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Effect of Organic Matter and Initial Moisture Content on Water Transmission Characteristics of Alfisols of Assam

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Abstract: A study was conducted to study the effect of organic matter and initial moisture content on water transmission behaviour of three texturally different Alfisols. Saturated hydraulic conductivity showed a variable increase with increase in organic matter. Soil water diffusivity D (è) showed an irregular trend with increasing levels of organic matter while sorptivity (s) increased with increasing levels of organic matter but, penetrability (P) of wetting front decreased. Weighted mean diffusivity did not show any particular trend amongst the treatments, however, it was found to be higher in treated soils as compared to untreated control. Specific water capacity increased with increasing levels of organic matter, while capillary conductivity (k) did not show any definite trend. All the water transmission parameters except sorptivity were found to be increased with an increase in initial moisture content. Diffusivity was in general higher at lower initial moisture content indicating that soil water diffusivity was greatly influenced by initial moisture content. Prediction of D (è) was, by and large, satisfactory in coarse textured soils and inconclusive in case of K (è) relation in most of the soils.

Key words : *Initial moisture, conductivity, diffusivity, penetrability.*

Introduction

Water transmission properties of soil influence the water regime of soil and constitute an important factor which influences crop growth and development. The movement of water in soil is of great significance in both rain-fed and irrigated agriculture. The ability of a soil to produce crops is dependent in addition to the adequate supply of nutrients, upon its physical condition influencing soil-air-water relationship, which in optimum ratio is needed for the maximum use of the available nutrients by the plants. Among the soil constituents known to influence hydraulic properties of soil, the role of organic matter has long been recognized. The initial soil physical condition is also of much significance that influences physico-chemical characteristics. Judicious exploitation of soil and water resources and their relation to organic matter and initial water content warrants considerable attention in present day research in the context of ever increasing demand for higher agricultural production. The capacity of the soil to transmit water helps in maintaining the water balance in soil and is greatly influenced by organic matter content and initial water content. The saturated hydraulic conductivity and weighted mean diffusivity of soil is known to increase significantly on application of organic matter (Poonia and Pal 1979). Similarly Prasad and Singh (1980) reported an improvement in saturated hydraulic conductivity on long-term use of organic matter in soil while Saxton and Rawls (2006) reported the influence of organic matter on soil water characteristics. Eusufzai and Fujii (2012) reported that addition of biomass increased the water retention characteristics, hydraulic conductivity, number of macro- and mesoporosity. *José Ricardo da Rocha Campos et al.* (2011) reported that organic matters were positively and mineral materials were negatively correlated with gravimetric moisture, respectively. The weighted mean diffusivity of soil is known to be influenced by initial water content tremendously. Tripathi and Ghildyal (1976) reported that soil water diffusivity was very rapid near saturation and below 33kpa and relatively constant between 11kpa and just below saturation. Soil water penetrability is also an important factor in determining water regime of soil. Higher penetrability is associated with poor soil physical condition leading to quicker drying of the soil. Kumar *et al* (1985) reported decreased

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penetrability of soil on addition of organic matter. Similarly, sorptivity reflects the rate of gradual adsorption of water by soil. Addition of organic matter affects the dispersion ratio of soil very much. This has a direct effect on enhanced sorptivity of soil. Having gone through the relevant literatures on the influence of organic matter and initial moisture on water transmission, it was thought worthwhile to carry out this experiment with texturally different soils treated with different levels of FYM.

Materials and Methods

Bulk soil samples (Alfisols) were collected from 12 locations *viz*., Baruabamungaon, Borhola, Bukahola, Dergaon, Dhekial, Golaghat, Nambor, Nogabat, Podumoni, Silonijan, Thuramukh and Titabor in Assam. Processed soils were treated with different levels of well decomposed FYM *viz*. 5, 10 and 15 tonnes ha^{-1} and then wetted to a constant water content nearing field capacity along with a no organic matter control. The soils were incubated for 8 months at room temperature with occasional mixing for attaining homogeneity. These soils were then dried and stored for further treatment.

Three texturally different soils were selected and three different initial water contents *viz* 4, 8 and 12 per cent were created. The amount of water required were computed and added to known weight of the treated soils. Water content in these soils was checked gravimetrically on replicated samples.

