Effects of conocarpus biochar on hydraulic properties of calcareous sandy soil: Influence of particle size and application depth

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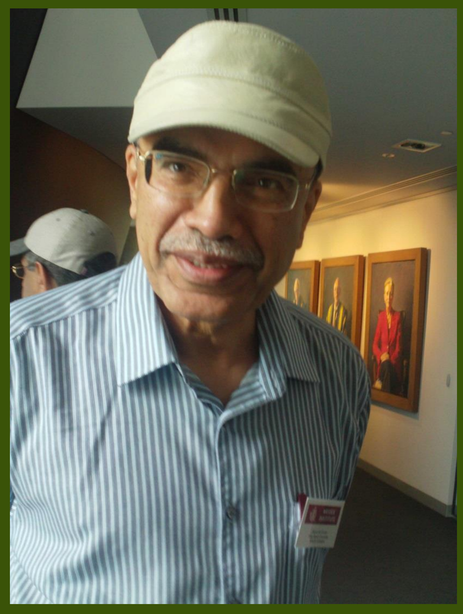

Abstract

A laboratory column experiment was conducted to investigate the effects of 400°C biochar with different particle sizes and application depths on hydro-physical properties of sandy loam soil including: soil water penetrability, infiltration rate, intermittent evaporation, water retention and saturated hydraulic conductivity. Biochar produced from conocarpus wastes was applied at 15 g kg^{-1} (32.9 t ha^{-1}) in different sizes ((< 0.5 mm (S_1), 0.5-1mm (S_2) and 1-2 mm (S_3)) as biochar-soil mixture layer 2-cm thick at 0 cm depth (D_0), 5 cm depth (D_5) and 10 cm depth (D_{10}). The results indicated that applying biochar decreased the waterfront and saturated hydraulic conductivity of sandy loam soil. The cumulative evaporation was the highest and amounted to 40.92 mm in the non-treated soil, but it recorded the lowest amount of 32.25-35.46 mm in the biochar-treated soil. Among different particle size of biochar, no significant differences of the cumulative evaporation were observed. The biochar addition caused significant (P<0.05) increases in the amount of conserved and retained water compared to control soil. The highest amount of water conserved in soil was found for S_2 biochar at D_5. In addition, the cumulative water infiltration through the soil was significantly reduced by S_1 and S_2 biochars at D_0. The values of saturated hydraulic conductivity for the biochar treatments were significantly (P<0.05) lower than those for the control, with the lowest values for S_1 at D_0 and D_5. These results strongly suggest positive improvement for some hydro-properties of coarse-textured soils following biochar addition, especially finer particles (< 1 mm) of biochar.

Introduction

In most arid and semi-arid regions, soils are characterized by high infiltration rate, low water holding capacity, high evaporation, low fertility, low organic matter and deep percolation, resulting in low water availability and use efficiency. (Glaser et al., 2002). Attempts have been made to improve the physico-chemical properties of such soils having coarse texture by the incorporation of organic and inorganic amendments (Al-Omran et al., 2004). Biochar produced from carbonization of organic wastes can be considered as an alternative additive, The addition of biochar to soils might modify soil porosity, aggregation and surface area, affecting hydro-physical soil properties (Glaser et al., 2002; Tryon, 1948). Tryon (1948) found that the addition of charcoal increased the available moisture content only in sandy soil. Additionally, biochars may be designed to selectively improve soil properties by altering feedstock's and pyrolysis conditions. There is limited information concerning how particle size of biochar can influence the physical properties of soil. Therefore, the objective of this study was to determine the influence of conocarpus biochar with different particle sizes and application depths on hydraulic properties of calcareous sandy loam soil.

Methods & Materials

Soil Sampling

The natural soil material for this study was obtained from the Agricultural Experimental Station in the farm of the College of Food and Agriculture Science, King Saud University, Riyadh, Saudi Arabia. The soil samples were collected from the surface soil layer (0 – 20 cm) from the plough horizon. Soil was content θ_i approximately 0.0012% (vol.). Physico-chemical characteristics of soil are presented in Table 1.

Biochar-soil mixture samples preparation

Biochar was produced by pyrolysis of (*Conocarpus* species) trees wastes. Were dried (moisture content was nearly 4.7%) and then chopped to small pieces (7-10 cm). After that, the pyrolysis process for conocarpus pieces was executed at a temperature of 400 ^oC ± 10 ^oC.

