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DETERMINING SOME SOIL HYDRAULIC PROPERTIES BY SOIL WATER RETENTION CURVE FOR FIVE DIFFERENT TEXTURED SOILS

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ABSTRACT
Soil water retention curves (SWRCs) are crucial for characterizing soil moisture dynamics and are particularly relevant in the context of irrigation management. A study was carried out to determine some hydraulic properties from soil water retention curve (SWRC) like pore size distribution, and hydraulic capacity along with effective pore diameter of soil for five different textured soils Sandy Loam, Loam, Sandy Clay Loam, Silt Loam, and Clay. The Mualem–van Genuchten model (MVG) is used for prediction of unsaturated hydraulic conductivity from water retention parameters.

KEYWORDS: SWRCs, irrigation, management, Mualem–van Genuchten model.

INTRODUCTION
In agriculture, soil water in unsaturated porous soil media is crucial for crop development (Zijlstra and Dane, 1996; Lin, 2012). Soil water retention curve (SWRC), which represents the relationship between the water pressure and water content, is fundamental to researching water flow and chemical transport in unsaturated media (Pollacco *et al*., 2017; Moret-Fernández and Latorre, 2017), SWRC is considered to be a paramount and a priori property of the hydraulic behavior of soils (Schwen *et al*., 2011; Le Bourgeois *et al*., 2016). Most of the soil functions depend directly or indirectly on soil water retention and transmission, which explains their importance for soil processes in rhizosphere zone (Kutílek, 2004; Lin *et al*., 2005; Blum, 2006; Lin, 2012; Banwart *et al*., 2013). Soil hydraulic properties reflect the structure of the soil porous system comprising pores of different geometry, sizes, and connectivity (Hillel, 1980; Lipiec *et al*., 2003; Lin *et al*., 2005). The effect of soil structure and texture is considered by changing hydraulic conductivity, water retention, root growth and transformation of the chemicals (Lipiec *et al*., 2003). However, the soil porous system has been affected by particle size distribution, shape of particles, cementing, and packing density (Nimmo, 2004). Pore space can be filled by water and, or air, it is effect by the soil texture (Huber *et al*., 2008; Schjønning *et al*., 2015). The soil pore space characterized in to two features porosity and pore size distribution. The pore size distribution considered the most important feature for its complicated and strong relationships with other soil characterize especially with soil structure, aggregates stability and texture (Assouline, 2006a; Assouline, 2006b). The pore space can be divided in to two volumetric groups. Macropores defined as the air pores and the micropores which known as capillary pores. The activities are affected by pores size distribution in which the capillary forces dominate such as cohesion, adhesion and the capability of water retention in micropores to become a source providing water and dissolved materials, while macropores was important to ventilate the soil (Nimmo, 2004, Eynard *et al*., 2004).
The most frequently explored expression of the soil water retention function is the equation of van Genuchten (1980). It describes the sigmoidal form of a smooth curve fitted by three to five parameters to the measured data. The SWRC was used for determining the soil hydraulic properties such as unsaturated hydraulic conductivity, soil water diffusivity, porosity and pore size distribution, and specific (or differential) water capacity, both SWRC and unsaturated hydraulic conductivity are often necessary for solving unsaturated flow problems (Chan, 2005; Mohammadi *et al*., 2009) . The SWRC is strongly related with soil pores size distribution which was considered a traditional way to evaluation and measuring pores size distribution (Dexter, 2004; Dexter, 2006; Stingaciu *et al*., 2010).
The main objectives were to determine and evaluate some soil hydraulic properties with different five soil pores systems.

MATERIALS AND METHODS
Five different-texture soil samples were taken from fields and all sample of disturbed soil were taken from the Ap horizon (0-30 cm).Sandy Loam (SL), Loam (L), Sandy Clay Loam (SCL), Silt Loam (SiL), and Clay (C) samples were air dried up, ground and sifted with a sieve of 2mm diameter sieve’s holes. Table (1) shown some soil physical properties.