Saturated hydraulic conductivity was determined in these disturbed soils by packing the soils in a core sampler maintaining a bulk density of 1.35 Mg m^{-3}. Then these soils were allowed to saturate for 48 hours and the saturated hydraulic conductivity was determined following the principle of Darcy's law. The method outlined by Bruce and Klute (1956) was adopted for determining the soil water diffusivity, soil water penetrability and sorptivity. The treated soils were packed into sectioned plexiglass diffusivity columns with a constant bulk density of 1.35 Mg m^{-3}. Water was allowed to enter the horizontal soil column in the diffusivity assembly and after the wetting front reached about 18 cm, the assembly was immediately dismantled and water content in different sections was determined. Diffusivity as a function of water content was estimated as:

$$D(\theta) = -\frac{1}{2t}\left(\frac{dx}{d\theta}\right)\int_{\theta i}^{\theta} x d\theta$$

Where D (θ) = soil water diffusivity at water content θ, x = distance of the wetting front, t = time required for the wetting front to reach distance x. θi = initial moisture content. The D (θ) at an interval of θ = 0.05, was taken to compute the weighted mean diffusivity ($\bar{D}$) following Crank (1956) as under

$$\bar{D} = \frac{5}{3}\left(\frac{1}{(\theta s - \theta i)}\right)^{(5/3)}\int_{\theta i}^{\theta s} D(\theta)(\theta - \theta i)^{2/3}.d\theta$$

Where θs = water content at saturation, θi = initial water content.

Soil water penetrability and sorptivity were determined from the advancement of wetting front by following the equation given by Phillip (1957) as under:

$P = x/\sqrt{t}$

$s = Q/\sqrt{t}$

Where P = Soil water penetrability, s = sorptivity, x = final distance of wetting front, Q = total volume of water absorbed by soil and t = time taken for completion of the horizontal infiltration.

Results and Discussion

Data on mechanical composition of soils along with their basic physical properties are presented in table 1. Soils varied in their texture from silty clay loam to sandy loam with sand per cent ranging from 59.6 (Nambor) to 18.2 per cent (Golaghat). The per cent silt had a maximum value of 50.0 (Podumoni) and a minimum of 22.9 (Silonijan) and the clay per cent varied from a maximum of 39.8 (Titabor) to a minimum of 10.0 (Nambor). Maximum (1.62 %) organic carbon was obtained in Nambor; while it was minimum (0.68 %) in Silonijan.

Data presented in (Table 2) indicates that bulk density was considerably reduced on addition of organic matter. This had resulted in increased porosity and reduced dispersion ratio of the soils. These changes had influenced the water transmission properties of the soils at varying proportions. The various soil water transmission properties *viz*. saturated hydraulic conductivity(Ks),weighted mean diffusivity ($\bar{D}$), penetrability (P) and sorptivity (S) are presented in (Table 2). Saturated hydraulic conductivity (Ks) showed variable increase in all the soils treated with organic matter as compared to untreated control (Table 2). The increase was pronounced in Silonijan and Thuramukh which is evident from the change in Ks from moderately slow to moderate and slow to moderately slow respectively. The highest value of Ks was observed in Nambor (sandy loam), while lowest in Titabor (clay loam). All the soils were categorized into slow to moderate class of hydraulic conductivity. It was observed that addition of organic matter positively influenced the saturated hydraulic conductivity (Table 2). This can be attributed to the increase in macropores resulting from the binding of silt and clay particles together by organic matter which ultimately reduced the bulk density of soil.

Data on weighted mean diffusivity (θ) did not show any definite trend among the treatments, but the value of (θ) was found to be higher in treated soils than the untreated control (Table 2). D (θ) increased exponentially with an increase in water content for all the soils. However, there was no definite trend of D (θ) with increasing level of organic matter. There was an increased sorptivity (S) over control in all the treated soils. The highest values of sorptivity were observed in Titabor, while the lowest in Nambor, irrespective of treatments. The values of soil water penetrability (P) were found to decrease with the progressive increase in organic matter in all the soils with the maximum value in Nambor and the minimum in Golaghat (Table 2).

