

## **EFFECTS OF SOIL CONDITIONER ON WATER CONTENT OF SANDY SOIL AND PEANUT PRODUCTION UNDER DIFFERENT IRRIGATION RATES**

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### **ABSTRACT**

*Effects of soil conditioner on water content of sandy soil and peanut production under different irrigation rates were investigated during the two growing summer seasons of 2015 and 2016 at Abdel Moniem Reyad Village (Latitude 30°41'8" N, Longitude 30°18'0" E, and altitude of 7m above sea level), Al-Bustan area, El-Beheira Governorate, Egypt. Also, the validity of a simulation model to predict changes in soil moisture contents with time as well as moisture distribution within the soil profile was tested. Four soil conditioner levels (SC0: control, SC1: 1 ton/fed, SC2: 2 ton/fed, and SC3: 3 ton/fed), and three irrigation rates (full irrigation: 100% ETo, moderate deficit: 75% ETo and severe deficit: 50% ETo) were tested. Reference evapotranspiration (ETo) values were based on class A pan measurements. Peanut (Ismailia 2 cultivar) was used in the experiments. Results indicated that, the performance of the sprinkler irrigation system at the experimental site is considered acceptable. The additions of soil conditioner to the sandy soil led to decreasing the bulk density and saturated hydraulic conductivity values and increasing the saturated soil moisture contents, field capacity, wilting point, available water, and air entry values. The tested simulation model proved to be accurate to predict changes in soil moisture contents with time as well as moisture distribution within the soil profile. Average seasonal values of applied irrigation water were 2986, 2240, and 1506 m<sup>3</sup>/fed for the 100, 75, and 50% ETo treatments, respectively. The tested treatments significantly affected peanut yield and yield components parameters tested under the experimental conditions. Applying amount of irrigation water equals to 100% ETo with 2 ton/fed of hydro-gel soil conditioner produced the highest pod yield of 1.83 and 1.89 ton/fed and straw yields of 1.33 and 1.32 ton/fed from the peanut crop grown in sandy soil.*

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*Results indicated also that, an average water productivity value of 0.65 kg pod/m<sup>3</sup> and 0.43 kg straw/m<sup>3</sup> can be achieved from the interaction between 100% ETo \* SC<sub>2</sub> treatment. The results indicated that, in sandy soils of poor water retentive capacity, high yields of peanut crop can be obtained with the application of 2-3 ton/fed soil conditioner and irrigating with amount of water equals to 100% ETo.*

**Key words:** *Peanut, soil conditioner, polymer, irrigation rate, water productivity*

### INTRODUCTION

Egypt lies in arid area and the agricultural activities depend heavily on irrigation. Annual rainfall is below 200 mm and agriculture depends almost totally on the water from a Nile river (55.5 Billion m<sup>3</sup>/year) and nonrenewable ground water in the western desert. Therefore, efficient use of water has become extremely important in recent years since the main source of water has been declining causing shortages in water supply. Due to the increasing of population growth, Egypt reclaimed new areas in the desert to meet the deficit of agricultural production. The desert land, classified as sandy soils, is characterized by low water holding capacity, high infiltration and evaporation rates, and deep percolation losses that induce low water use efficiency, as well as low fertility levels (Al-Omran et al., 2010). The use of modern irrigation systems and amendment materials such as soil conditioners has helped improving crop production in the newly reclaimed areas. Soil amendments greatly affect the physical and chemical properties of the soils and could reduce the harmful effect of saline irrigation water (El-Maghraby et al., 1996, Beheiry et al., 1997, and Wassif et al., 1997). Using small amounts of natural or artificial products as soil conditioning help improving soil physical conditions by making air, water, and heat movements' optimal (Salem et al., 1990). The hydrogels or super absorbent polymer (SAP) materials are considered as important soil conditioners. Super absorbent polymers are compounds that absorb water and swell many times of their original size and weight. The SAP is applied into soil to create a water reserve near the roots and benefit agriculture (Zohuriaan-Mehr and Kabiri, 2008, and Han et al., 2010). The

addition of SAP to the sandy loam soil resulted in a significant increase of the soil water retention compared to the control. Also, seed germination was significantly higher in SAP amended soil as well as the survival times of grass and wood plants were prolonged under water stress conditions as compared with the soil without SAP (Lixia et al., 2014). The effect of highest doses of hydrogel on water retention was best visible at  $p^F$  values in the range of 1.5–2 bars. The highest doses increased retention capacity by 260% when added in the concentration of  $4 \text{ g}\cdot\text{dm}^{-3}$  and by 440% at the dose of  $6 \text{ g}\cdot\text{dm}^{-3}$ . At  $p^F$  values varied between 0 and 1.5, water retention increased by 42 and 170% at doses of 4 and  $6 \text{ g}\cdot\text{dm}^{-3}$ , respectively, in comparison with the control (Leciejewski, 2009). The hydrogels are water-retaining polymers that can absorb water about 100 to 150 times of their own weight. A significant fraction of this absorbed water is available to plants and thus, acts as an additional water reservoir for the soil–plant–air system (Bhardwaj et al., 2007). Hydrogels can absorb a volume of water 400 times their own weight (Bouranis et al., 1995), and due to this high water-holding capacity (Chatzoudis and Rigas 1999) they have been used successfully in agriculture and forest restoration as soil amendments (Viero et al., 2000; 2002, and Günes, 2007).

Peanut or groundnut (*Arachis hypogaea* L.) is one of the important legume crops of tropical and semiarid tropical countries, where it provides a major source of edible oil and vegetable protein. Groundnut kernels contain 47-53% oil and 25-36% protein. The crop is cultivated between  $40^\circ \text{ N}$  to  $40^\circ \text{ S}$  of the equator. Groundnut is a self-pollinated crop whereby flowers are produced above ground and, after fertilization, pegs move towards the soil, and seed-containing pods are formed and developed underneath the soil and helps maintain soil fertility through nitrogen fixation (Bogino et al., 2006; and Vara et al., 2011). The cultivated area of peanut in Egypt reached about 142857 feddans during 2016, and produced about 210000 metric tons of yield (USDA, 2016). The peak yield of peanut requires 500 to 700mm of water. Peanut crop coefficient (kc) values for the initial stage (15 to 35 days) are 0.4-0.5, the crop development stage (30 to 45 days) are 0.7-0.8, the mid-season stage

(30 to 50 days) are 0.95-1.1, the late-season stage (20 to 30 days) are 0.7-0.8, and at harvest are 0.55-0.6 (Doorenbos and Kassam, 1986).

The objectives of the present study were to determine the effect of different levels of a locally manufactured soil conditioner and the rates of irrigation water on amounts of applied irrigation water, water consumptive used, water productivity, moisture properties of sandy soil and on the productivity of peanut crop. Also, to test the validity of a simulation model to predict changes in soil moisture contents with time as well as moisture distribution within the soil profile.

### **MATERIALS AND METHODS**

#### Experimental site:

A field experiment was carried out during the two successive summer seasons of 2015 and 2016 at Abdel Moniem Reyad Village (altitude: 7m above sea level, latitude: 30°41'8" N, and longitude: 30°18'0" E), El-Bustan area, El-Beheira governorate, Egypt. Some physical properties (particle size analysis, textural class, bulk density (BD), moisture content at field capacity (FC) and wilting point (WP), and saturated hydraulic conductivity (ks)) and chemical properties (soil reacting (pH), electric conductivity (EC), and soluble anions and cations) of the soil at the experimental site were determined. The measured parameters were determined according to Black et al. (1985) and presented in Tables (1) and (2). Soil bulk density was determined by using cylindrical cores (0.04 m long and 0.052 m I.D.) according to Blake and Hartge (1986).

