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Water retention and transmission characteristics of jute growing soils of Nagaon district of Assam

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ABSTRACT

Water retention and transmission characteristics of the jute growing soils of Nagaon district, Assam were studied. The multi–location soil samples were collected from six jute–growing blocks, namely Khagorijan, Raha, Rupohi, Dhing, Laowkhowa and Juria. The soils were acidic in reaction and clay loam in texture. The Soils were enriched in organic carbon content (1.02% to 1.11%) and medium to marginally high in available nutrient contents. The characteristics of soil water retention indicated that at any given suction, the magnitude of water retention follow the order: Rupohi > Raha > Khagorijan > Dhing > Laowkhow > Juria. Available water capacity among the various soils varied in between 0.18 $m^3 m^{-3}$ and 0.30 $m^3 m^{-3}$. Wide variations among the soils were observed in unsaturated hydraulic conductivity K(θ) and water diffusivity D(θ). The K(θ) fluctuated from 0.12×10^{-11} to 0.33×10^{-3} cm min^{-1} whereas the soil water diffusivity among the various blocks varied in between 0.08×10^{-7} and 0.02×10^{-3} $cm^2 min^{-1}$. It is evident in the present study that the soils of Rupohi, Raha and Khagorijan blocks of Assam had high moisture retention and available water capacity but low K(θ) and D(θ). In rainfed condition, raising jute as well as other crops is possible in the soils of Rupohi, Raha and Khagorijan blocks of Nagaon district if the crop and time of its sowing are properly selected. Proper moisture conservation practices should be adopted for growing *rabi* crop in the soils of Dhing, Laowkhow and Juria blocks of Nagaon district as they had medium moisture retentivity and available water and relatively high K(θ) and D(θ).

1. INTRODUCTION

Water is considered to be the key input for augmenting agricultural production as well as for minimizing the adverse effects of vagaries of weather as prevalent in any region. However, the scenario of this resource has changed with increase in population and change in management practices. Per capita availability of water has radically reduced from over 5000 m^3 in the 50's to a meager 1656 m^3 in 2007 and is conjectured to be well less than the internationally prescribed level (1700 m^3) to 1140 m^3 by 2050 (Sen, 2009). North–east hill region is endowed with bounty of water resources accounting for about 46% of the total water resources in the country. The tentative assessment of this dynamic resource in the region is about 60 M ha m mostly because of high amount of rainfall. But lack of appropriate rainwater management conditions coupled with lack of suitable soil and water conservation measures reduce the crop productivity.

Jute, being second most important fibre crop in India, is in great demand in Assam. It is the second largest jute producing state in India. Assam alone produces 1.6 million bales of jute in Nagaon, Goalpara, Barpeta and Darrang districts, the main jute producing districts of Assam. Nagaon district having several jute mills has maximum area under jute cultivation. However, jute cultivation is facing some problems for the last few years because of erratic rainfall pattern, a climate change effect. A clear understanding of the hydraulic functions of such soils may help in formulating improved water management strategies and thus improving the prospect of crop production. Preparation of any management strategy in water conservation, drainage and solute migration and development of various hydrological models require basic information on soil hydraulic properties (Singh and Bhargava, 1993). Among hydraulic properties of a soil, water retention and hydraulic conductivity are highly non–linear functions of pressure head. The time, cost and difficulty involved in measuring these soil properties and the relationship between soil water content and potentials remain a major limitation (Adhikary *et al*., 2008 and Saha *et al*., 2013). However, no information is available on soil moisture retention–transmission characteristics under this agro–ecosystem. The present investigation, therefore, has been undertaken in various blocks of Nagaon district of Assam to evaluate the soil water dynamics and soil water transmission and retention properties.

2. MATERIALS AND METHODS

The study was conducted under All India Network Project on Jute and Allied Fibres (AINPJAF) programme on the soils of jute growing blocks of Nagaon district, Assam. Nagaon is centrally located district in Assam, situated on the southern bank of the Brahmaputra river between 25°45' to 26°45'N latitudes and 91°50' and 93°20'E longitudes with an altitude of about 61 m above mean sea level. It is bounded by Sonitpur and the Brahmaputra to the north, west Karbi Anglong, Hojai and Dima Hasao to the south, east Karbi Anglong and Golaghat to the east and Morigaon to the west. The climate is tropical in Nagaon. In winter, there is much less rainfall in Nagaon than in summer. The average annual temperature is 26.5°C in Nagaon. January has the lowest average temperature (23.3°C) of the year, while May is the warmest month. The mean annual rainfall here is around 2401 mm yr^{-1}.

