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EFFECT OF IRRIGATION TREATMENTS ON SOME HYDRO-PHYSICAL PARAMETERS OF SANDY SOIL UNDER DIFFERENT RATES OF BIOCHAR

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ABSTRACT

A field experiment was carried out in a sandy soil condition of Ismailia Governorate in Egypt (Latitude 30° 35' 30" N, Longitude 32° 14' 50" E) and Elevation 3 meters above sea level, during the winter season of 2020/2021, with an objective to study the interaction of three irrigation levels i.e., 50, 75, and 100% of soil water depletion with four biochar addition rates 0, 1, 2, and 3 kg/m^2 on some soil hydro-physical properties such as pore size classes, water holding capacity, field capacity, permanent wilting point and infiltration rate.

The results of the mean effect of irrigation rate revealed that using irrigation rate of 100% of water depletion gave, in general, the highest values of water holding capacity, field capacity, permanent wilting point and infiltration rate indices compared to the other treatments. The biochar rate 3 kg/m^2 was superior to the other treatments for water holding capacity, field capacity, permanent wilting point, and led to a decrease infiltration rate. The biochar rate 3 kg/m^2 and irrigation rate100% were the highest for water holding capacity and field capacity.The interaction between water irrigation rates and biochar treatments was highly significant for all pore size classes. Mean effect of irrigation rate 100 % and biochar 1kg\m^2 was highest for quickly drainable pores (QDP) and the ratio of air/water on other treatments. While the biochar rate 3 kg/m^2 and irrigation rate of 50 % was highest for slowly drainable pores (SDP), fine capillary pores (FCP), and total drainable pores (TDP). Biochar rate 3 kg/m^2 and 100 % of irrigation rate gave the highest water holding pores (WHP) and water storage pores (WSP).

Conclusively, *it can be concluded that the biochar rate of 3 kg/m^2 was superior to the other treatments for water holding capacity, field capacity, permanent wilting point, water holding pores, water storage pores and led to a decrease infiltration rate.*

Keywords: Irrigation, Biochar, Pore Size, Soil Water Properties.

INTRODUCTION

The irrigated agriculture in Egypt is challenged by many obstacles. Irrigation water shortage is the most important one of them. Climate change also, has a great impact on agriculture in this country where more than 95% of its land is desert. It is a very important issue to study soil water properties as affected by irrigation. Organic matter also in these desert soils is very low. Irrigation is a fundamental practice in arid-land agriculture where rainfall alone cannot replenish the very high crop evapotranspiration rates. Biochar organic material is gaining more reputation due to its impacts on soil physical characteristics.

Biochar is a carbonaceous, solid, and recalcitrant compound derived from the pyrolysis of waste biomass. Its yield and properties are strongly influenced by pyrolysis conditions and feedstock composition (Pandey *et al.,* 2020). It is a carbon-rich product that is obtained by the burning of biomass, produced during slow thermal decomposition of biomass at temperatures from 300– 1000 °C under zero or low oxygen conditions (Joseph and Lehmann, 2009; Sohi *et al.,* 2010; Pandey *et al.,* 2020). Biochar is a useful material for the soil where leads to improvements of soil physical and chemical properties such as water holding capacity, surface area, improve soil texture, bulk density, soil porosity, and chemical properties such as cation and anion exchange capacity and adsorption of nutrients for soil solution in sandy soil (Glaser *et al.,* 2002; Aslam *et al.,* 2014; Pandey *et al.,* 2020). Also, owing to its low–cost, presence of surface functional groups, porosity, and moderate surface area, biochar is considered as a support material for improving soil properties and immobilizing the enzymes where a part of the biomass is transformed into gaseous, liquid, solid compounds. The biochar remains as a concrete mass of stable carbon (Teβin, 2016; Pandey *et al.,* 2020).