Table (1). Some physical properties of the soil at the experimental site.

Soil depth (cm)	Particle size (%)			Textural class	BD (Mg m <sup>-3</sup> )	FC wt/ wt	WP wt/ wt	Ks (m s <sup>-1</sup> )
	Sand	Silt	Clay					
0-20	92.7	5.05	2.25	Sandy	1.59	0.143	0.062	4.15E-05
20-40	93.5	4.36	2.14	Sandy	1.56	0.146	0.066	4.34E-05
40-60	93.3	4.44	2.26	Sandy	1.58	0.145	0.064	4.67E-05

Table (2). Some chemical properties of the soil at the experimental site.

Soil depth (cm)	pH (1: 2.5)	EC (dS/m)	Soluble cations (meq/l)				Soluble anions (meq/l)			
			Ca <sup>2+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>	K <sup>+</sup>	CO <sub>3</sub> <sup>2-</sup>	HCO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup>	Cl <sup>-</sup>
0-20	7.98	1.31	3.2	2.5	6.3	0.7	-	3.7	2.2	6.7
20-40	8.11	1.33	3.1	1.9	6.2	0.9	-	3.5	2.4	6.2
40-60	8.15	1.34	3.0	2.1	6.3	0.8	-	3.7	2.1	6.5

Experimental design and tested treatments:

A split plot design with three replicates was used to conduct the field experiment. The main plots represented four soil conditioner treatments, and the sub-plots were assigned for three irrigation rates.

Soil conditioner treatments (main plots):

SC0: without soil conditioner (control),

SC1: Applied soil conditioner at the rate of 1 ton/fed.

SC2: Applied soil conditioner at the rate of 2 ton/fed.

SC3: Applied soil conditioner at the rate of 3 ton /fed.

Irrigation rate treatments (sub-plots):

Full irrigation: 100% of reference evapotranspiration (ET<sub>o</sub>).

Moderate deficit: 75% of reference evapotranspiration (ET<sub>o</sub>).

Severe deficit: 50% of reference evapotranspiration (ET<sub>o</sub>).

Cultural practices:

The experimental field was prepared by plowing three times. Before the last plow, phosphorus fertilizer as triple superphosphate at 200 kg/fed and 50 kg/fed potassium fertilizer as potassium sulphate were applied prior to planting. Peanut cultivar (Ismailia 2) was used at rate of 45 kg seed/fed. Three seeds were planted per hill and the seedlings were thinned to two plants per hill 15 days after sowing (DAS). The planting and harvesting dates were 10, 15 May and 15, 21 Sep. in first and second seasons, respectively. Only the two central rows were used for sampling of each treatment.

Soil conditioner:

The soil conditioner used to amend the soil at the experimental site was manufactured as granules by the ARC, Soil Amendment Factory located at the research farm of Abdel Moniem Reyad Village, El-Bustan area, Egypt. The soil conditioner was made from hydrogel polymer powder mixed with taffla at 1:5 ratio. In the 1<sup>st</sup> season only, soil conditioner was distributed according to the study rates and incorporated into the surface 20-30cm layer of the soil before last plowing.

Irrigation system:

A solid-set sprinkler irrigation system was used. The components and parameters of the irrigation system network at the experimental site are

summarized in Table (3). The discharge from the sprinkler nozzle was calibrated and the pressure was measured in the field using a hypodermic needle assembly and dial pressure gage as recommended by the ASAE standard (1988).

Table (3). Specifications of sprinkler irrigation network.

Item	Specification	Item	Specification
Sprinkler type	RC235	Sprinkler wetted diameter	24 (m)
Nozzle diameter $\phi$	3.2 (mm)	PVC. lateral diameter	63 (mm)
Raiser height	120 (cm)	Sprinkler spacing	6 $\times$ 12 (m)
Steel riser diameter	26.7 (mm)	PVC main line diameter	110 (mm)
Working pressure	250 (kPa)	Pump pressure head	380 (kPa)
sprinkler flow rate	0.61(m <sup>3</sup> /h)	Power of electric motor	15 (kW)

#### Sprinkler irrigation system evaluation:

The irrigation system was evaluated before planting, at mid-season and after harvesting. Maintenance, was conducted before each growing season. Average water depth ( $d_{av}$ ), average lower quarter depth ( $d_{lq}$ ), distribution uniformity ( $DU$ ), distribution efficiency ( $CU$ ), and water application efficiency ( $Ea$ ) evaluation parameters were determine according to (Keller and Bliesner, 1990) and expressed by the following equations:

$$d_{av} = \frac{\sum X_i}{n} \quad (1)$$

$$d_{lq} = \frac{\sum X_{\min 25\%}}{n_{\min 25\%}} \quad (2)$$

$$DU = \frac{d_n}{d_{av}} \times 100 \quad (3)$$

$$CU = \left( 1 - \frac{\sum |X_i - X_m|}{X_m \times n} \right) \quad (4)$$

$$Ea = \frac{d_{lq}}{d_a} \times 100 \quad (5)$$

where:

$X_i$  = individual depth of water for each observation from the uniformity test (mm).

$X_m$  = mean depth of water (mm).

$n$  = number of collection catch cans which were distributed in a grid system of  $2 \times 1$  meter.

$\sum |x_i - x_m|$  = sum of the absolute deviation from the mean measurements

$d_a$  = average depth of irrigation water applied (sprinkler application rate for a given time (mm)).

The distribution uniformity test lasted half an hour, three quarter an hour and one hour under the operating pressure.

Crop water requirement (ETc):

Crop water requirement (ETc) was calculated as the sum of water loss through transpiration and soil evaporation based on Doorenbos and Pruitt (1992) and expressed as follows:

$$ET_c = ET_o \times K_c \quad \text{mm day}^{-1} \quad (6)$$

$$ET_o = ET_{pan} \times K_{pan} \quad \text{mm day}^{-1} \quad (7)$$

where:

$ET_o$  = evapotranspiration of a reference plant under specified conditions calculated using the class A pan (mm day<sup>-1</sup>) at the experimental site.

$K_c$  = the crop coefficient values of peanut crop.

$E_{pan}$  = measured class A pan values (mm day<sup>-1</sup>).

$K_{pan}$  = pan coefficient equals to 0.8 under experimental conditions.

Gross irrigation water depths (GIWD):

The gross irrigation water depths (GIWR) was calculated according to Brouwer et al. (1989) as follows:

$$GIWD = \frac{I_r}{E_a \times LR} \quad (8)$$

$$I_r = A \times ET_c \quad (9)$$

where:

$I_r$  = net irrigation depth (mm).

$A$  = the plot area (m<sup>2</sup>).

$E_a$  = irrigation system application efficiency as calculated from system evaluation.

$LR$  = leaching requirements to control the soil salinity, estimated according to Doorenbos and Pruitt (1977) by the following formula for surface irrigation methods (including sprinklers) as:

$$LR = \frac{EC_w}{5 EC_e - EC_w} \quad (10)$$

where:

$EC_e$  = electrical conductivity of the soil saturation extract.

$EC_w$  = electrical conductivity of the irrigation water.

#### Irrigation duration ( $Ti_{spr}$ ):

The irrigation time for the sprinkler irrigation system ( $Ti_{spr}$ ) was calculated according to Ismail (2002) as follow:

$$Ti_{spr} = \frac{GIWD}{A_r} \times In \quad (11)$$

where:

$A_r$  = sprinkler application rate (mm/h).

$In$  = irrigation intervals (day).