TABLE . shown some soil physical properties

Property	Soil samples				
	Sandy Loam	Loam	Sandy Clay Loam	Silt Loam	Clay
SAND (%)	71.20	38.78	65.20	20.49	7.50
SILT (%)	12.40	35.64	11.10	60.66	35.30
CLAY (%)	16.40	25.88	23.70	18.85	57.20
BULK DENSITY	1.55	1.52	1.45	1.38	1.21
K_S(CM.HR^{-1})	1.283	0.4942	0.4556	0.9852	0.2516

The relation between volumetric water content θ and matric section ψ were estimated for the soil samples. A Tempe cells have been used to measure the moisture content at matric section between 1-1000 cm, and a pressure plate apparatus in the range -2500 to -15000 cm. soil moisture were calculated according to Soil Lab (2003) No. 415 (Tuller and Or, 2003). van Genuchten(1980) equations used to describe the relation between θ and ψ:

$$\theta = \theta_r + (\theta_s - \theta_r)[1 + (\alpha\psi)^n]^{-m} (1)$$

Where θ is volumetric water content (cm^3.cm^{-3}) at any value of ψ, θ_s and θ_r are the saturated and residual volumetric water content of soil, respectively (cm^3.cm^{-3}). ψis matric section(cm). α is related to the inverse of air entry value (cm^{-1}), the n parameter is related to the pore size distribution of the soil, and the$m$parameter is related to the asymmetry of the model.

Where n and m parameters in the SWRC equation can have a fixed relationship with:

$$m = 1 - \frac{1}{n} \quad (2)$$

Eq. 1 differential was used to find the slope of SWRC (dθ/dψ) which is called differential water capacity or hydraulic capacity of soil. The differential formula of soil water capacity is:

$$\frac{d\theta}{d\psi} = -\alpha n m(\theta_s - \theta_r)(\alpha\psi)^{n-1}[1 + (\alpha\psi)^n]^{n-1} \quad (3)$$

Pore size diameters were determined from soil water retention curves by the relationship between equivalent cylindrical pore size diameter (d) and ψ (Hillel, 1980):

To estimate pores size diameter (d) by equation below:

$$d = \frac{4\gamma \cos\beta}{\rho_w g \psi} \quad (4)$$

Where d is effective pore diameter (cm) of the largest filled pore (in contact with air), γ is a water surface tension (at 20°C= 72.7 g.s^{-2}), cosβ= 1, (β is contact angle between soil pore wall and water its 0 for a wetted surface), ρ_w water density (at 20°C= 0.998 g.cm^{-3}), and g is the acceleration due to gravity (980 cm.s^{-2}), results in:

$$d \approx \frac{0.298}{\psi} \quad (5)$$

where h is in m and d is in cm.

Unsaturated hydraulic conductivity k(θ) of soils were calculated using Mualem-van Genuchten (van Genuchten, 1980) in θ ranged $\theta_r<\theta<\theta_s$.

RESULTS AND DISCUSSION

Fig. (1) Showed relationships between θ and ψ for measured and fitted SWRCs for five different soil types. There were differences between the curves of the SWRCs for different soil samples. The soil samples ability to retain water increase by the increasing of clay contents at different matric section (from 1 to 15000 -cm H_2O). The amount of retained water at lower matric section (1 cm) decreased with the increasing sand, the volumetric water content (θ) were0.389, 0.412, 0.447, 0.487, and 0.548 cm^3.cm^{-3} for Sandy Loam, Loam, Sandy Clay Loam, and Clay, respectively.