Soil amendment with biochar may consequently retain more water from irrigation and also reduce the frequency of irrigation, hence sustaining and optimizing the limited water available for crop production. Deficit irrigation practices are used to sustain crop productivity under reduced water application by improving soil water extraction by plant roots. This is because Full irrigation practice is considered a water luxury, which is not sustainable in a water-limited environment. (Oktem, 2008; El-Hendawy and Schmidhalter, 2010; Karimi and Gomrokchi, 2011). Faloye *et al.,* (2019) showed that the insignificant interaction occurred between biochar and irrigation on maize productivities. Therefore, amending soil with biochar under a limited water supply might be a novel approach for enhancing maize yield and water use efficiencies by minimizing the negative impact of drought stress.

Soil hydrological properties such as moisture content, water holding capacity, water retention, and infiltration rate are invariably related to the surface area, porosity, bulk density, and aggregate stability. Several studies have reported alterations in water-holding capacity and water retention in biochar-amended soils (Laird *et al.*, 2010; Jones *et al.*, 2011; Uzoma *et al.*, 2011) with as low as 0.5% (g g^{-1}) biochar application rate sufficient to improve water-holding capacity. Alghamdi, *et al.*, (2020) results showed that the largest increase in both water content at field capacity and available water content was observed with the smallest biochar particle size due to increased micro-porosity as a result of the larger internal surfaces and the porous structure of the biochar particles. Toková *et al.*, (2020) found that during the dry period, a relative increase in soil water content was observed at all biochar treatments-the largest after re-application of biochar at a dose of 20 t ha^{-1} at all fertilization levels. The biochar application also significantly increased plant available water. Verheijen *et al.*, (2010) revealed that the biochar is highly porous, therefore its application to sandy soil is considered to improve various soil physical properties such as bulk density, porosity, water retention, and hydraulic conductivity. Ajayi and Rainer, (2016) found that the notably, biochar addition improves soil water retention and available water capacity. This is commonly observed in coarse-textured soils or soils with large amounts of macro-pores, although the amount of biochar often required to enhance water retention is high and vary with soil type (Glaser *et al.*, 2002).

Therefore, the aim of this work is to study the interaction of three irrigation levels with four biochar addition rates on sandy soil hydro-physical properties.

MATERIALS AND METHODS

A field experiment was carried out in split plot design with three replicates, during the winter season 2020/2021 under sandy soil conditions. The experiment was performed at Ismailia Agricultural Research Station (Latitude 30° 35' 30" N, Longitude 32° 14' 50" E and Elevation 3 meters above sea level), Agricultural Research Center (ARC), Egypt, to investigate the effect of different irrigation levels and biochar rates on some soil physical and hydraulic properties such as pore size classes, water holding capacity, field capacity, permanent wilting point and infiltration rate.

MATERIALS

Soil: One type of soil was used for this work. The studied soil was a sandy soil located at Ismailia Agricultural Research Station, Ismailia governorate, Egypt. Some initial physical and hydro-physical properties of the studied soil are shown in Table 1.

Table (1): Some initial routine soil analyses of the studied soil.

Property	Value
Particle size distribution (%)	
Clay	2.97
Silt	4.77
Sand	92.26
Texture class	Sand
Infiltration rate (cm h^{-1})	16.83
Saturation percentage (%)	21.53
Field capacity (%)	10
Permanent wilting point (%)	4.9
Water holding capacity (%)	21.3
Bulk density (g cm^3)	1.65
particle density (g cm^3)	2.65
Porosity (%)	37.73
pH (Soil suspension 1:2.5)	7.88
EC (dSm^{-1}) at soil paste extract	0.47

Irrigation:

- ***Water source:*** *Fresh water of Ismailia canal.*
- ***Irrigation System:***
  - Solid set sprinkler irrigation system (10 m between lines and 10 m between Sprinklers).
  - Lateral line is 90 meters long with 9 sprinklers.
  - Sprinkler service circle = 78.5 m^2.
- $\mathbf{I_E}$ = Irrigation efficiency of the sprinkler irrigation system in the field (assumed to be 80% of the total water applied).
- Sprinkler discharge 1.13m^3 h^{-1} was measured in-situ as described by Ismail, (2014).
- Soil depth = 30 cm
- **Gross Irrigation requirement:** The amount of water needed for irrigation at each level, was calculated via the Eq. (Katerji *et al.,* 2008):

$$I_g = ((\theta_{fc} - \theta_{pwp}) \times \tau \times \rho \times D \times A \times 100)/I_E$$

Where:

- I_g is the gross irrigation requirement (m^3)
- θ_{fc} is the percentage of soil moisture content at the soil field capacity point
- θ_{pwp}, is the percentage of moisture content of the soil at the wilting point
- τ is the moisture depletion percentage from the soil (50%, 75%, and 100%)
- ρ is the soil bulk density (kg m^{-3})
- D is the root zone depth (m)
- A is the plot area (m^2)

- I_E is the irrigation efficiency, which was considered as 80% on average according to sprinkler irrigation method.

- Irrigation time was calculated using the following equation from (Ismail, 2002):

Irrigation time =

$$= \frac{\text{Bulk density } (g\ kg^{-1}) \text{ x soil moisture at field capacity x soil depth x Area} (m^2)}{\text{Sprinkler flow rate} (m^3\ h) \text{ x reciprocal of irrigation efficiency}}$$

$$\text{Irrigation time} = \frac{1.65 \text{ X } .1 \times .3 \text{ X } 78.5}{1.13 \text{ X } 1.25} = 2.75 \text{ h} \approx (165 \text{ minutes})$$

- Irrigations treatments were divided into three levels:
  - A_1: 100% Irrigation time of the field capacity (2.75 h^{-1}).
  - A_2: 75% Irrigation time of the field capacity (2.06 h^{-1}).
  - A_3: 50% Irrigation time of the field capacity (1.37 h^{-1}).

***Biochar amendments*:** Biochar was made from some plant sources and attained from Jordan Maser Company for import, export and public procurement, Giza, Egypt. The biochar materials were added one week before the treatment.

Table (2): Some physio-chemical characteristics of biochar used in the experiment.

Property	Value
EC (dSm^{-1}) at soil paste extract	2.09
pH (Soil suspension 1:2.5)	7.98
Total carbon ($g\ kg^{-1}$)	482
CEC($cmole_{(+)}\ kg^{-1}$)	36.13
N ($g\ kg^{-1}$)	4.31
P ($g\ kg^{-1}$)	2.26
K ($g\ kg^{-1}$)	8.42
Ca ($g\ kg^{-1}$)	5.14
Mg ($g\ kg^{-1}$)	2.87
Bulk density ($g\ cm^3$)	.52

***Experimental design*:**

The study was laid out in a split plot design with three replicates. Irrigation levels were assigned to the main plot as three levels (50%, 75% and 100% of the filed capacity) corresponding to 1.55, 2.33 and 3.10 m^3.The sub plots included biochar at four rates (0, 1, 2 and 3-kg biochar / m^2) corresponding to 0, 6, 12 and 18 kg $plot^{-1}$. The materials used as sources of biochar have been crushed and sieved to size (< 2 mm). The total experimental area was 216 m^2 divided to 36 plots, each plot 2m× 3m = $6m^2$.

METHODS OF ANALYSES:

Soil analyses: Top soil samples (0-30 cm) before starting and at the end of the experiment were taken air dried, crushed, and sieved through a 2 mm sieve, mixed well and prepared for routine and targeted physical and chemical analyses:

a) Particle size distribution was accomplished using the international pipette method as described by Piper (1950).

b) Soil reaction (pH) was measured using a glass electrode pH - meter in (1:2.5) soil water suspension while, Electrical conductivity (EC) as well as soluble ions was measured in (1:2.5) water extracts as described by Jackson, (1973).