#### Peanut water consumptive use (WCU):

WCU values were estimated according to Simonne and Dukes (2010) as:

$$WCU = \frac{\sum D (\theta_{vi} - \theta_{vf})}{100 \times ND} \quad (12)$$

where:

$D$  = thickness of the soil layer (mm).

$\theta_{vi}$  = initial volumetric soil moisture content (%).

$\theta_{vf}$  = volumetric soil moisture content after irrigation (%).

$ND$  = No. of days between irrigations.

#### Soil moisture simulation:

Gravimetric soil samples, from soil surface down to 0.6 m depth at 0.20 m intervals were collected during the growing season from all treatments



before and after each irrigation to determine water consumptive use (WCU, mm/day) or crop evapotranspiration (ETc). The distribution of measured soil moisture contents within the soil surface layer (0 - 0.6m) was compared with the values predicted by a mathematical simulation model developed by Allam (2004). The simulation model was based on Richard's equation, developed from the two soil physical principles of Darcy's law and continuity equation. The equation governs the flow of water in the soil in terms of diffusivity form is reported by Miller and Klute (1967) as:

$$\frac{\partial \theta}{\partial t} = \frac{\partial}{\partial x} \left( D(\theta) \frac{\partial \theta}{\partial x} \right) + \frac{\partial}{\partial y} \left( D(\theta) \frac{\partial \theta}{\partial y} \right) + \frac{\partial}{\partial z} \left( D(\theta) \frac{\partial \theta}{\partial z} \right) - \frac{\partial K(\theta)}{\partial z} \quad (13)$$

where

$\theta$  is the volumetric soil water content in  $\text{m}^3 \text{m}^{-3}$ .

$t$  is time (min.).

$D(\theta)$  is the soil water diffusivity as a function of water content ( $\text{m}^2 \text{min}^{-1}$ ).

$K(\theta)$  is the unsaturated hydraulic conductivity as a function of water content ( $\text{m min}^{-1}$ ).

$x, y$  are the horizontal coordinates.

$z$  is the vertical coordinate which is considered to be positive downward.

The simulation model was used to simulate the distribution of irrigation water in the soil under the current study conditions. The simulation model was also used to evaluate the sprinkler irrigation system. The hydro-physical parameters of the soil at the experimental site needed as inputs to the simulation model were calculated using the following equation:

$$\psi_m = \psi_e \left( \frac{\theta}{\theta_s} \right)^b \quad (14)$$

where:

$\psi_m, \psi_e$  are matric and the air entry potential.

$\theta, \theta_s$  are volumetric and the saturated water content and  $b$  is a constant.

Details of the simulation model, governing equations, and application examples are given in Allam (2004), Khalifa et al. (2004), and El-Shafei et al. (2008).

Yield and yield components:

At harvest, plant samples from an area of 1.2 m<sup>2</sup> from the two central ridges were uprooted from each treatment randomly and topped to determine yields of seeds and straw per feddan and yield components (pod weight/plant, kernel weight/plant, and 100 kernel/plant). Kernels crude protein percentage was calculated by analyzing samples at the Faculty of Agriculture, Alex. University. Shelling % was calculated according to the following equation:

$$\text{Shelling \%} = \frac{\text{kernel weight / plant}}{\text{Pod weight / plant}} \times 100 \quad (15)$$

Water productivity (WP):

Water productivity (kg m<sup>-3</sup>) of peanut crop was calculated as proposed by Molden (2003).

$$WP = \frac{Y}{I} \quad (16)$$

where:

$Y$  is pods or straw yield in kg fed<sup>-1</sup> and  $I$  is applied irrigation water in m<sup>3</sup> fed<sup>-1</sup>.

Statistical analysis:

The collected data were analyzed using Costat 6.311 Win. of CoHort Software (2005) statistical program. Average values from the three replicates of each treatment were interpreted using the analysis of variance (ANOVA). The Duncan's Multiple Range Test (SNK) was used for comparisons among different sources of variance.

## RESULTS AND DISCUSION

Field evaluation of the sprinkler irrigation system:

The irrigation system was evaluated three times, before planting, mid-season stage, and after harvesting. Evaluation results are presented in Table (4). Results showed that, the calculated  $E_a$  values varied from

69.18 to 71.49% in the 1<sup>st</sup> season and from 71.11 to 74.32% in the 2<sup>nd</sup> season, respectively. According to the ASCE (1988), the obtained values are considered as acceptable values. Results indicated also that, the seasonal average distribution efficiency (CU) and distribution uniformity (DU) values were 91.1 and 85.2% in the 1<sup>st</sup> season, and were 91.2 and 86.3% in the 2<sup>nd</sup> season, respectively. The measured CU and DU values were in the recommended range (Benami and Ofen, 1984). As a result of these criteria, the performance of the sprinkler irrigation system is considered acceptable.

Table (4). Results of the field evaluation of sprinkle irrigation system.

Testing time	First season			Second season		
	Ea (%)	CU (%)	DU (%)	Ea (%)	CU (%)	DU (%)
Before planting	71.49	91.98	86.45	74.32	91.03	86.99
Mid-season	69.18	91.07	85.18	71.11	92.79	87.88
After harvesting	70.77	91.25	86.90	72.46	91.78	86.03

**Effect of soil conditioner treatments on some soil physical properties:**

In general, the addition of soil conditioner causes change in soil properties, especially the hydraulic properties. The effect of soil conditioner treatments on some soil physical properties is presented in Table (5) and illustrated in Figure 1. Results indicated that, increasing the rate of soil conditioner addition to sandy soil reduced the bulk density. The BD value of SC<sub>3</sub> treatment (3 ton/fed) was 1.422 Mg m<sup>3</sup> or about 10.6% less than that of SC<sub>0</sub> treatment (control). Saturated soil moisture content ( $\theta_s$ ) increased from 0.36 to 0.44 m<sup>3</sup>m<sup>-3</sup> or by 22% for the SC<sub>0</sub> and SC<sub>2</sub> treatments, respectively. There was no difference between  $\theta_s$  values of SC<sub>2</sub> and SC<sub>3</sub> treatments. Results indicated also that, increasing soils conditioner rates reduced soil saturated hydraulic conductivity values. The K<sub>s</sub> values were 4.15E-5 and 2.79E-5 m s<sup>-1</sup> (32.8% less) for the SC<sub>0</sub> and SC<sub>3</sub> treatments, respectively. The obtained results were in agreement with the findings reported by Bhardwaj et al. (2007), Andry et al. (2009), and Leciejewski (2009). Results revealed also that, both air entry ( $\psi_e$ ) and the constant *b* values increased with increasing soil conditioner rates. For the SC<sub>0</sub>, the  $\psi_e$  and *b* values were -0.344 m and 1.741, while the same values for SC<sub>3</sub> treatment were -0.572 m and 2.156.

Figure 1. Effect of soil conditioner levels on water content at field capacity (FC) and permanent wilting point (WP) and available water (AW).

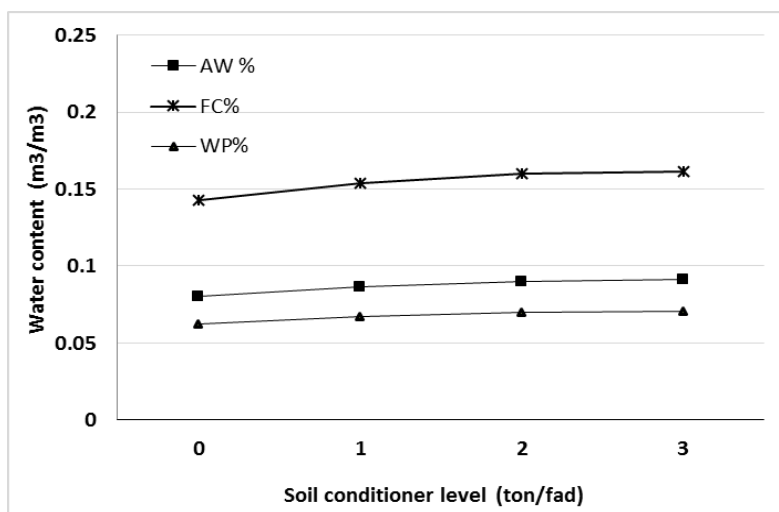


Table 5. Effect of soil conditioner treatments on some physical properties of soil at the experimental site.