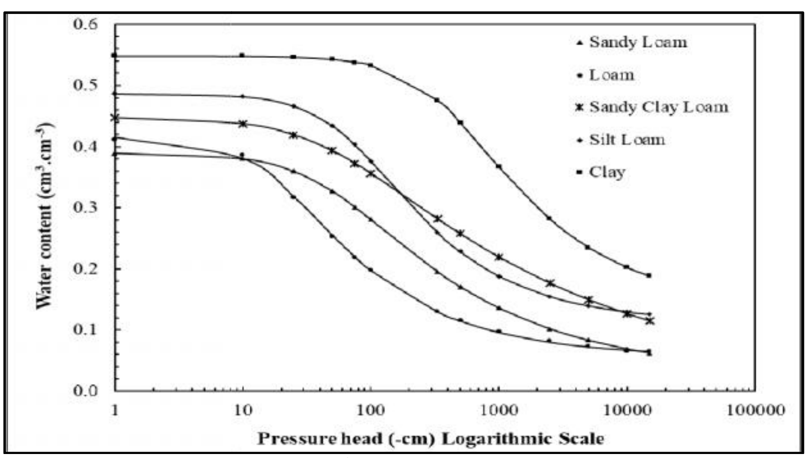

FIGURE 1. Soil water retention curves for Sandy Loam, Loam, Sandy Clay Loam, and Clay

The residual water content θ_r decreased with the increasing of sand, θ_r were 0.063, 0.065, 0.115, 0.126, and 0.1891cm^3.cm^{-3} for Sandy Loam, Loam, Sandy Clay Loam, and Clay, respectively. The solid line in the fig. 1 refer to the best fitting of data of pressure head or matric section (ψ) against θ using van Genuchten equation (Eq.1). Eq. 1 shows good fitting between the measured data and fitted data, the determination coefficient (R^2) value was more than 0.99962 for soil samples, and declines the residual man square of θ ($RMSE_\theta$), were3.41×10^{-04}, 2.30×10^{-03}, 4.13×10^{-04}, 2.74×10^{-04}, and 4.36×10^{-0}4 (cm^3.cm^{-3}), table 2 shows van Genuchten parameters (θ_s, θ_r, α, n, and m).

TABLE 2. values of van Genuchten equation parameters (θs, θr, α, n, and m) for SWRCs of soil samples (Sandy Loam, Loam, Sandy Clay Loam, and Clay), and the values of best fitting parameters (R^2, $RMSE_\theta$)

Soil type	θ_s	θ_r	α	n	m	R^2	$RMSE_\theta$
Sandy Loam	0.390	0.063	0.01893	1.40370	0.28760	0.99999	3.41×10^{-04}
Loam	0.415	0.065	0.05019	1.56370	0.36049	0.99962	2.30×10^{-03}
Sandy Clay Loam	0.447	0.115	0.01935	1.23890	0.19283	0.99999	4.13×10^{-04}
Silt Loam	0.487	0.126	0.01279	1.61970	0.38260	0.99999	2.74×10^{-04}
Clay	0.548	0.189	0.00243	1.55410	0.35654	0.99999	4.36×10^{-04}

The difference of water content between pressure head 1 and 330 cm represents soil air-filled porosity (pores size bigger than 9.03×10^{-04} cm) as effective pores diameter (Eq. 5), while water content difference between pressure head 100 and 15000 cm represents water-filled porosity (pores size less than 9.03×10^{-04}cm) and also defined as water holding capacity or available water or field capacity (Startsev and McNabb, *etal*. 2001; Eynard, 2004). Fig 2 shows ratio of pores volume which is filled by air, water and residual water content to bulk soil volume of different texture soils.

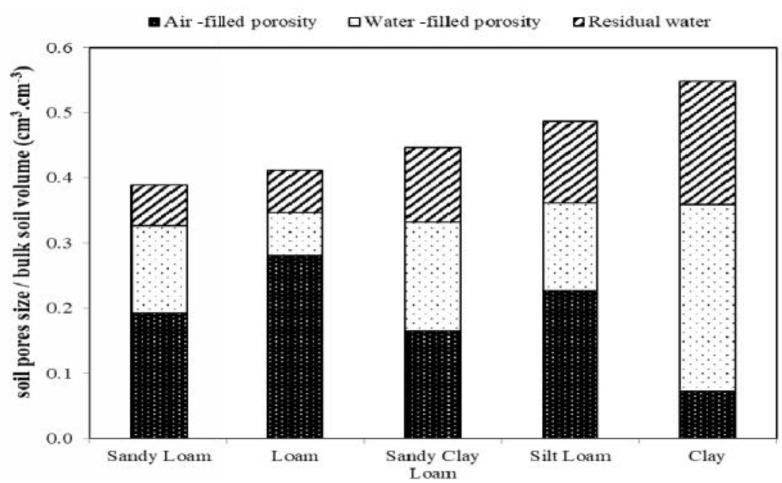

FIGURE 2. Air and water distribution in three soil sample, Air-filled pore volume (pores >9.03×10^{-04} cm) and water-filled pore volume (pores < 9.03×10^{-04} cm, water + residual water)