Surface (0–15 cm) and sub–surface (15–30 cm) soil samples were collected from different locations of the six blocks of Nagaon district, Assam. There were 8, 4, 14, 4, 6 and 6 samples (more specifically number of locations) from Khagorijan, Raha, Rupohi, Dhing, Laowkhowa and Juria blocks, respectively. Soil samples were air dried and passed through a sieve with 2 mm size opening and thereafter analyzed for their pH, 1:2.5 (w:w) soil water suspension by pH meter, mechanical composition and organic carbon as suggested by Black (1965). The bulk density (BD) of majority of the soil samples were measured by core sampler method. The available nutrients (N, P and K) status of the soils was estimated by the standard procedure (Jackson, 1973). The aggregate size distribution was determined using the wet sieving method (Yoder, 1936) and the mean weight diameter (MWD) values were calculated after oven–drying (van Bavel, 1949). Soil water retention characteristics ($\Psi - \theta$) were determined by using pressure plate apparatus (Richards, 1949). Soil water retained at varied matric potentials (Ψ) starting from 0.03 MPa to 1.5 MPa. After saturating soil samples with tap water for 24 hours, soil water content at the field capacity (FC) was measured equilibrating soil moisture for 24 hours at 0.03 MPa on a ceramic plate, and the permanent wilting point (PWP) was measured equilibrating soil moisture for 96 hours at 1.5 MPa on a pressure plate apparatus. The available water was computed by subtracting the amount of water held at 1.5 MPa from that at 0.03 MPa.

Saturated hydraulic conductivity (Ks) for all the soil depths was estimated following the constant head method (Klute and Dirksman, 1986). Soil samples in the cylinders were submerged in water for a night to reach saturated conditions. 2 ± 0.1 cm height of water at the top of soil columns was pounded using a Mariotte bottle. Outflow volumes obtained from bottom of soil columns were used in Darcy equation to find saturated hydraulic conductivity (Ks). In order to establish $\Psi(\theta)$, $K(\theta)$ and $D(\theta)$ functional relationship, the procedure outlined by Campbell (1974) and subsequently used by Komos *et al.* (1979) and Oswal (1993) was followed. For this, a graph between log Ψ and log $\theta / \theta s$ (where θs is the water content at saturation point) was plotted for each soil. The constants 'Ψ_e' and 'b' were calculated by plotting Ψ against $\theta / \theta s$ on a log–log scale. From the graph, the data points corresponding to near saturation were discarded and the remaining data best fitted statistically to the Campbell's equation:

$$\Psi / \Psi_e = (\theta / \theta s)^{-b}$$

Where, Ψ = soil moisture tension corresponding to volumetric moisture content θ, Ψ_e = air entry suction, θs = saturated moisture content and b = a constant soil parameter. From the estimation of θ, θs, b and Ks, the $K\theta$ was computed by Campbell equation:

$$K\theta / Ks = (\theta / \theta s)^{2b+3}$$

Soil water diffusivity ($D\theta$) was computed by putting the value of Ks, b and Ψ_e in the equation described by Komos *et al.* (1979):

$$D\theta = b.\Psi_e.Ks\,(\theta / \theta s)^{b+2}\ \theta s^{-1}$$

3. RESULTS AND DISCUSSION

Physico–Chemical Properties

Physico–chemical properties of the soils from various jute growing areas of Nagaon district, Assam are presented in Table 1. The soils are mostly clay loam in texture and acidic in reaction with pH ranging from 5.45 to 5.69, which may be due to higher Al and Fe content and low base saturation (Prasad, 1987). The clay contents of the experimental soils varied from 33.44% to 37.53%. The organic carbon content of the soils varied in between 1.02% to 1.11% among the various blocks. The soils of Juria block had the lowest organic carbon content (1.02%), which is significantly lower than the soil of Dhing and Laowkhowa block (1.11%). This fluctuation may be attributed by the topographical changes as well as by variation in precipitation and cropping systems. The soils of jute growing areas of Nagaon district were having very high water stable aggregate; WSA (range: 69.09% to 80.08%) as well as MWD (range: 0.82 mm to 1.08 mm). This could be ascribed to well structured soils in these blocks with intensive vegetative cover throughout the year resulted in higher organic carbon

Table: 1
Soil physico–chemical characteristics of jute growing areas of Nagaon district, Assam

