) and are presented in Table 1(a). Soil bulk density, saturation water content and saturated hydraulic conductivity for each layer was found out by core method (Blake and Hartge, 1986), gravimetric method (Wilcox, 1951) and constant head method (Klute and Dirksen, 1986) respectively and is presented in Table 1(b).

In order to establish relationships between soil water suction and water content, procedure outlined by Campbell (1974) and subsequently used by Oswal (1993), and Singh and Bhargava (1994) was used. For this a graph between log ψ and log (θ/θ_s) (θ_s = soil water content at saturation) was plotted for each soil layer. For the graph, data points corresponding to near-saturation were discarded and remaining data were best fit statistically to the Campbell's equation:

$$\psi/\psi_e = (\theta/\theta_s)^{-b} \quad \ldots(1)$$

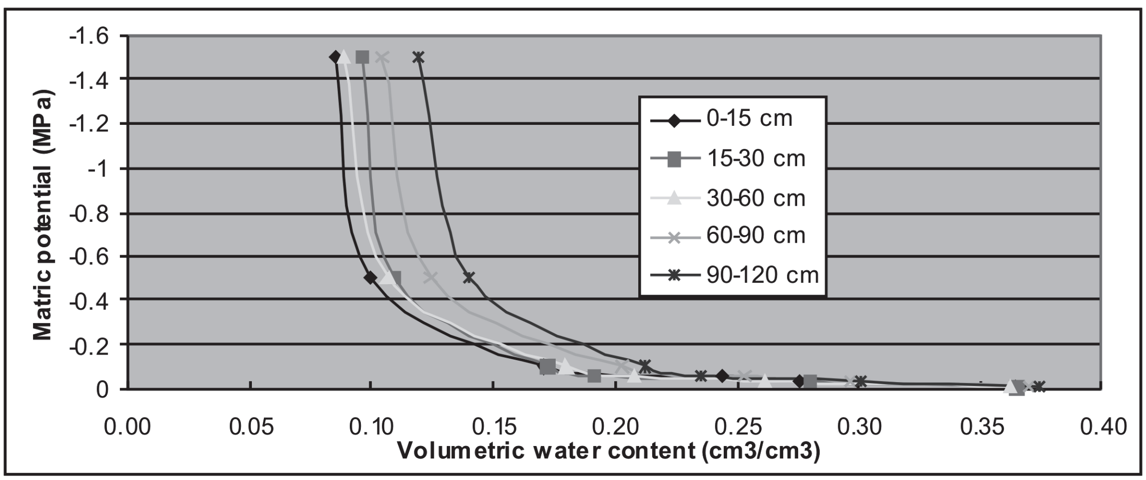

Fig. 1a. Matric potential *vs.* volumetric water content relationship of sandy loam soils (Site A)

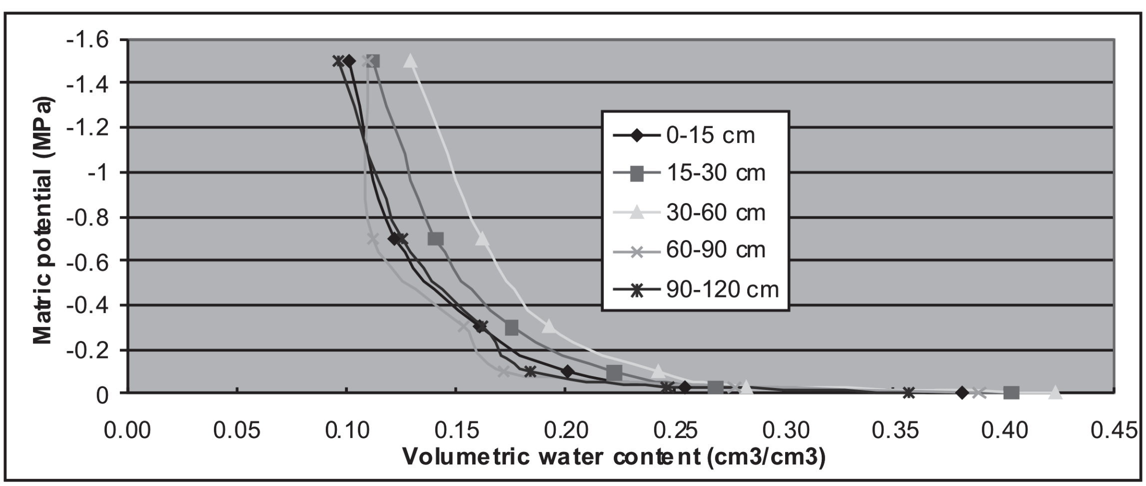

Fig. 1b. Matric potential *vs.* volumetric water content relationship of loam soils (Site B)