Soil conditioner treatments	BD (Mg m <sup>-3</sup> )	Ψ <sub>e</sub> (m)	b	θ <sub>s</sub> (m <sup>3</sup> m <sup>-3</sup> )	ks (m s <sup>-1</sup> )
SC <sub>0</sub>	1.591	-0.344	1.741	0.36	4.15E-5
SC <sub>1</sub>	1.541	-0.394	1.897	0.40	3.87E-5
SC <sub>2</sub>	1.483	-0.508	1.991	0.44	3.05E-5
SC <sub>3</sub>	1.422	-0.572	2.156	0.44	2.79E-5

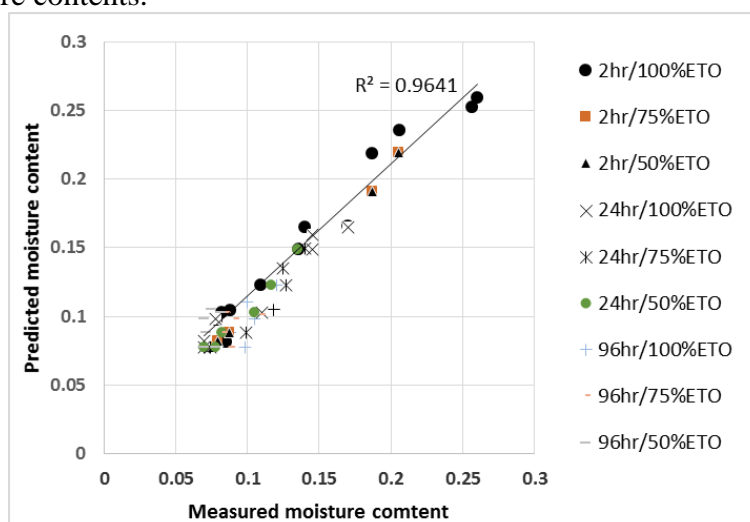
The effect of soil conditioner rates on soil moisture contents is illustrated in Fig. 1. Results showed that, increasing SC rates increased soil moisture contents at field capacity (FC) and at wilting point (WP). The available water (AW) values increased from 0.7 to 0.9 for the SC<sub>0</sub> and SC<sub>3</sub> treatments, respectively.

#### **Effect of tested treatments on soil moisture distribution:**

The simulation model was used to predict soil moisture contents at different depths after different elapsed irrigation times. The model was validated by comparing the predicted soil moisture values with those gravimetrically measured in the field. A regression equation was

developed to relate the predicted and the measured soil moisture values at different times (2 hrs to 96 hrs) after irrigation. The developed relation is illustrated in Fig. 2. Results indicated that the value of determination coefficient ( $R^2$ ) was 0.96 showing very close agreement between the predicted and measured values and the model is valid to predict soil moisture contents under the current experimental conditions scattering for both values.

Figure 2. Relationship between predicted and measured volumetric moisture contents.



The distribution of measured and predicted soil moisture in the soil profile as affected by soil conditioner levels and applied irrigation rates after 2, 24, 72, and 96 hrs. from irrigation is illustrated in Figs. 3 and 4. Results indicated, in general, that there was a close agreement between the measured and predicted moisture contents under all tested treatments. Moisture contents were higher for the SC<sub>3</sub> and 100% ETo treatments than the other treatments. After 2 hrs. from irrigation, moisture contents were high at the soil surface and decreased with depth. After 24 hrs., moisture contents decreased at the surface (0 - 5cm) and increased in the 5-20cm layer.

For the 100% ETo treatment, average soil moisture contents for the surface 20 cm layer were 0.129, 0.139, 0.145, and 0.146 m<sup>3</sup>/m<sup>3</sup> for the SC<sub>0</sub>, SC<sub>1</sub>, SC<sub>2</sub>, and SC<sub>3</sub> treatments, respectively (Table 6).

Table 6. Average soil moisture contents,  $\theta_{lq}$  (average soil moisture content for lower quarter), and  $\Delta\theta$  (range of soil moisture content ( $m^3/m^3$ )) as affected by soil conditioner and irrigation treatments after 24, 72, and 96hrs. after irrigation.

ET	Soil depth cm	SC0									SC1								
		24hr after irrigation			72hr after irrigation			96hr after irrigation			24hr after irrigation			72hr after irrigation			96hr after irrigation		
		$\theta_{av}$	$\theta_{lq}$	$\Delta\theta$	$\theta_{av}$	$\theta_{lq}$	$\Delta\theta$	$\theta_{av}$	$\theta_{lq}$	$\Delta\theta$	$\theta_{av}$	$\theta_{lq}$	$\Delta\theta$	$\theta_{av}$	$\theta_{lq}$	$\Delta\theta$	$\theta_{av}$	$\theta_{lq}$	$\Delta\theta$
100%	0-20	0.129	0.119	0.0284	0.111	0.107	0.011	0.106	0.103	0.008	0.139	0.128	0.031	0.120	0.115	0.011	0.114	0.111	0.009
	20-40	0.102	0.089	0.028	0.110	0.103	0.020	0.108	0.102	0.015	0.111	0.096	0.043	0.119	0.111	0.022	0.116	0.110	0.016
	40-60	0.082	0.078	0.016	0.089	0.099	0.030	0.102	0.093	0.025	0.088	0.084	0.017	0.106	0.095	0.032	0.110	0.100	0.027
75%	0-20	0.109	0.099	0.023	0.093	0.090	0.009	0.089	0.086	0.007	0.116	0.107	0.025	0.101	0.097	0.009	0.095	0.092	0.007
	20-40	0.086	0.075	0.033	0.093	0.087	0.017	0.091	0.085	0.012	0.093	0.080	0.036	0.100	0.093	0.018	0.098	0.093	0.014
	40-60	0.079	0.076	0.013	0.083	0.074	0.025	0.086	0.078	0.021	0.085	0.082	0.015	0.089	0.080	0.027	0.092	0.084	0.022
50%	0-20	0.099	0.091	0.021	0.085	0.082	0.008	0.081	0.079	0.006	0.106	0.097	0.023	0.091	0.088	0.009	0.087	0.085	0.007
	20-40	0.084	0.075	0.031	0.085	0.079	0.015	0.083	0.078	0.011	0.088	0.077	0.033	0.091	0.085	0.016	0.089	0.086	0.012
	40-60	0.075	0.076	0.012	0.081	0.076	0.017	0.078	0.075	0.019	0.080	0.077	0.013	0.087	0.082	0.018	0.084	0.077	0.022
		SC2									SC3								
100%	0-20	0.145	0.133	0.032	0.125	0.121	0.012	0.120	0.115	0.009	0.146	0.134	0.032	0.126	0.121	0.012	0.119	0.116	0.009
	20-40	0.116	0.100	0.045	0.124	0.116	0.022	0.122	0.116	0.018	0.116	0.101	0.045	0.125	0.117	0.023	0.122	0.116	0.017
	40-60	0.092	0.088	0.018	0.112	0.099	0.034	0.115	0.105	0.028	0.093	0.088	0.018	0.112	0.100	0.034	0.116	0.105	0.028
75%	0-20	0.122	0.112	0.027	0.105	0.101	0.010	0.100	0.097	0.008	0.123	0.113	0.027	0.106	0.102	0.010	0.101	0.098	0.008
	20-40	0.097	0.084	0.038	0.104	0.097	0.019	0.102	0.098	0.014	0.098	0.084	0.038	0.105	0.098	0.019	0.103	0.097	0.014
	40-60	0.088	0.085	0.015	0.094	0.083	0.028	0.097	0.087	0.023	0.089	0.085	0.015	0.094	0.084	0.028	0.097	0.088	0.023
50%	0-20	0.111	0.103	0.024	0.096	0.093	0.009	0.091	0.088	0.007	0.111	0.102	0.024	0.097	0.093	0.009	0.092	0.089	0.007
	20-40	0.092	0.080	0.034	0.095	0.089	0.017	0.093	0.087	0.013	0.096	0.081	0.035	0.096	0.089	0.017	0.094	0.088	0.013
	40-60	0.084	0.081	0.014	0.091	0.085	0.019	0.088	0.080	0.021	0.084	0.081	0.014	0.092	0.086	0.018	0.089	0.081	0.021