Jute growing soils (Blocks)	pH (1:2.5)	SOC* (%)	BD (Mg m^{-3})	Clay (%)	WSA (> 0.25 mm) (%)	MWD (mm)	Available Nutrients (kg ha^{-1})		
							N	P	K
Khagorijan block	5.59	1.09	1.37	34.08	79.92	0.91	297.78	21.60	167.36
Raha block	5.63	1.04	1.40	33.80	77.35	1.08	287.00	21.18	158.00
Rupohi block	5.69	1.08	1.39	33.44	79.75	0.95	299.65	22.30	163.40
Dhing block	5.45	1.11	1.41	35.89	76.13	1.01	275.40	22.28	184.45
Laowkhowa block	5.50	1.11	1.41	35.72	69.09	0.82	285.60	22.68	161.78
Juria block	5.62	1.02	1.40	37.53	80.08	0.95	294.32	20.63	171.02
LSD (P = 0.05)	0.08	0.09	0.02	0.98	5.93	0.10	12.89	1.72	13.15

**SOC – Soil organic carbon, BD – Bulk density, WSA – Water stable aggregates, MWD – Mean weight diameter, Available N, P, K – Available nitrogen, phosphorus, potassium*

contents in soils. The available nutrients in the soils showed marginal variations among various blocks. Available N varied in between 275.40 kg ha^{-1} and 299.65 kg ha^{-1}. Similarly, available P and K varied in between 20.63 kg ha^{-1} to 22.68 kg ha^{-1} and 158.00 kg ha^{-1} to 184.45 kg ha^{-1}, respectively. Available K was highest in the soils of Dhing block (184.45 kg ha^{-1}), which was 16.74% higher than that of Raha block (158 kg ha^{-1}). In other soils, the available K content was in the order of: Juria block (171.02 kg ha^{-1}) > Khagorijan block (167.36 kg ha^{-1}) > Rupohi block (163.40 kg ha^{-1}) > Laowkhowa block (161.78 kg ha^{-1}).

Water Retention–Transmission Characteristics

Field capacity, permanent wilting point and available water

Soil water retention characteristics (Ψ – θ relationships) of the soils (Table 2) revealed that water retention at 0.03 MPa was highest by the soils of Rupohi block (0.42 m^3 m^{-3}) lowest being in Laowkhowa and Juria block (0.28 m^3 m^{-3}). Similarly at 1.5 MPa, the highest water was retained by Raha block (0.13 m^3 m^{-3}) and the lowest in Laowkhowa and Juria block (0.10 m^3 m^{-3}). The magnitude of water content decreased with increasing suction probably due to the differences in releasing pattern of soil (Fig. 1). Functional relationships between Ψ and θ were developed for all the soils. These relationships may be used for predicting moisture content in the soils under various matric potentials. The values of the slope of the moisture retention characteristics 'b' and air entry suction 'Ψ_e' are shown in Fig. 2. The 'b' values varied from 4.09 to 6.49 in various soils under study. Higher values of 'b' were observed in the soils of Raha, Khagorijan and Rupohi blocks than the soils of other blocks. Similar trend observed in case of 'Ψ_e' under these soils. Available water among the various soils varied in between

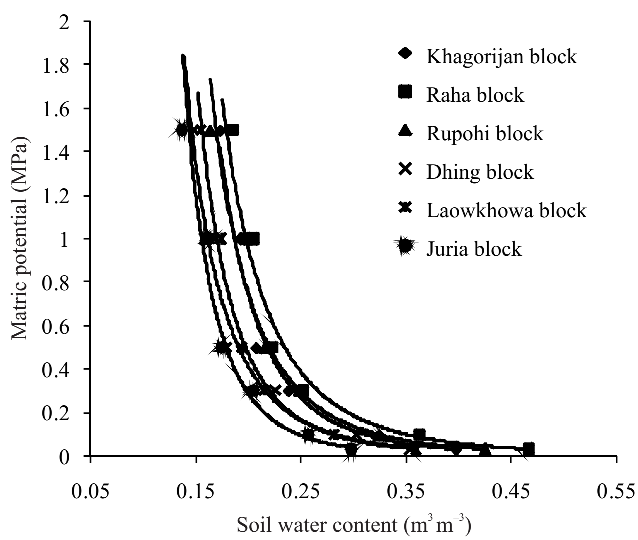

Fig. 1. Soil moisture characteristic curves for jute growing areas of Nagaon district, Assam

Table: 2
Water content (θ) at different FC and PWP (ψ), available water (m^3 m^{-3}) and moisture retention–transmission characteristics of jute growing areas of Nagaon district, Assam