Table 1(a). Selected soil physico-chemical properties of Site A and Site B

Depth (cm)	Sand (%)		Silt (%)		Clay (%)		Texture		pH		EC (dS/m)		Organic carbon (%)	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
0-15	64.00	40.60	16.80	38.60	19.20	20.80	SL	L	7.87	7.82	0.82	0.81	0.86	0.53
15-30	64.40	38.45	10.70	38.90	24.90	22.65	SCL	L	8.32	7.01	0.74	0.78	0.66	0.41
30-60	63.80	39.90	10.00	36.75	26.20	23.35	SCL	L	7.82	7.80	0.83	0.76	0.64	0.31
60-90	59.80	39.80	10.00	39.80	30.20	20.40	SCL	L	8.12	7.91	0.71	0.74	0.6	0.19
90-120	53.70	41.10	13.40	40.25	32.90	18.65	SCL	L	8.15	7.96	0.76	0.80	0.58	0.14

Table 1(b). Selected soil physico-chemical properties of Site A and Site B

Depth (cm)	Bulk density (g/cm^3)		Air-entry suction (cm)		Soil Parameter, b		Saturation water content (cm^3/cm^3)		Saturated hydraulic conductivity (cm/hr)	
	A	B	A	B	A	B	A	B	A	B
0-15	1.58	1.40	99.04	58.84	3.11	3.87	0.394	0.426	1.01	0.13
15-30	1.61	1.47	71.81	62.49	3.47	4.09	0.399	0.440	0.82	0.12
30-60	1.64	1.48	71.71	63.90	3.41	4.43	0.401	0.452	0.71	0.09
60-90	1.71	1.50	84.80	63.97	3.65	3.64	0.414	0.428	0.49	0.06
90-120	1.72	1.50	72.06	60.19	4.17	4.02	0.411	0.398	0.39	0.05

where, ψ_e is the air entry suction, which refers to negative pressure of the soil water when the air at the atmospheric pressures enters the soil with a continuous water phase (Bouwer, 1966) and 'b' is a soil parameter. The parameters ψ_e and b were evaluated by measuring slope and intercept of the best fit equation, respectively.

From the knowledge of K_s (saturated hydraulic conductivity), θ_s (saturation water content) and b (soil parameter); capillary conductivity (K) was functionally related to water content by using the Campbell's equation:

$$K/K_s = (\theta / \theta_s)^{2b+3} \quad \dots (2)$$

K-ψ functional relationship was then worked out by using following relationship:

$$K = K_s (\psi_e/\psi)^{2+3/b} \quad \dots (3)$$

Soil water diffusivity (D) was computed from the following relationship:

$$D = b\, \psi_e\, K_s\, (\theta^{b+2}/\theta_s^{b+3}) \quad \dots (4)$$

Results and Discussion

Important physico-chemical properties of soils of two sites are presented in Table 1(a) and (b). The sand content at site A varied from 53.7 to 64.4% and at site B from 38.45 to 41.1% with increasing depth. The silt content at site A varied from 10.0 to 16.8% and at site B from 36.75 to 40.25% layer wise. The clay content ranged from 19.2 to 32.9% at site A and 18.65 to 23.35% at site B. Site A was basically sandy clay loam in texture and site B was loam in texture. Electrical conductivity (EC) varied from 0.71 to 0.83 dS/m at site A and from 0.74 to 0.81 at site B implying no salinity problem existing in the soils of both site. The soil pH ranged from 7.82 to 8.32 at site A and 7.01 to 7.96 at site B indicating the soil is neutral to slightly alkaline in reaction at both the sites. The organic carbon content varied between 0.86 to 0.58% at site A and 0.53 to 0.14% at site B. The organic carbon content at both the sites decreased from surface to lower soil depths. Bulk density varied between 1.58 to 1.72 g/cc at site A and 1.40 to 1.50 g/cc at site B. Like organic carbon, bulk density also showed decreasing trend depth wise at both the places. The values of 'b' and 'ψ_e' were obtained from the best fit lines between log ψ and log θ/θ_s. Saturation water content (θ_s) of site A varied between 0.39 to 0.41 cm^3/cm^3 and of site B 0.40 to 0.45 cm^3/cm^3. Air entry suction varied between 71.71 to 99.04 cm at site A and 58.84 to 63.97 cm at site B. The