Figure 3. Distribution of measured and predicted water content in the soil profile as affected by the tested treatments after 2 and 24 hr from irrigation.

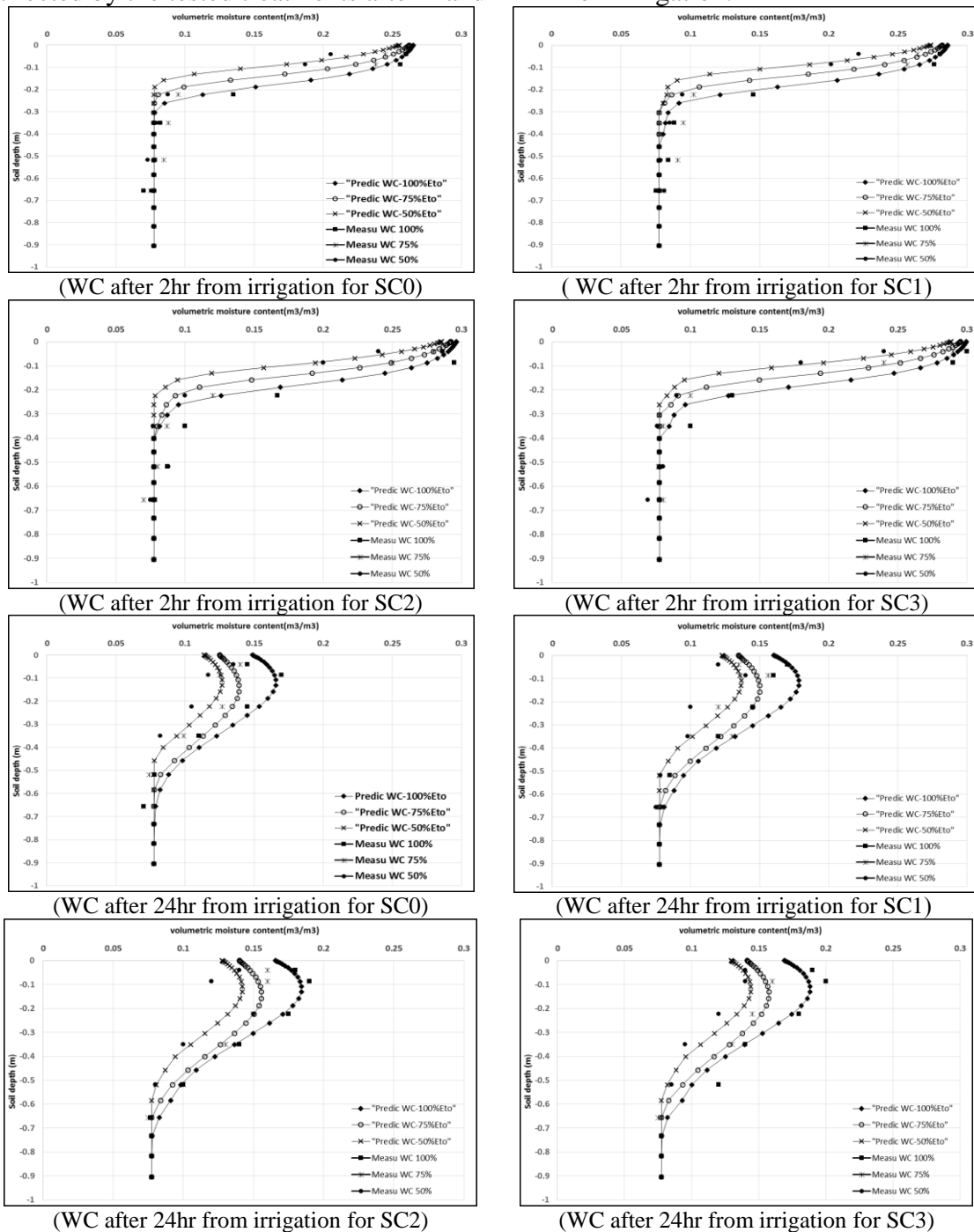
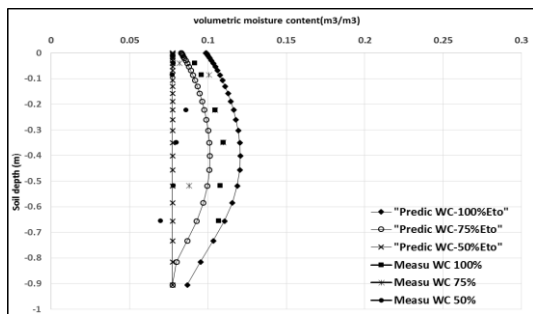
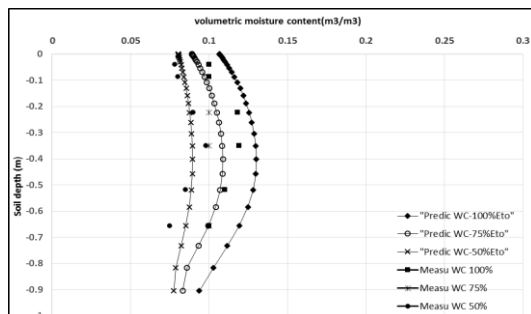


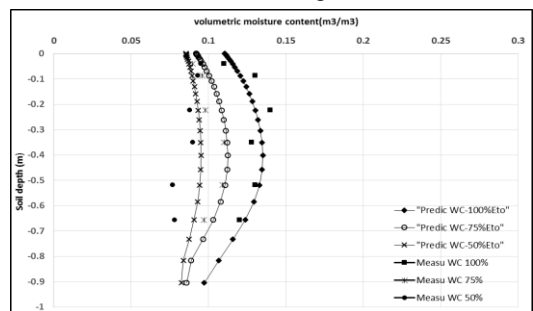
Figure 4. Distribution of measured and predicted water content in the soil profile as affected by the tested treatments after 72 and 96 hrs. from irrigation.