Jute growing soils (Blocks)	Moisture content (θ) at FC* (m^3 m^{-3})	Moisture content (θ) at PWP** (m^3 m^{-3})	Available water (m^3 m^{-3})	Sat. Hydra. Conductivity (Ks) (cm min^{-1}) (X 10^{-3})	Diffusivity (cm^2 min^{-1}) (X 10^{-3})
Khagorijan block	0.35	0.12	0.23	0.49	0.33
Raha block	0.39	0.13	0.26	0.74	0.59
Rupohi block	0.42	0.12	0.30	1.00	0.62
Dhing block	0.32	0.12	0.20	1.24	1.02
Laowkhowa block	0.28	0.10	0.18	1.33	1.14
Juria block	0.28	0.10	0.18	1.25	0.71
LSD (P = 0.05)	0.06	0.03	0.04	0.39	0.02

**FC – Field capacity, **PWP – Permanent wilting point*

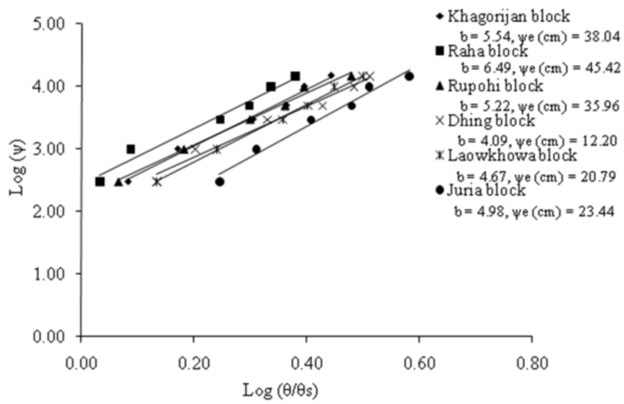

Fig. 2. Relation between soil water suction and moisture contents of jute soils at Nagaon district, Assam

0.18 $m^3 m^{-3}$ and 0.30 $m^3 m^{-3}$. The magnitude of the available water capacity follows the order: Rupohi > Raha > Khagorijan > Dhing > Laowkhowa / Juria block. This can be attributed to differences in quantity and nature of colloidal materials present, pore size distribution and organic carbon content present in the respective soils. Soils with high clay and organic carbon contents are expected to retain more soil moisture as it is evident from this study (Chakraborty *et al*., 2011).

Hydraulic Conductivity and Diffusivity

Saturated hydraulic conductivity (Ks) values, an indicator to know about the water transmission pattern in the whole soil profile, revealed that there were wide variations under different jute growing areas in Nagaon district, Assam (Table 2). It was almost 2.5 folds faster under Laowkhowa, Juria and Dhing block (1.33 cm min^{-1}, 1.25 cm min^{-1}, and 1.24 cm min^{-1}) than Khagorijan block (0.49 cm min^{-1}). Saturated hydraulic conductivity values among the other blocks varied between 0.74 cm min^{-1} and 1.00 cm min^{-1}. Soil water diffusivity among the soils of various jute growing blocks showed similar trend. The soils of Laowkhow block had highest soil water diffusivity value (1.14 $cm^2 min^{-1}$) while the lowest value was found in Khagorijan block (0.33 $cm^2 min^{-1}$). These may be ascribed to significant difference in pore geometry, organic carbon content among the jute growing areas in Assam (Singh, 2004).

Data on hydraulic conductivity and diffusivity in the soils as functions of water content are presented in Fig. 3 and Fig. 4, respectively. Wide variations among the soils were observed in both the parameters. Irrespective of soil characteristics, the values of unsaturated hydraulic conductivity K(θ) and water diffusivity D(θ) invariably decreased with decrease in their water content. The unsaturated hydraulic conductivity (between 0.15 to 0.24 $m^3 m^{-3}$ moisture contents in soil) fluctuated from 0.12×10^{-11} to 0.33×10^{-3} cm min^{-1} whereas the soil water diffusivity among the various blocks varied in between 0.08×10^{-7} $cm^2 min^{-1}$ and 0.02×10^{-3} $cm^2 min^{-1}$. Magnitude of the change in K(θ) and D(θ) with soil