Hydro-physical parameters:

Infiltration rate (IR):

Infiltration rate, as a very important indicator for sprinkler irrigation, was estimated by the double ring infiltrometer method as described in detail in (FAO, 2002) by Kostiakov equation as described in (Kostiakov, 1932).

$$Z = ct^{m}$$

Where: Z = Filtration rate. T= Time after the onset of filtration.

C, m = constants that depend on the type of soil and its initial condition.

***Soil bulk density*:**

Soil bulk density was estimated by the core method as described in (Black *et al.*, 1982).

***Particle density*:**

Soil Particle Density was estimated by the Pycnometer method as described in Estefan *et al.*, (2013).

Field capacity:

Field capacity was measured in-situ by the method described in Gardner,(1960).

Saturation percentage:

Saturation percentage was estimated by the saturated paste method by following equation as described in Richards (1954):

$$\text{Saturation percentage} = \frac{\text{Total mass of water}}{\text{Mass of oven-dry soil}} \times 100$$

Porosity: Porosity was estimated as described in FAO (2020) by the following equation**:**

$$\text{Soil porosity (\%)} = \left(1 - \frac{\rho}{2.65}\right) \times 100$$

Where: ρ = Soil bulk density (gm/cm^{3}),

Table (3): Soil moisture retention (percent %) in the different Irrigation rate and biochar levels.

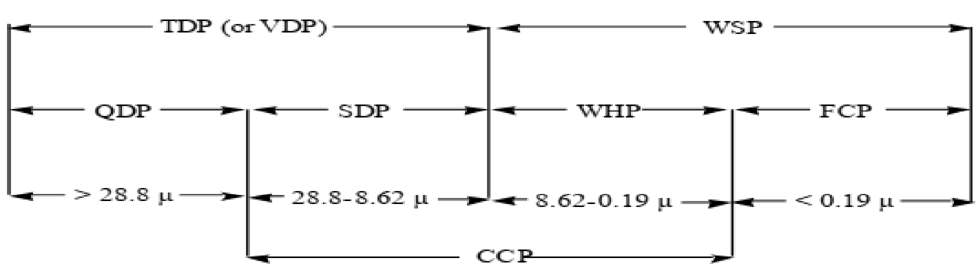
Irrigation rate (I)	Biochar rate Kg / m^2 (B)	Split plot design					
		0.001	**0.10**	**0.33**	**0.66**	**1.00**	**15.0**
100 % F.C	**Without (B)**	21.40	19.47	17.27	14.30	9.80	5.03
	1 Kg (B)	22.90	20.47	17.87	14.10	9.70	5.83
	2 Kg (B)	23.60	21.97	19.21	16.00	11.20	6.63
	3 Kg (B)	25.10	23.17	19.98	17.30	12.30	6.83
75 % F.C	**Without (B)**	21.30	18.87	16.95	13.70	9.00	4.53
	1 Kg (B)	22.60	20.77	17.81	14.50	9.00	6.33
	2 Kg (B)	23.30	21.67	18.90	15.60	10.60	6.53
	3 Kg (B)	24.80	22.77	19.91	16.20	11.80	6.93
50 % F.C	**Without (B)**	21.30	19.27	16.98	14.20	9.70	4.93
	1 Kg (B)	22.30	20.27	17.77	14.90	9.30	5.93
	2 Kg (B)	23.20	21.27	18.65	15.80	10.40	6.23
	3 Kg (B)	24.9	22.87	19.56	16.40	11.70	7.13

***Soil-water retention curves and pore size classes*:**

Pore size classes were estimated using soil-water retention curves. These curves were determined by exposing the completely saturated samples to constant suction levels of 0.001, 0.1, 0.33, 0.66, 1.0, and 15 atm. using the pressure membrane method (Stakman, 1966).