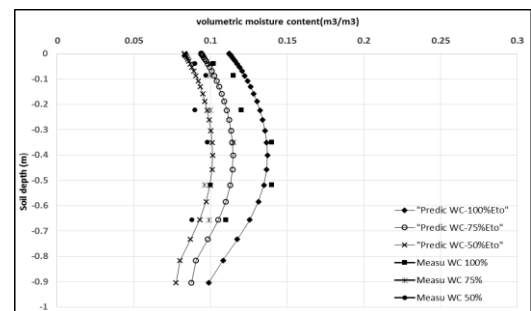
(WC after 72hr from irrigation for SC0)



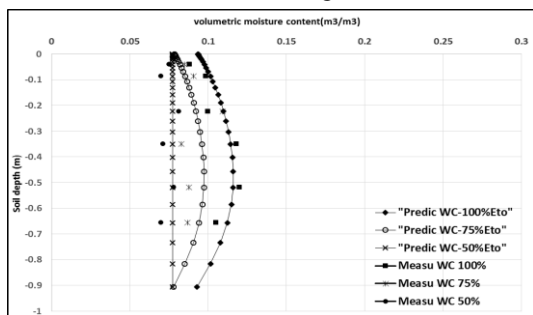
(WC after 72hr from irrigation for SC1)



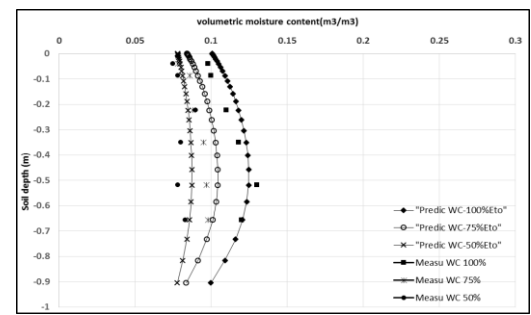
(WC after 72hr from irrigation for SC2)



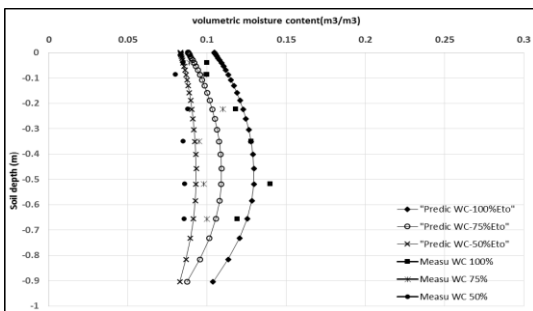
(WC after 72hr from irrigation for SC3)



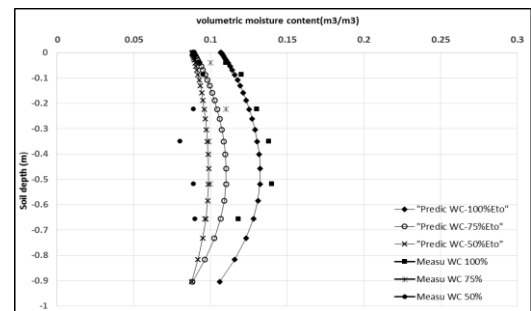
(WC after 96hr from irrigation for SC0)



(WC after 96hr from irrigation for SC1)



(WC after 96hr from irrigation for SC2)



(WC after 96hr from irrigation for SC3)



After 96hrs., average moisture contents in the surface 20cm layer were 0.106, 0.114, 0.119, and 0.12  $\text{m}^3/\text{m}^3$  for the same respective soil conditioner treatments. Results presented in Table 6 and Figs. 3 and 4 indicated for the 100% ETo treatment that, soil moisture contents at the 40-60cm layer after 96hrs. were 0.102, 0.11, 0.115, and 0.116  $\text{m}^3/\text{m}^3$  for the SC<sub>0</sub>, SC<sub>1</sub>, SC<sub>2</sub>, and SC<sub>3</sub> treatments, respectively. Results showed also that, decreasing the irrigation rates decreased soil moisture contents within the soil profile.

### **Amounts of applied irrigation water (AIW) and water consumptive use (WCU):**

Results in Table (7) show the amounts of water applied to the peanut crop during the two seasons. Results showed that the amounts of irrigation water were 3099, 2325 and 1550  $\text{m}^3/\text{fed}$  in 2015 and 2873, 2155 and 1462  $\text{m}^3/\text{fed}$  in 2016 for the full irrigation (100% ETo), moderate deficit (75% ETo) and severe deficit irrigation (50% ETo) treatments, respectively. The amounts of water applied for full irrigation and moderate deficit agreed with those reported by Attia and Hammad (1999) and Doorenbos and Kassam (1986).

Seasonal water consumptive used (WCU) by peanut plants during the two seasons as affected by the soil conditioner and irrigation rates treatments are presented in Table (7).

Table 7. Seasonal applied water and consumptive use ( $\text{m}^3/\text{fed}$ )

Irrigation treatment	Soil Conditioner	Applied water ( $\text{m}^3/\text{fed}$ )			Water consumption ( $\text{m}^3/\text{fed}$ )			WCU/AIW (%)
		2015	2016	Average	2015	2015	Average	
100% ETo	SC <sub>0</sub>	3099	2873	2986	2759.40	2533.27	2646	88.6
	SC <sub>1</sub>				2875.37	2633.36	2754	92.2
	SC <sub>2</sub>				2900.86	2693.49	2797	93.6
	SC <sub>3</sub>				2959.00	2853.34	2906	97.3
75% ETo	SC <sub>0</sub>	2325	2155	2240	2110.10	1971.05	2041	91.1
	SC <sub>1</sub>				2190.31	1991.13	2091	93.3
	SC <sub>2</sub>				2219.69	2019.23	2119	94.6
	SC <sub>3</sub>				2250.79	2051.11	2151	96.0
50% ETo	SC <sub>0</sub>	1550	1462	1506	1462.00	1373.56	1418	94.2
	SC <sub>1</sub>				1481.45	1385.61	1434	95.2
	SC <sub>2</sub>				1494.71	1398.69	1447	96.1
	SC <sub>3</sub>				1510.79	1403.60	1457	96.7

Results indicated that, WCU increased with increasing soil conditioner and irrigation water rates. Results showed also that, average WCU values increased from 2646 to 2906 m<sup>3</sup>/fed for the 100% ETo, and from 2041 to 2151 m<sup>3</sup>/fed for the 75% ETo, and from 1418 to 1457 m<sup>3</sup>/fed as soil conditioner values increased from zero (SC<sub>0</sub>) to ton/fed (SC<sub>3</sub>). Water consumed from applied water increased with decreasing the amounts of applied water. Average WCU/AIW values were 93, 93.8, and 95.6% for the 100, 75, and 50% ETo irrigation treatments, respectively.

### **Effect on peanut yield and yield components:**

The effect of tested treatments on pod weight (g/plant), kernels weight (g/plant), 100-kernels (g), and shelling (%) are presented in Table (8).

Table 8. Effect of tested treatments on yield components of peanut crop in the two seasons.