The data on effect of initial moisture content on water transmission characteristics of soils are presented in (Table 4.) Weighted mean diffusivity (θ) in the selected three soils was found to increase with increase in initial moisture content irrespective of textural make- up of the soils. However, the relative degree of increase was more in Nambor (sandy loam) and less in Titabor (clay loam). Influence of initial moisture content on soil water diffusivity (D (θ)) at various water content is shown in fig. 1 (a,b,c). D (θ) increased with increasing initial water content of soils. The soil water penetrability (P) was found to increase contrary to sorptivity (S) with increase in initial moisture content of soils.

Although soil water diffusivity at field capacity moisture (r = 0.19) and permanent wilting point (r = 0.21) showed non-significant positive correlations with organic carbon, the weighted mean diffusivity, on the other hand, maintained a significant positive correlation (r =0.37 at 5% level of significance) through the impact of favourable pore geometry of soils. Application of organic matter in soils increased the retentivity of water by soils, thereby decreased the rate of advancement of the wetting front which in-turn reduced the penetrability, as evident from the non-significant negative correlation (r = -0.18) between penetrability and organic carbon; contrary to this a positive correlation (r = 0.27) although non-significant, between sorptivity and organic carbon may be attributed to the increase in porosity as a result of addition of organic matter.

Soil water diffusivity increased with increase in initial moisture content of soils. D (θ) at field capacity and permanent wilting point as well as weighted mean diffusivity (θ) showed positive correlations with initial moisture content (r = 0.21, r s = 0.28 and r = 0.47, respectively), which is probably due to a water storage effect (Bhadoria and Datta 1980). Increase in initial

Table 1 : Mechanical composition of the soils

Site	**Sand**	**Silt**	**Clay**	**Textural class**
		%		
Baruabamungaon	23.4	37.2	35.6	Clay loam
Borhola	35.5	29.7	31.4	Clay loam
Bukahola	31.2	34.0	32.5	Clay loam
Dergain	26.6	38.5	32.6	Clay loam
Dhekial	25.8	36.5	33.8	Clay loam
Golaghat	18.2	40.5	38.6	Silty clay loam
Nambor	59.6	24.6	10.0	Sandy loam
Nogabat	25.0	38.1	34.6	Clay loam
Podumoni	26.7	50.0	21.8	Silty loam
Silonijan	54.0	22.9	20.0	Sandy loam
Thuramukh	19.2	41.0	36.4	Silty clay loam
Titabor	21.0	37.2	39.8	Clay loam

Table 2. Effect of organic matter on basic physical and water transmission properties of soil