The percent of moisture content (volume basis) of soil samples at equilibrium with different potentials represent two limits of each pore size class as follows according to Amer (2016):

Pore size class	**Pore size range (μ)**	**Potential range (atm)**
Quickly (or rapidly) drainable pores (QDP or RDP)	**> 28.8**	**0.001 - 0.10**
Slowly drainable pores (SDP)	**28.80 - 8.62**	**0.10 - 0.33**
Water holding pores (WHP)	**8.62 - 0.19**	**0.33 - 15.0**
Fine capillary pores (FCP)	**< 0.19**	**> 15.0**



Source: Amer (2016)

The ratio of air to water was calculated as the relation between the total or volume drainable pores (TDP) and water storage pores (WSP), i.e.

$$\frac{\text{Air}}{\text{Water}} = \frac{\text{TDP}}{\text{WSP}} = \frac{\text{QDP} + \text{SDP}}{\text{WHP} + \text{FCP}}$$

***Statistical analysis*:**

Results were statistically analyzed using STATISTIX software. The ANOVA test was used to determine the significance ($p \leq 0.01$ or $p \leq 0.05$) treatment effect and Duncan Multiple Range Test was used to determine the significance of the difference between individual means **(Gomez and Gomez, 1984).**

RESULTS AND DISCUSSION

Hydro-physical parameters

Data in Table (4) showed significant effect of biochar addition rate in increasing WHC, FC, PWP and IR value while the effect of irrigation rate was only significant to increase value of WHC and FC. The mean effect of biochar addition rate followed the sequence: 3kg B > 2kg > 1kg > without B for WHC, FC, and PWP as well as without > 1kg > 2kg ≥ 3kg for infiltration rate. This effect of biochar may be due to increased micro-porosity as a result of the larger internal surfaces and the porous structure of the biochar particles. In addition Alghamdi***, et al.*, (2020)** showed that the largest increase in both water content at field capacity and available water content was observed with the smallest biochar particle size due to increased micro-porosity as a result of the larger internal surfaces and the porous structure of the biochar particles.

As for the irrigation rate, the effect followed the order: 100% FC > 75% FC ≥ 50% FC for WHC and FC. Highest value (25.1 and 23.2%) of WHC and FC, respectively were obtained as affected by the treatment of 3kg biochar under 100% FC of irrigation rate while, the highest value (7.13%) of PWP was observed with 3 kg biochar under 50 % FC of irrigation rate. For IR, the preferable effect was due to addition of 3 kg biochar under 50 % FC of irrigation rate. These results may be related to the effect of biochar at a suitable concentration on improving the physical properties of the sandy soil, especially when the soil contains a suitable amount of water consequently. In addition Laird *et al*., (2010) found that the soil hydrological properties such as moisture content, water holding capacity, water retention, and infiltration rate are invariably related to the surface area, porosity, bulk density, and aggregate stability. Several studies have reported alterations in water-holding

Table (4): Hydro-physical parameters in sandy soil as affected by Irrigation rate and biochar levels.

Irrigation rate (I)	Biochar rate (Kg / m^2)	WHC (%)	FC (%)	PWP (%)	IR (cm h^{-1})
100 % F.C	Without (B)	21.40	19.47	5.03	14.61
	1 Kg (B)	22.90	20.47	5.83	14.25
	2 Kg (B)	23.60	21.97	6.63	13.64
	3 Kg (B)	25.10	23.17	6.83	13.64
	Mean	**23.25a**	**21.27a**	**6.08**	**14.03**
75 % F.C	Without (B)	21.30	18.87	4.53	14.66
	1 Kg (B)	22.60	20.77	6.33	14.21
	2 Kg (B)	23.30	21.67	6.53	13.59
	3 Kg (B)	24.80	22.77	6.93	13.65
	Mean	**23.00b**	**21.02b**	**6.08**	**14.03**
50 % F.C	Without (B)	21.30	19.27	4.93	14.32
	1 Kg (B)	22.30	20.27	5.93	14.12
	2 Kg (B)	23.20	21.27	6.23	13.88
	3 Kg (B)	24.90	22.87	7.13	13.46
	Mean	**22.93b**	**20.92b**	**6.06**	**13.95**
Mean effect of B-rate					
Without (B)		**21.33d**	**19.20d**	**4.83d**	**14.53a**
1 Kg (B)		**22.60c**	**20.50c**	**6.03c**	**14.20b**
2 Kg (B)		**23.37b**	**21.63b**	**6.47b**	**13.70c**
3 Kg (B)		**24.93a**	**22.93a**	**6.97a**	**13.58c**
F Test					
I		**	**	NS	NS
B		**	**	**	**
I×B		**	**	NS	NS