Irrigation rates	SC rate (ton/fed)	Pod weight (g/plant)		kernels weight (g/plant)		100-kernels (g)		Shelling (%)	
		2015	2016	2015	2016	2015	2016	2015	2016
100%		77.84a	78.75a	54.81a	55.94a	86.44a	87.44a	70.41a	71.01a
75%		72.72b	73.84b	50.06b	51.06b	80.06b	81.56b	68.53b	68.85b
50%		58.50c	57.44c	38.04c	38.19c	57.81c	56.69c	65.01c	66.42c
LSD 0.05		1.237	1.488	1.373	1.401	1.183	0.955	1.214	1.602
	SC <sub>0</sub>	63.29c	61.63c	42.17c	41.25c	68.00c	66.25c	66.36b	66.71b
	SC <sub>1</sub>	67.17b	67.42b	45.42b	46.08b	71.58b	72.00b	67.37b	68.02ab
	SC <sub>2</sub>	73.67a	75.50a	51.06a	53.08a	79.33a	81.50a	68.97a	70.11a
	SC <sub>3</sub>	74.63a	75.50a	51.91a	53.17a	80.17a	81.17a	69.23a	70.20a
LSD 0.05		1.203	1.575	1.151	1.524	1.239	1.206	1.300	2.522
100%	SC <sub>0</sub>	71.38	69.75	50.25	49.00	80.75	78.75	65.04	70.25
	SC <sub>1</sub>	76.00	77.00	53.25	54.75	83.75	85.75	70.06	71.13
	SC <sub>2</sub>	82.50	84.25	57.25	60.00	90.00	92.75	70.25	71.22
	SC <sub>3</sub>	82.50	84.00	58.5	60.00	91.25	92.50	70.92	71.44
75%	SC <sub>0</sub>	64.00	62.13	41.00	40.25	70.25	68.75	64.02	64.81
	SC <sub>1</sub>	68.25	69.00	45.75	47.00	74.75	75.75	67.00	68.09
	SC <sub>2</sub>	78.50	82.25	56.25	58.50	87.00	91.75	71.65	71.15
	SC <sub>3</sub>	80.13	82.00	57.25	58.50	88.25	90.75	71.44	71.33
50%	SC <sub>0</sub>	54.5	53.00	35.25	34.50	53.00	51.25	64.65	65.05
	SC <sub>1</sub>	57.25	56.25	37.25	36.50	56.25	54.50	65.04	64.86
	SC <sub>2</sub>	61.00	60.00	39.68	40.75	61.00	60.75	65.02	67.95
	SC <sub>3</sub>	61.25	60.50	40.00	41.00	61.00	60.25	65.33	67.82
LSD 0.05		***	***	***	***	***	***	***	***

Results showed that, there were significant effect of irrigation rates and soil conditioner levels on the tested parameters. Decreasing the amounts of applied irrigation water, significantly decreased all the tested parameters. As for soil conditioner levels, there was no significant difference between SC<sub>3</sub> and SC<sub>2</sub> levels, while they both differed significantly with SC<sub>1</sub> and SC<sub>0</sub> levels. The interaction between 100% ETo and SC<sub>2</sub> treatments recorded the highest pod weight/plant of 82.5 and 84.25 g/plant in the 2015 and 2016 seasons, respectively. The same treatments achieved the highest kernel weight per plant of 58.5 and 60 g/plant in the same respective seasons. The highest 100-kernel weight of 91.25 and 92.75 g were recorded for the interaction between 100% ETo and SC<sub>3</sub> and the 100% ETo and SC<sub>2</sub> treatments in the two seasons, respectively. As for the shelling %, the highest values of 70.92 and 71.44% were recorded for the 100% ETo and SC<sub>3</sub> treatment in the two seasons. The lowest values of the previous parameters were recorded for the interaction between 50% ETo and SC<sub>0</sub> treatments in both seasons.

The effect of irrigation rates and soil conditioner levels on kernel protein and straw protein, pod and straw yields in the two growing seasons is presented in Table (9). Results indicated, in general that, there was a significant effect of the tested treatments on the abovementioned parameters. All the tested parameters were significantly different at each irrigation rate, with highest values at 100% ETo rate and lowest values at the 50% rate in the two seasons. As for soil conditioner effect, results showed no significant difference between SC<sub>2</sub> and SC<sub>3</sub> rates on pod and straw yields, while they both differed than SC<sub>1</sub> and SC<sub>0</sub> rates. This trend was not the same for kernel and straw proteins. The interaction 100% ETo \* SC<sub>3</sub> the highest values of 29.75 and 28.5% for the kernel protein parameter in the two seasons, and the value of 15.13% for the straw protein in the 2015 season. While, the interaction 100% ETo \* SC<sub>2</sub> recorded the highest value of 14.34% for the straw protein parameter in the 2016 season. The same interaction recorded the highest pod yields of 1.83 and 1.89 ton/fed and the straw yields of 1.31 and 1.32 ton/fed in the 2015 and 2016 growing seasons, respectively.

Results showed also that, the interaction between 50% ETo \* SC<sub>0</sub> recorded the lowest values of kernel and straw proteins and pod and

straw yields in the two seasons. The obtained results of peanuts yield components were consistent with those reported by El-Shafei et al., (2008), Abdrabbo, (2009) and Badawi et al., (2011).

Table 9. Effect of the tested treatments on kernel and straw proteins and on pod and straw yields in the two seasons.

Irri. rate	SC rate (ton/fed)	Kernels protein (%)		Straw protein (%)		Pod yield (Mg/fed)		Straw yield (Mg/fed)	
		2015	2016	2015	2016	2015	2016	2015	2016
100%		28.50a	27.69a	14.76a	14.48a	1.65a	1.67a	1.18a	1.22a
75%		25.30b	25.19b	13.24b	13.13b	1.42b	1.48b	1.03b	1.06b
50%		21.13c	20.47c	11.74c	11.38c	1.05c	1.02c	0.78c	0.80c
LSD 0.05		0.620	0.731	0.419	0.419	0.048	0.046	0.042	0.049
	SC <sub>0</sub>	23.1b	22.00c	12.41c	12.12b	1.09c	1.09c	0.76c	0.78c
	SC <sub>1</sub>	23.71b	23.71b	12.81c	12.92a	1.25b	1.18b	0.95b	0.98b
	SC <sub>2</sub>	26.21a	25.92a	13.55b	13.44a	1.59a	1.66a	1.14a	1.17a
	SC <sub>3</sub>	26.88a	26.17a	14.21a	13.49a	1.58a	1.63a	1.14a	1.16a
LSD 0.05		0.963	1.090	0.573	0.647	0.068	0.066	0.071	0.081
100%	SC <sub>0</sub>	27.75	25.75	14.63	14.31	1.44	1.47	1.02	1.03
	SC <sub>1</sub>	28.00	28.00	14.76	14.95	1.59	1.46	1.14	1.20
	SC <sub>2</sub>	28.5	28.5	14.5	14.34	1.83	1.89	1.31	1.32
	SC <sub>3</sub>	29.75	28.50	15.13	14.30	1.75	1.85	1.25	1.33
75%	SC <sub>0</sub>	23.49	22.75	12.33	12.03	1.05	1.04	0.69	0.69
	SC <sub>1</sub>	23.94	24.63	12.99	13.20	1.25	1.22	1.00	1.04
	SC <sub>2</sub>	26.50	26.63	13.38	13.73	1.69	1.84	1.22	1.25
	SC <sub>3</sub>	27.25	26.75	14.25	13.55	1.71	1.81	1.23	1.24
50%	SC <sub>0</sub>	18.09	17.50	10.26	10.03	0.78	0.78	0.57	0.62
	SC <sub>1</sub>	19.19	18.50	10.68	10.60	0.91	0.87	0.71	0.70
	SC <sub>2</sub>	23.63	22.63	12.79	12.25	1.24	1.24	0.89	0.94
	SC <sub>3</sub>	23.63	23.25	13.25	12.63	1.29	1.22	1.23	0.91
LSD 0.05		***	**	***	***	***	***	***	**

### **Effect on water productivity (WP):**

The effect of tested treatments on water productivity of peanut crop is presented in Table (9). Results indicated that WP values were significantly affected by both irrigation rates and soil amendment treatments. Results revealed that, decreasing the amounts of applied water, increased the WP values. While, increasing the soil conditioner rates increased the WP values. The lowest WP values of 0.53 and 0.58 kg pods/m<sup>3</sup> of applied water were obtained from plots received full irrigation (100% ETo) in the 2015 and 2016 seasons, respectively. Also, the lowest values of 0.38 kg straw/m<sup>3</sup> and 0.42 kg straw/m<sup>3</sup> of applied water were recorded for the respective two seasons.