Soil location	FYM ($t\ ha^{-1}$)	Organic carbon (%)	Bulk density ($Mg\ m^{-3}$)	Porosity (%)	Dispersion ratio	Saturated hydraulic conductiviy ($cm\ hr^{-1}$)	Weighted mean diffusivity ($cm^2 min^{-1}$)	Sorptivity ($ml\ min^{-1}$)	Penetrability ($cm\ min^{-0.5}$)
Barua-bamungaon	0	1.26	1.46	50.00	6.52	5.24	0.65	10.14	1.37
	5	1.32	1.43	51.85	6.18	5.76	0.84	11.18	1.32
	10	1.44	1.41	53.60	5.84	6.27	1.43	12.22	1.26
	15	1.56	1.39	56.22	5.49	6.91	1.19	13.20	1.21
Borhola	0	0.96	1.41	45.60	4.91	6.14	0.61	9.43	1.58
	5	1.08	1.38	46.90	4.50	6.75	1.08	10.36	1.52
	10	1.19	1.37	47.95	4.09	7.49	1.10	11.20	1.45
	15	1.30	1.35	49.80	3.68	8.10	0.86	12.04	1.38
Bukahola	0	1.20	1.45	46.85	4.89	5.87	0.44	9.47	1.45
	5	1.28	1.43	47.80	4.51	6.30	1.02	10.27	1.38
	10	1.39	1.42	48.90	4.13	7.17	0.79	11.04	1.32
	15	1.49	1.40	49.95	3.76	7.91	0.52	11.76	1.26
Dergaon	0	0.90	1.40	48.08	5.62	5.72	0.44	10.00	1.50
	5	1.04	1.38	49.81	5.27	6.22	0.55	10.96	1.44
	10	1.15	1.37	51.45	4.92	7.09	0.99	11.76	1.37
	15	1.28	1.34	53.34	4.57	7.71	1.04	12.56	1.31
Dhekial	0	0.80	1.48	48.72	6.04	5.56	0.50	9.90	1.43
	5	0.87	1.47	50.00	5.69	6.18	0.99	10.82	1.38
	10	0.99	1.45	51.70	5.33	6.80	1.06	12.25	1.31
	15	1.11	1.42	53.42	4.98	7.36	0.65	12.85	1.26
Golaghat	0	1.30	1.43	53.00	7.58	3.00	0.35	12.29	1.06
	5	1.39	1.40	55.10	6.95	3.25	0.63	13.26	1.03
	10	1.50	1.38	56.85	6.64	3.75	0.60	14.22	0.99
	15	1.61	1.35	58.90	6.32	4.75	0.48	15.22	0.96
Nambor	0	1.62	1.51	39.47	3.61	21.03	0.75	6.64	2.17
	5	1.67	1.50	42.28	2.89	22.88	2.01	7.48	2.07
	10	1.76	1.47	45.70	2.53	25.11	1.09	8.19	1.94
	15	1.86	1.46	47.90	2.17	28.46	2.38	8.80	1.80
Nogabat	0	1.00	1.48	49.43	6.19	5.44	0.80	10.26	1.43
	5	1.06	1.46	50.84	5.84	6.01	0.85	11.20	1.37
	10	1.17	1.43	52.40	5.50	6.59	1.24	12.12	1.32
	15	1.29	1.40	54.60	5.16	7.16	1.10	12.95	1.25
Podumoni	0	0.92	1.38	45.62	4.53	6.32	0.20	9.27	1.67
	5	0.99	1.35	46.80	4.18	7.12	0.77	10.29	1.60
	10	1.09	1.33	48.10	3.83	7.98	14.08	11.30	1.52
	15	1.20	1.30	49.05	3.48	8.60	0.95	12.16	1.45
Silonijan	0	0.66	1.50	40.06	4.08	19.65	0.64	7.85	2.01
	5	0.72	1.48	41.80	3.49	21.39	0.90	8.67	1.91
	10	0.82	1.45	43.50	2.91	24.26	0.69	9.40	1.79
	15	0.94	1.42	45.20	2.33	28.30	1.08	10.08	1.68
Thuramukh	0	1.30	1.40	51.06	6.78	4.94	0.68	11.59	1.25
	5	1.36	1.38	53.10	6.45	5.32	0.81	12.61	1.21
	10	1.47	1.35	55.00	6.13	5.93	0.71	13.57	1.16
	15	1.58	1.32	57.00	5.81	6.68	1.09	14.52	1.11
Titabor	0	1.12	1.46	53.18	7.79	2.63	0.17	13.25	1.08
	5	1.24	1.44	55.25	7.14	2.88	0.35	14.31	1.05
	10	1.37	1.41	57.58	6.81	3.25	0.70	15.50	1.02
	15	1.49	1.39	60.00	6.49	4.50	0.38	16.87	0.98

moisture content in soil capillaries makes the liquid phase more continuous and tends to reduce the tortuosity of the flow path resulting in an increase of the rate of wetting front advance and ultimately increases the diffusivity and weighted mean diffusivity. The soil water diffusivity increased almost exponentially with increase in initial water content (Barua *et al.* 1985).

Soil water penetrability increased with increasing initial moisture content which in evident from the positive correlation (r = 0.23) existing between them. This may be interpreted by the fact that, with the increase in organic matter wider pores become available to the incoming water front without the need for it to traverse the intricate, narrow and dead pores, as they are already filled with water; this causes the effective pore radii to increase, resulting in an increase in penetrability.