Experimental set-up of the soil column

Thirty transparent Acrylic columns were prepared prior to the preparation of the soil samples. The Acrylic columns were 50 mm internal diameter, 400 mm in length and 5 mm thick. A schematic diagram of the experiment is shown in Figure 1.

Intermittent evaporation

Over a 35-day period, 110 mm of tap water (EC = 0.4 dSm^{-1}) were added to each soil column for five wetting/dry cycles. These amounts of water were added with 7-day intervals.

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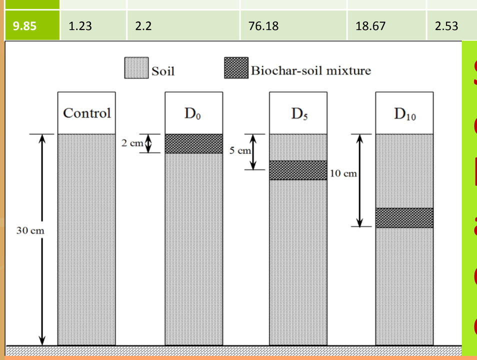
Soil moisture distribution

At the end of the five wetting/drying cycles, the soil columns were covered by parafilm sheet for stopping the natural evaporation. Gravimetric measurements of soil water distribution were determined.

Characteristics of soil and biochar

Soil properties							
Sand (%)	Silt (%)	Clay (%)	Texture	pH	EC dS m^{-1}	CaCO3 (%)	OM (%)
6.5	25	68.5	sandy loam	7.7	1.40	25.3	0.04

Biochar properties										
pH	EC dS m^{-1}	Ash content (%)	C (%)	O (%)	H (%)	N (%)	Bulk density g cm^{-3}	Pore size diameter (µm)	Surface area (m^2 g^{-1})	Average particle size (nm)
9.85	1.23	2.2	76.18	18.67	2.53	0.42	0.35	5-50	109.8	54.6



Schematic diagram explain the 2-cm layer of biochar-soil mixture applied in different depths of D_0 (0 cm), D_5 (5 cm), and D_{10} (10 cm).

Infiltration measurement

$$I = St^{0.5} + A_1 t \quad (1)$$

$$i = 0.5\,St^{-0.5} + A_1 \quad (2)$$

Saturated hydraulic conductivity (K_S)