Volume ratio of air-filled porosity decreased with increase clay content and the clay soil sample had lowest air-filled pores ratio (0.073cm^3.cm^{-3}), while loam soil sample had the highest air-filled pores ratio (0.281cm^3.cm^{-3}). The water-filled pores ratio was low in loam soil sample (0.066cm^3.cm^{-3}) and highest water-filled pores ratio was in clay soil (0.2859cm^3.cm^{-3}), and this means soil ability to lose water increases with increase of sand content and this may attribute to ability of these samples to release more water quantity than samples have less sand content at the same water potentials. This can be interpreted by using the slope of water retention curves (dθ/dψ). The residual volumetric water content (θ_r) of soil samples increased with increasing of clay content, in this case the volume of retained water depend on the specific surface area of soil particle and the clay had highest specific surface area (table 2).

The relationship between absolute value of SWRCs slope or hydraulic capacity of soil (dθ/dψ) and pressure head for five different soil types are shown in fig. (3). Fig. (3) showed that soil water capacity increases with pressure head increase till reaching the highest slope peak, and this was happened at 25, 10, 10, 50, and 100 cm pressure head, with maximum values were 1.25×10^{-03}, 4.49×10^{-03}, 8.95×10^{-04}, 1.26×10-^{03}, and 1.19×10^{-03}of soil samples Sandy Loam, Loam, Sandy Clay Loam, and Clay respectively. The change taken place in the absolute value of SWRC slope and the obtained change in the peak of soil water capacity was a result of an effect of soil texture on pores volume distribution and this shows progressive curvature in curve peaks with sand content increase. In results, the soil sample content highest sand has more ability to lose water. Fig. 4 shows the relationship between effective pore diameter (d) and soil water capacity values.

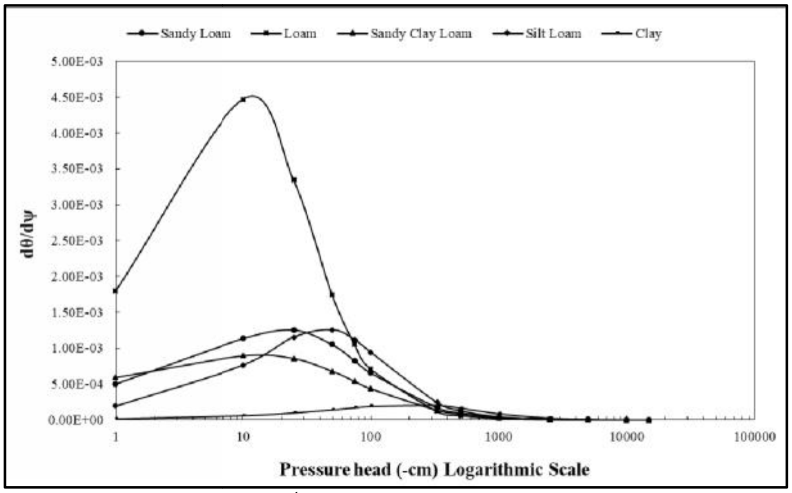

FIGURE 3. The relationship between dθ/dψ (cm^{-1}) with pressure head (cm) for Sandy Loam, Loam, Sandy Clay Loam, and Clay