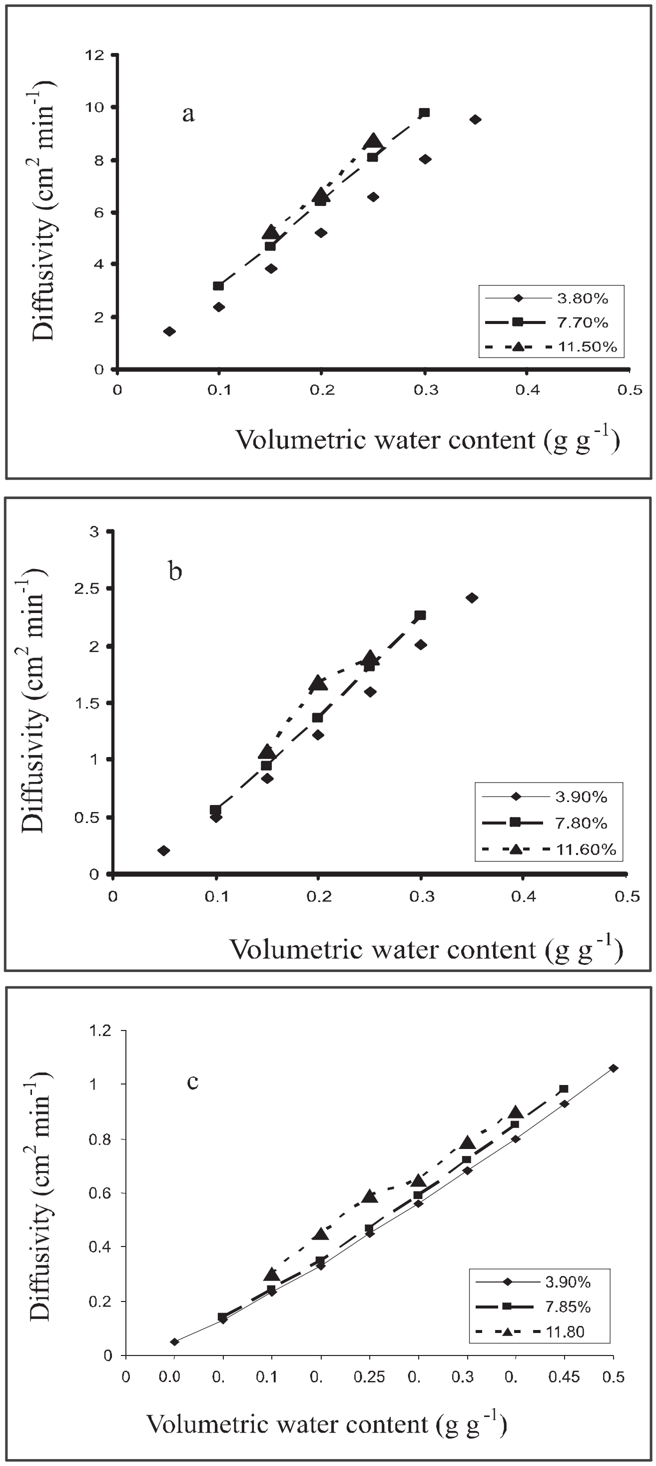

Fig. 1. Effect of initial moisture content on soil water diffusivity in (a) Nambor, (b) Podumoni (c) Titabor soils

A negative correlation (r = -0.27) obtained between sorptivity and initial moisture content may be substantiated by the fact that with increasing moisture content, most of the storage pores become filled with water resulting in a decrease in sorptivity; or it may be due to a decrease in soil water contact angle with increasing initial moisture content (Philip, 1957).

Table 3. Effect of initial moisture content on water transmission properties of soil

Soil location	Initial moisture content (%)	Weighted mean diffusivity (cm^2 min^{-1})	Sorptivity (ml min^{-1})	Penetrability (cm min^{-1})
Nambor	3.8	1.14	6.5	2.36
	7.7	3.13	5.88	2.6
	11.5	3.33	5.16	2.81
Podumoni	3.9	0.34	8.83	1.75
	7.8	0.59	8.17	1.85
	11.6	0.75	7.46	2
Titabor	3.9	0.22	12.69	1.1
	7.85	0.27	11.91	1.13
	11.8	0.33	10.96	1.18

Conclusion

It is evident that addition of organic matter in these soils did not result in significant improvement of water transmission properties. However, the time period of incubation may have to be increased from the 8 months, supplemented by the experimental results from fields, to ascertain the results of the present investigation. Prediction of D (è) was, by and large, can be successfully utilized in coarse textured soils and but not K (è) relation in most of the soils. Also, the role of organic matter may be more pronounced in increasing the storage pores, but not in transmission pores. Besides, it may be of help in improving transmissivity in fine textured soils more than the light textured soils.

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