Table 2. Capillary conductivity of soils of Site A and Site B

Depth (cm)	Capillary conductivity (m/sec)							
	Site A				Site B			
	0.01 MPa	0.033 MPa	0.1 MPa	1.5 MPa	0.01 MPa	0.033 MPa	0.1 MPa	1.5 MPa
0-15	1.38×10^{-06}	1.05×10^{-07}	1.27×10^{-09}	2.07×10^{-12}	1.09×10^{-07}	1.39×10^{-09}	1.13×10^{-10}	6.91×10^{-14}
15-30	9.48×10^{-07}	6.78×10^{-08}	5.64×10^{-10}	1.61×10^{-12}	1.25×10^{-07}	1.37×10^{-09}	1.60×10^{-10}	7.66×10^{-14}
30-60	7.40×10^{-07}	3.00×10^{-08}	7.52×10^{-10}	7.42×10^{-13}	1.17×10^{-07}	9.64×10^{-10}	1.50×10^{-10}	8.60×10^{-14}
60-90	3.39×10^{-07}	3.52×10^{-08}	6.97×10^{-10}	7.83×10^{-13}	6.24×10^{-08}	1.90×10^{-09}	7.68×10^{-12}	1.44×10^{-13}
90-120	2.91×10^{-07}	2.41×10^{-08}	4.52×10^{-10}	7.13×10^{-13}	4.18×10^{-08}	7.17×10^{-10}	2.78×10^{-11}	2.37×10^{-14}

Table 3. Soil water diffusivity of soils of Site A and Site B

Depth (cm)	Soil water diffusivity (m^2/sec)							
	Sandy loam soil				Loam soil			
	0.01 MPa	0.033 MPa	0.1 MPa	1.5 MPa	0.01 MPa	0.033 MPa	0.1 MPa	1.5 MPa
0-15	1.48×10^{-05}	3.55×10^{-06}	3.08×10^{-07}	8.76×10^{-09}	1.00×10^{-06}	9.27×10^{-08}	2.34×10^{-08}	4.12×10^{-10}
15-30	8.80×10^{-06}	2.06×10^{-06}	1.48×10^{-07}	5.88×10^{-09}	1.13×10^{-06}	9.68×10^{-08}	3.01×10^{-08}	4.68×10^{-10}
30-60	7.01×10^{-06}	1.20×10^{-06}	1.57×10^{-07}	3.48×10^{-09}	1.04×10^{-06}	7.70×10^{-08}	2.81×10^{-08}	4.91×10^{-10}
60-90	5.44×10^{-06}	1.57×10^{-06}	1.83×10^{-07}	4.40×10^{-09}	5.29×10^{-07}	7.79×10^{-08}	3.79×10^{-09}	4.27×10^{-10}
90-120	2.73×10^{-06}	7.03×10^{-07}	8.08×10^{-08}	2.41×10^{-09}	4.39×10^{-07}	4.78×10^{-08}	8.12×10^{-09}	1.72×10^{-10}

b value varied between 3.11 to 4.17 at site A and 3.64 to 4.43 at site B. The saturated hydraulic conductivity at site A varied between 1.01 cm/hr to 0.39 cm/hr and at site B between 0.13 to 0.05 cm/hr. The saturated hydraulic conductivity showed decreasing trend with depth at both the sites.

Water contents measured in 5 depths of each site at different suctions are presented in Figure 1(a) and (b). At site A, at any given suction maximum water was retained in soils of 90-120 cm and least was retained in soils of 0-15cm. Retention of water in remaining soils of three depths were in the middle of the range. For site B, at any given suction maximum water was retained in soils of 30-60 cm soil depth and least was retained in soils of 60-90 cm soil depth. Difference between water content at 0.33 and 15.0 bar suctions is generally taken as available water content of soil. It is found that available water content was highest (0.192 cm^3/cm^3) in soils of 60-90 cm depth and lowest (0.173 cm^3/cm^3) in soils of 30-60 cm depth at site A. For site B, available water was highest (0.167 cm^3/cm^3) in soils of depth 60-90 cm depth and lowest (0.150 cm^3/cm^3) in soils of 90-120 cm depth. Observed differences in retention and availability of water in the soils could generally be attributed to the difference in their clay content, clay mineralogy, organic matter content etc. The ψ-θ relationship of soils suggested that frequent irrigation using small amount of water each time will be required to improve use efficiency of water applied without any adverse effect on soil.

Data on soil water diffusivity and capillary conductivity of soils at different suctions (0.01, 0.033, 0.1 and 1.5 MPa) of two sites are presented in Table 2 and 3. Soil water diffusivity as well as capillary conductivity decreased with increase in suction. Regardless of soil type, highest and lowest values were recorded at 0.01 and 1.5 MPa suction respectively. At a particular suction, capillary conductivity and soil water diffusivity were generally higher in fine-than in coarse textured soils. Continuity of the pores in the fine textured soils could be a possible reason for the higher diffusivity and conductivity observed. At all levels of suction, capillary conductivity and soil water diffusivity were high in soils of site A than site B.

Conclusions

Thus from this study it may be concluded that at a particular suction, capillary conductivity and soil water diffusivity were generally higher in the fine textured soils than coarse textured soils. Hence, frequent and light irrigations, preferably drip or sprinkler irrigation, will prove useful to improve use efficiency of applied water and increasing crop yields in coarse textured soils.

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