$$Q = A \times J_w t \quad (3)$$

$$J_w = K_S\, i \quad (4)$$

$$Q = AKs\, H\, t/L \quad (5)$$

$$Ks = (Q\, L)/(AtH) \quad (6)$$

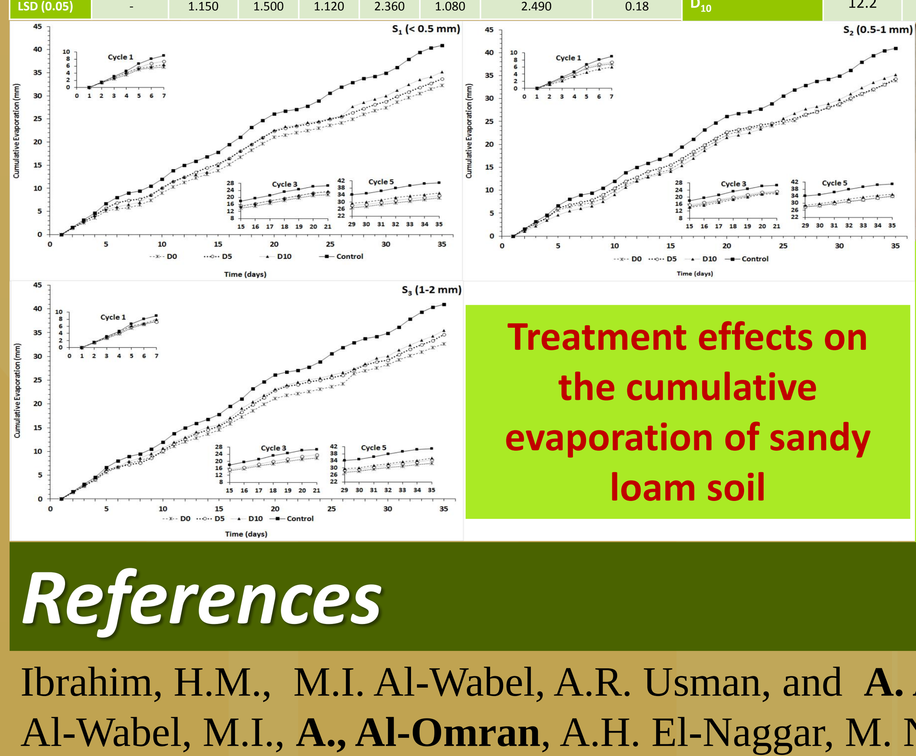
Results

Effects of 2-cm layer W/E cycles

Application Depth, cm	Applied Water, mm	Evaporation (mm) Week1	Week 2	Week 3	Week 4	Week 5	Cumulative Evaporation, mm	Water Conserved, mm
		Biochar size, S_1 = < 0.5 mm						
control	58.36	8.99	7.80	9.95	7.01	7.16	40.92	15.76
D_0	58.36	5.81	7.25	8.42	4.56	6.21	32.25	18.02
D_5	58.36	7.43	7.02	8.52	4.28	6.38	33.64	18.14
D_{10}	58.36	6.49	6.99	9.85	5.22	6.67	35.21	17.85
LSD (0.05)	-	1.140	1.560	1.190	2.340	0.550	1.96	0.31
		Biochar size, S_2 = 0.5-1 mm						
control	58.36	8.99	7.80	9.95	7.01	7.16	40.92	15.76
D_0	58.36	6.92	6.93	8.98	4.35	6.77	33.96	17.72
D_5	58.36	7.39	7.32	8.56	3.84	7.14	34.26	18.60
D_{10}	58.36	5.98	7.55	8.51	6.21	6.95	35.20	17.60
LSD (0.05)	-	0.560	0.710	1.050	0.640	0.620	1.36	0.39
		Biochar size, S_3 = 1-2 mm						
control	58.36	8.99	7.80	9.95	7.01	7.16	40.92	15.76
D_0	58.36	7.50	6.19	8.12	5.16	5.62	32.59	17.58
D_5	58.36	7.22	7.36	9.11	4.46	6.49	34.63	17.87
D_{10}	58.36	7.91	7.20	8.88	4.49	6.99	35.46	16.75
LSD (0.05)	-	1.150	1.500	1.120	2.360	1.080	2.490	0.18