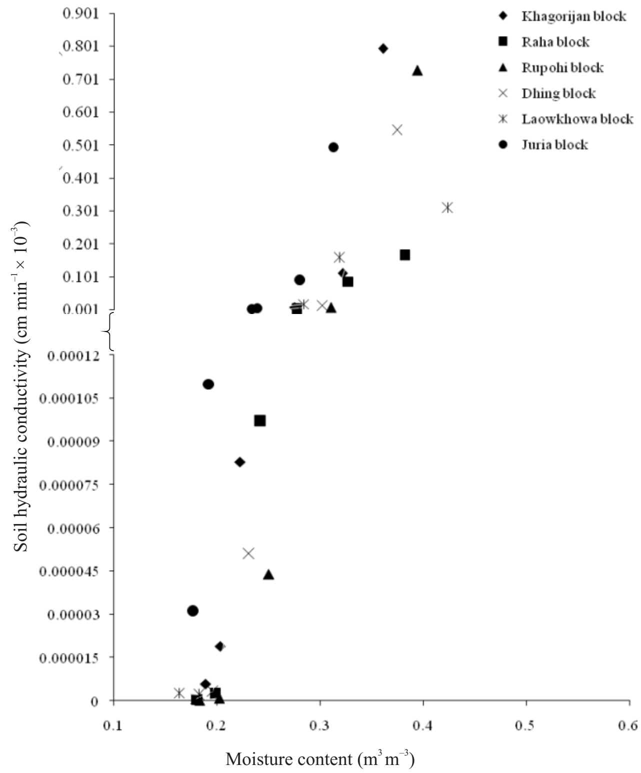

Fig. 3. Hydraulic conductivity as a function of moisture content of jute growing areas of Nagaon district, Assam

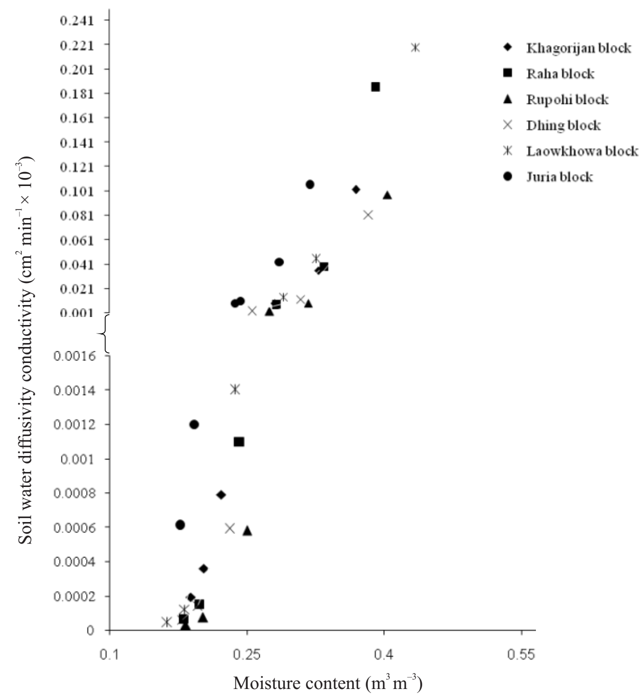

Fig. 4. Soil water diffusivity as a function of moisture content of jute growing areas of Nagaon district, Assam

water content, (θ) also varied with the soils of different blocks. Similar results under different soil groups in Orissa were reported by Singh *et al.* (2000). At high water, K(θ) and D(θ) were high in the soils of Laowkhow and Juria blocks may be because of near saturation of their large pores. A gradual decrease in soil water content sharply reduced the K(θ) and D(θ) in the soils of these two blocks of Assam compared to that in other blocks. The magnitude of change in K(θ) and D(θ) with soil water content θ was also different in these soils. This could be attributed by the effect of pore geometry, which is governed by soil biota influencing through formation of stable aggregates, development of organo– mineral complexes by improving macro porosity and continuity of pores from surface to the sub–soil which, ultimately controls the water transmission and runoff (Lal and Hawksworth, 1991). At higher suction or low soil moisture content K(θ) and D(θ) values were marginally fluctuated among the various jute growing soils might be due to the fact a considerable portion of their pores remains filled with water even at low moisture content influenced by the nature of colloidal materials present in the soil.

4. CONCLUSIONS

It appears from the present study that the soils of Rupohi, Raha and Khagorijan blocks of Assam had high moisture retention and available water capacity but low K(θ) and D(θ). In rainfed condition, raising jute or any other crop is possible in these soils if the crop and time of its sowing are properly selected. The soils of Laowkhow, Juria and Dhing blocks of Assam showed low to medium moisture retention and available water capacity and relatively high K(θ) and D(θ). In this condition, *rabi* crop in such soils is only possible if proper moisture conservation practices like mulching etc. are adopted.

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