capacity and water retention in biochar-amended soils (Jones *et al*., 2011; Uzoma *et al.*, 2011) with as low as 0.5% (g g^{-1}) biochar application rate sufficient to improve water-holding capacity.

Drainable and water storage pores

Tables (5 and 6) revealed that the irrigation rates F test was significant for the water storage pores (WSP) and water holding pores (WHP) and non-significant for quickly drainable pores (QDP), slowly drainable pores (SDP), fine capillary pores (FCP), total drainable pores (TDP), available water ratio and the ratio of air/water. The mean effect of 50% FC of irrigation rate showed that the highest value (2.01, 2.68, 4.68, 0.67 and 0.26) of quickly drainable pores (QDP), slowly drainable pores (SDP), total drainable pores

Table (5): Effect of Irrigation rate and biochar levels in Pore size classes as a percent of total volume pores in sandy soil**.**

Irrigation rate (I)	Biochar rate Kg / m^2 (B)	QDP <10 kPa ΔS%	SDP 10-33kPa ΔS%	WHP 33-1500kPa ΔS%	FCP >1500kPa ΔS%
100 % F.C	Without (B)	1.93	2.19	12.24	5.03
	1 Kg (B)	2.43	2.60	12.03	5.83
	2 Kg (B)	1.63	2.75	12.58	6.63
	3 Kg (B)	1.93	3.18	13.15	6.83
	Mean	**1.98**	**2.68**	**12.50a**	**6.08**
75 % F.C	Without (B)	2.43	1.91	12.42	4.53
	1 Kg (B)	1.83	2.96	11.48	6.33
	2 Kg (B)	1.63	2.77	12.36	6.53
	3 Kg (B)	2.03	2.85	12.98	6.93
	Mean	**1.98**	**2.62**	**12.31ab**	**6.08**
50 % F.C	Without (B)	2.03	2.29	12.05	4.93
	1 Kg (B)	2.03	2.50	11.84	5.93
	2 Kg (B)	1.93	2.61	12.42	6.23
	3 Kg (B)	2.03	3.30	12.43	7.13
	Mean	**2.01**	**2.68**	**12.18b**	**6.06**
Mean effect of B-rate					
Without (B)		**2.13a**	**2.13c**	**12.24c**	**4.83d**
1 Kg (B)		**2.10a**	**2.68b**	**11.78d**	**6.03c**
2 Kg (B)		**1.73b**	**2.71b**	**12.46b**	**6.47b**
3 Kg (B)		**2.00a**	**3.11a**	**12.85a**	**6.97a**
F Test					
I		**NS**	**NS**	*	**NS**
B		**	**	**	**
I×B		*	*	**	**

Table (6): Effect of Irrigation rate and biochar levels in Pore size classes as a percent of total volume pores in sandy soil.