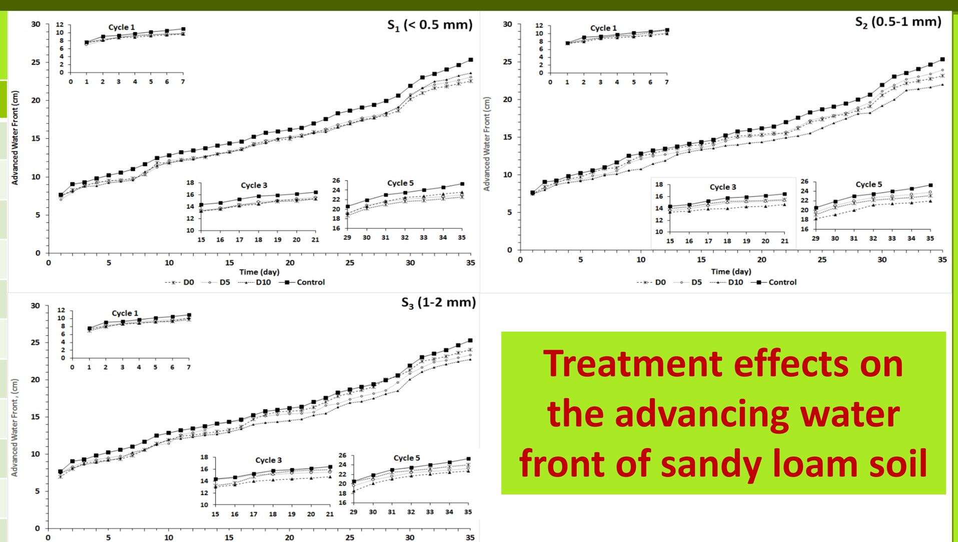
Effects of 2-cm layer Control

Application Depth, cm	Soil depth (cm) 2	4	6	8	10	20	30
	Biochar size, S_1 = < 0.5 mm						
D_0	33.4	23.8	10.8	5.8	5.4	3.8	52.0
D_5	25.2	19.7	13.4	11.1	7.0	10.4	34.4
D_{10}	15.3	15.5	6.0	12.6	10.8	7.5	39.0
	Biochar size, S_2 = 0.5-1 mm						
D_0	6.6	16.4	9.7	9.0	5.4	3.1	56.9
D_5	24.2	19.1	15.9	14.0	7.1	7.3	65.5
D_{10}	34.9	32.3	19.1	14.2	9.3	2.3	16.9
	Biochar size, S_3 = 1-2 mm						
D_0	29.6	21.1	9.3	7.7	4.1	5.2	29.5
D_5	27.3	18.8	10.6	6.0	0.9	5.9	46.8
D_{10}	12.2	9.0	1.3	3.4	2.7	2.0	25.6

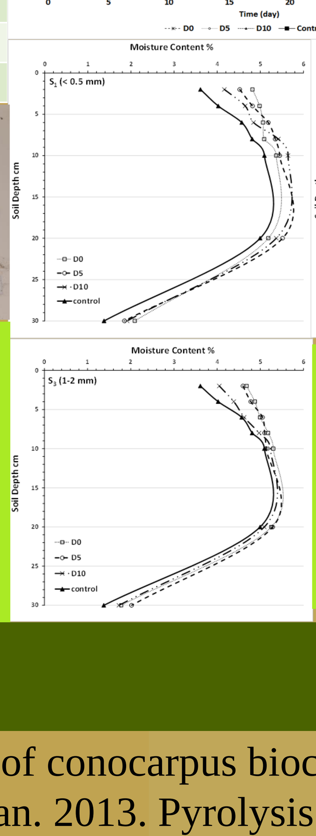


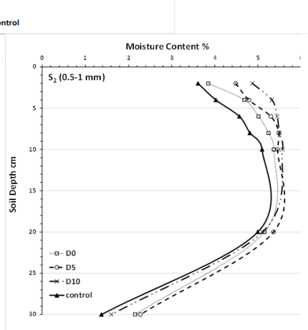
Treatment effects on the cumulative evaporation of sandy loam soil