Table 10. Water productivity as affected by the different soil conditioner levels and irrigation rates

Irrigation rate	SC rate (ton/fed)	Water productivity (kg pod/m <sup>3</sup> )		Water productivity (kg straw/m <sup>3</sup> )	
		2015	2016	2015	2016
100%		0.53c	0.58c	0.38c	0.42c
75%		0.61b	0.69b	0.44b	0.49b
50%		0.68a	0.71a	0.50a	0.55a
LSD 0.05		0.0215	0.0210	0.0236	0.030
	SC <sub>0</sub>	0.47c	0.51c	0.33c	0.37c
	SC <sub>1</sub>	0.54b	0.56b	0.42b	0.46b
	SC <sub>2</sub>	0.71a	0.79a	0.50a	0.56a
	SC <sub>3</sub>	0.71a	0.78a	0.51a	0.56a
LSD 0.05		0.0327	0.0305	0.0373	0.0497
100%	SC <sub>0</sub>	0.46	0.51	0.33	0.36
	SC <sub>1</sub>	0.51	0.51	0.37	0.42
	SC <sub>2</sub>	0.59	0.66	0.42	0.46
	SC <sub>3</sub>	0.65	0.65	0.40	0.46
75%	SC <sub>0</sub>	0.45	0.48	0.30	0.32
	SC <sub>1</sub>	0.54	0.57	0.43	0.48
	SC <sub>2</sub>	0.72	0.86	0.52	0.58
	SC <sub>3</sub>	0.73	0.84	0.53	0.58
50%	SC <sub>0</sub>	0.50	0.54	0.37	0.43
	SC <sub>1</sub>	0.58	0.61	0.45	0.49
	SC <sub>2</sub>	0.80	0.86	0.57	0.65
	SC <sub>3</sub>	0.83	0.85	0.61	0.63
LSD 0.05		***	***	***	***

As deficiency of irrigation water intensified, WP improved and reached 0.68 kg pods/m<sup>3</sup> and 0.71 kg pods/m<sup>3</sup> as well as 0.50 kg straw/m<sup>3</sup> and 0.55 kg straw/m<sup>3</sup> in 2015 and 2016 seasons, respectively.

As for soil conditioner, increasing the SC rates from zero to 3 ton/fed increased the WP values from 0.47 to 0.71 kg pods/m<sup>3</sup> in 2015 and from 0.51 to 0.79 kg pods/m<sup>3</sup> in 2016. The same trend was recorded for the WP of straw yield. The Wp values increased from 0.33 to 0.51 kg straw/m<sup>3</sup> in 2015 and from 0.37 to 0.56 kg straw/m<sup>3</sup> in 2016. Results in Table (9) showed significant interaction between irrigation rate and soil conditioner on WP values. The values of water productivity for different treatments agreed with those obtained by El-Shafei et al., (2008), Yinhong et al., (2009) and Xiaolin et al., (2015).

### CONCLUSIONS

From the obtained results it could be concluded that:

- The addition of the soil conditioner to sandy soil improves its water storage capability and decreases its saturated hydraulic conductivity.
- The tested simulation model proved to be accurate to predict changes in soil moisture contents with time as well as moisture distribution within the soil profile.
- Applying amount of irrigation water equals to 100% ETo with 2 ton/fed of hydro-gel soil conditioner will produce the highest pod and straw yields of peanut crop grown in sandy soil.
- In the sandy soil, an average water productivity value of 0.65 kg pod/m<sup>3</sup> and 0.43 kg straw/m<sup>3</sup> can be achieved from the interaction between 100% ETo \* SC<sub>2</sub> treatment.

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الملخص العربي**تأثير محسن التربة علي المحتوى الرطوبي للأرض الرملية وإنتاجية الفول السوداني تحت معدلات مياه ري مختلفة**خليل عبدالحليم علام<sup>١</sup>

لدراسة تأثير إضافة محسن للتربة على المحتوى الرطوبي للتربة الرملية وإنتاجية الفول السوداني تحت معدلات ري مختلفة اجريت تجربة حقلية خلال موسم نمو صيفيين ٢٠١٥ و ٢٠١٦ في قرية عبد المنعم رياض (خط عرض ٨° ٤١' ٣٠" شمالاً، خط الطول ٠° ١١٨' ٣٠" شرقاً، و ٢٠ متراً فوق مستوى سطح البحر)، بمنطقة البستان، محافظة البحيرة، مصر. كما تم اختبار صحة نموذج لمحاكاة للتنبؤ بالتغيرات في المحتوى الرطوبي للتربة مع الزمن. اشتملت الدراسة علي اربعة مستويات من محسنات التربة ( SC0 بدون اضافته و SC1 : ١طن/الفدان و : SC2 ٢طن/الفدان و SC3 : ٣طن/الفدان ) وكذلك ثلاثة معدلات مياه ري (الري الكامل: ١٠٠٪، الري بمعدل نقص معتدل: ٧٥٪ الري بمعدل نقص شديد: ٥٠٪ من البخرنتج المرجعي) قيم البخرنتج (ET<sub>o</sub>) المرجعية اتخذت على اساس قياسات وعاء قياس البخر النوع أ US Class A-Pan وصنف الفول السوداني المستخدم في التجربة هو اسماعيلية ٢.

أشارت النتائج إلى أن أداء نظام الري بالرش في الموقع التجريبي يعتبر مقبولاً. إضافة محسن التربة بالمعدلات المذكورة إلى التربة الرملية أدت الي خفض الكثافة الظاهرية وقيم معامل التوصيل الهيدروليكي المشبعة وزيادة محتويات الرطوبة المشبعة، والسعة الحقلية، ونقطة الذبول وبالتالي زيادة الماء المتاح، وقيم دخول الهواء. زيادة محتويات التربة الرطوية. أثبت نموذج المحاكاة المختبر أنه دقيق للتنبؤ بالتغيرات في محتويات رطوبة التربة مع مرور الوقت وكذلك توزيع الرطوبة داخل قطاع التربة. وكان متوسط قيم كمية مياه الري المضافة خلال موسم النمو ٢٩٨٦ و ٢٢٤٠ و ١٥٠٦ م<sup>٣</sup> / فدان للمعاملات و ١٠٠ و ٧٥ و ٥٠٪ من البخر نتج على التوالي. وقد تأثرت العوامل المتغيرة للمختبرة للمحصول ومكوناته لمحصول الفول السوداني معنوياً بشكل ملحوظ بالمعاملات المختبرة في ظل الظروف التجريبية. وقد أدى إضافة كمية مياه ري مساوية لـ ١٠٠٪ من البخرنتج مع ٢ طن محسن تربة/ فدان من محسن التربة إلى إنتاج أعلى محصول قرون بلغت ١.٨٣ و ١.٨٩ طن / الفدان ومحصول قش بلغت ١.٣٣ و ١.٣٢ طن / الفدان لمحصول الفول السوداني المزروع في التربة الرملية. كما اشارت النتائج ايضاً إلى أنه يمكن تحقيق متوسط انتاجية وحدة المياه بمقدار ٠.٦٥ كجم قرون / م<sup>٣</sup> و ٠.٤٣ كجم من القش / م<sup>٣</sup> من التفاعل بين ١٠٠٪ SC2 \* ET<sub>o</sub>. وأظهرت النتائج أنه في التربة الرملية ذات القدرة الضعيفة على الاحتفاظ بالماء، يمكن تحسين هذه القدره والحصول على انتاجية عالية مع إضافة محسن التربة مع عمق الماء المضاف يساوي ١٠٠٪ كما يمكن تقليل تأثير الإجهاد المائي علي النبات عند الري بمستويات منخفضة من ماء الري .

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