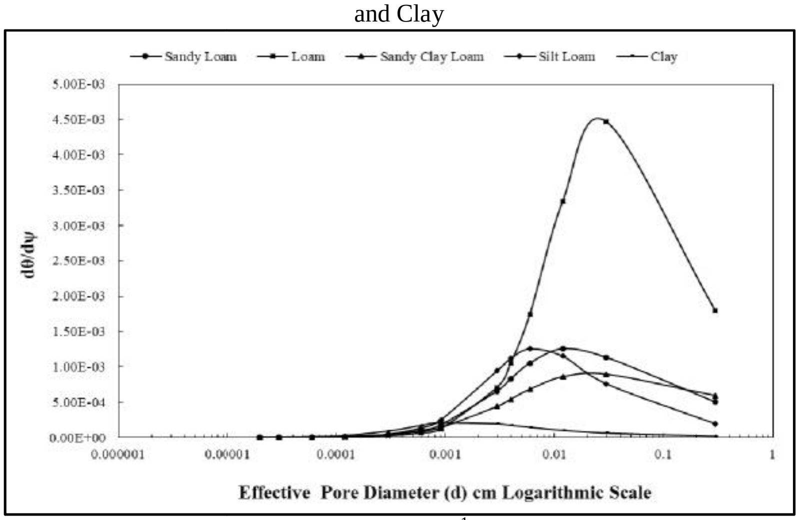

FIGURE 4. The relationship between dθ/dψ(cm^{-1}) with effective pores diameter (cm)

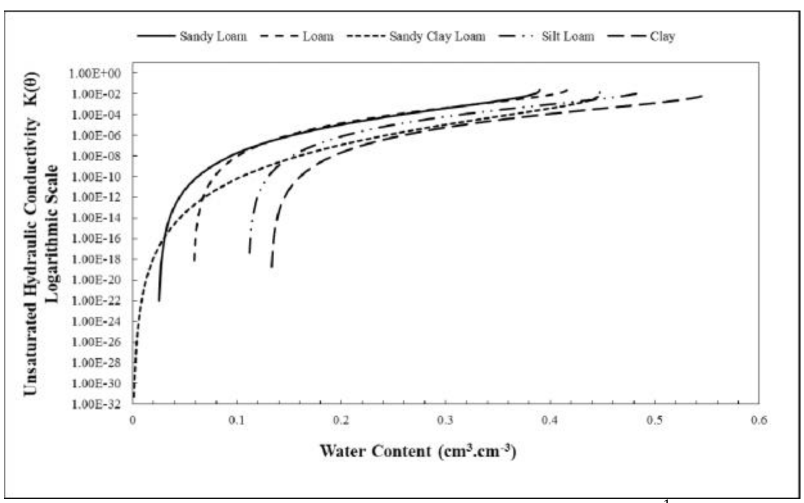

FIGURE 4. The relationship between unsaturated hydraulic conductivity K(θ)($cm.min^{-1}$) and Water Content ($cm^3.cm^{-3}$)for Sandy Loam, Loam, Sandy Clay Loam, and Clay

Fig. (5) showed the relationship between soil unsaturated hydraulic conductivity as a water content function K(θ) and water content θ ($\theta_r<\theta<\theta_s$).soil unsaturated hydraulic conductivity values near the saturation were 2.73×10^{-02}, 2.56×10^{-02}, 1.41×10^{-02}, 1.98×10^{-02}, and 1.06×10^{-02}, lowest unsaturated hydraulic conductivity values were 9.40×10^{-23}, 8.82×10^{-19}, 4.98×10^{-32}, 4.22×10^{-18}, and $2.04\times10^{-19}$of soil samples Sandy Loam, Loam, Sandy Clay Loam, and Clay respectively. Increasing the soil's ability to transport water at high moisture content can be attributed to the fact that all the water flow section contributes to water transfer. The soil, which has a large volume distribution of pores of the large type, transports a larger and faster water through the large soil pores, and decreasing of soil's ability to transport water at low moisture content can be attributed to transport of some of the soil pores of their water content, and since the large pores are the first to be discharged, this leads to a significant reduction in the area of the water flow section and remains pores medium and small size is the conductor of water (Udawatta *et al*., 2008, Alaoui *et al*., 2011).

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