(In Progress) Impact of Adding biochar on corn in sandy calcareous soil

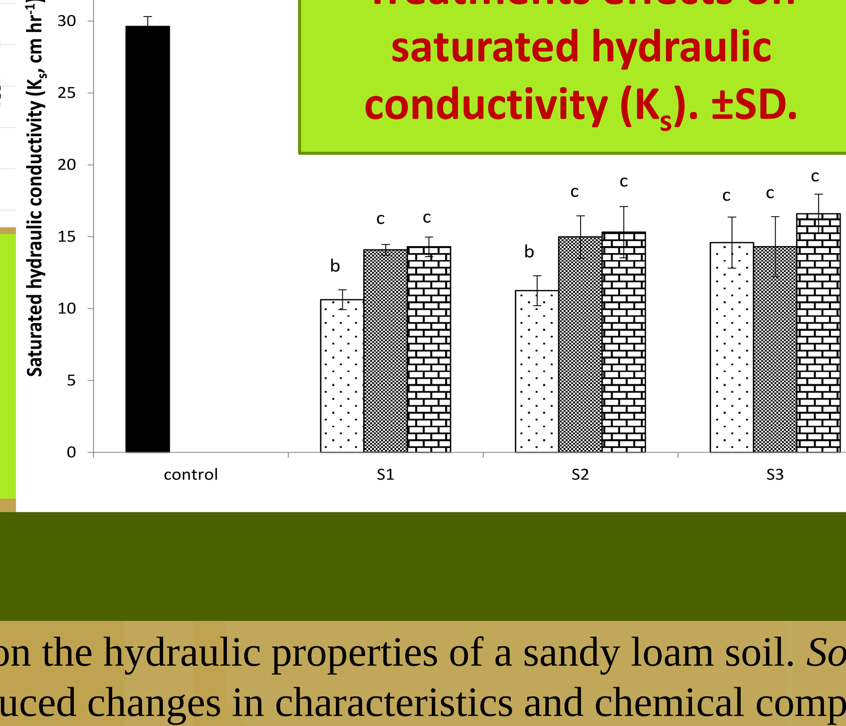


Treatment effects on the advancing water front of sandy loam soil

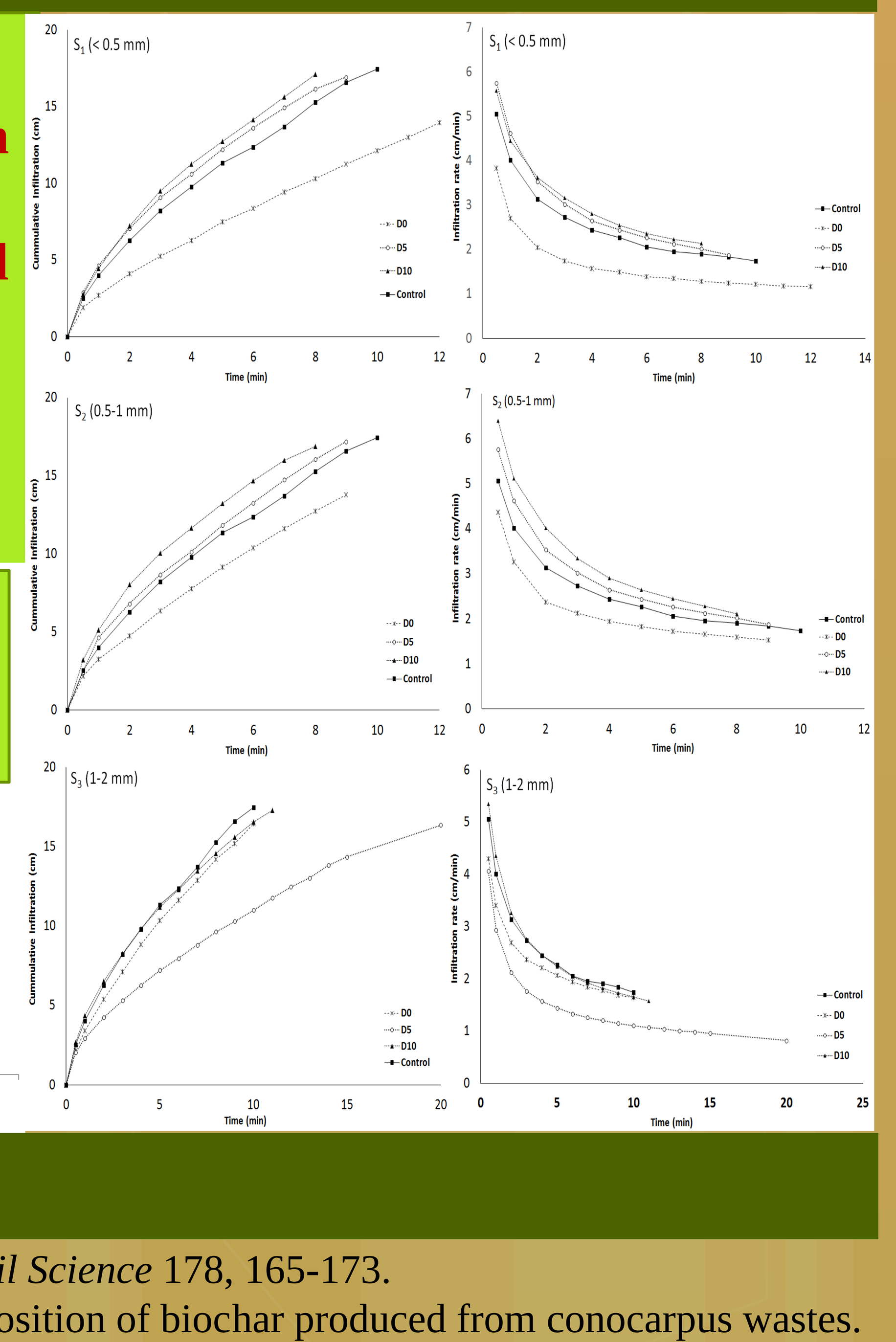




Treatment effects on soil moisture content distribution.



Treatments effects on saturated hydraulic conductivity (K_s). ±SD.



Treatment effects on the cumulative infiltration (cm) and infiltration rate (cm/min) of sandy loam soil.

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