Irrigation rate (I)	Biochar rate Kg / m^2 (B)	TDP <33kPa ΔS%	WSP >33kPa ΔS%	*AWR*	$\frac{Air}{Water}$ *ratio*
100 % F.C	**Without (B)**	4.13	17.27	0.71	0.24
	1 Kg (B)	5.03	17.87	0.67	0.28
	2 Kg (B)	4.39	19.21	0.65	0.23
	3 Kg (B)	5.12	19.98	0.66	0.26
	Mean	**4.67**	**18.58a**	**0.67**	**0.25**
75 % F.C	**Without (B)**	4.35	16.95	0.73	0.26
	1 Kg (B)	4.79	17.81	0.64	0.27
	2 Kg (B)	4.40	18.90	0.65	0.23
	3 Kg (B)	4.89	19.91	0.65	0.25
	Mean	**4.61**	**18.39ab**	**0.67**	**0.25**
50 % F.C	**Without (B)**	4.32	16.98	0.71	0.25
	1 Kg (B)	4.53	17.77	0.67	0.26
	2 Kg (B)	4.55	18.65	0.67	0.24
	3 Kg (B)	5.34	19.56	0.64	0.27
	Mean	**4.68**	**18.24b**	**0.67**	**0.26**
Mean effect of B-rate					
Without (B)		**4.26c**	**17.07d**	**0.72a**	**0.25b**
1 Kg (B)		**4.78b**	**17.82c**	**0.66b**	**0.27a**
2 Kg (B)		**4.45c**	**18.92b**	**0.66b**	**0.24c**
3 Kg (B)		**5.11a**	**19.82a**	**0.65c**	**0.26ab**
F Test					
I		**NS**	*	**NS**	**NS**
B		**	**	**	**
I×B		*	*	**	*

**AWR* is the available water ratio, and ΔS is the saturation degree.

(TDP), available water ratio and the ratio of air/water. For the mean effect of 100 % FC of irrigation rate showed that the highest value (12.50, 6.08 and 18.58) of Water holding pores (WHP), fine capillary pores (FCP), and the water storage pores (WSP).

Regarding the F test for biochar rates showed that the highly significant for quickly drainable pores (QDP), slowly drainable pores (SDP), water holding pores (WHP), fine capillary pores (FCP), total drainable pores (TDP), the water storage pores (WSP), available water ratio and the ratio of air/water. Mean effect of biochar rates for Pore size classes under this study revealed that the biochar rate 3 kg was highest value (3.11, 12.85, 6.97, 5.11 and 19.82) of slowly drainable pores (SDP), Water holding pores (WHP), fine capillary pores (FCP), total drainable pores (TDP), and the water storage pores (WSP). While, that the biochar rate Without (B) was the highest value (2.13 and 0.72) for quickly drainable pores (QDP) and available water ratio, but the biochar rate 1 kg was the highest value (0.27) for the ratio of air/water. These results are in agreement with those reported by Sun *et al.*, (2013), in addition, Tammeorg *et al*., (2014) reported that biochar amendment is conducive to reduce soil density and increase soil porosity, and thus can improve soil structure and facilitate plant root growth. Atkinson *et al*., (2010) showed that decrease in bulk density of biochar amended soil could be one of the indicators of enhancement of soil structure or aggregation, and aeration, as well as could be soil-specific. The higher the total porosity (micro- and macro-pores) the higher is soil physical quality because micro pores are involved in molecular adsorption and transport while macro pores affect aeration and hydrology.

The interaction between water irrigation rates and biochar treatments was highly significant for all pore size classes. Mean effect of irrigation rate 100 % FC and biochar 1kg was highest value (2.43 and 0.28) for quickly drainable pores (QDP) and the ratio of air/water on other treatments. While the biochar rate 3 kg and 50 % FC of irrigation rate was highest value (3.30, 7.13 and 5.34) for slowly drainable pores (SDP), fine capillary pores (FCP), and total drainable pores (TDP). Regarding biochar rate 3 kg and 100 % of irrigation rate was highest value (13.15 and 19.98) for Water holding pores (WHP) and the water storage pores (WSP). But the Without (B) biochar rates and 75% FC of irrigation rate were highest value (0.73) for the available water ratio. Ajayi and Rainer, (2016) found that the notably, biochar addition improves soil water retention and available water capacity. This is commonly observed in coarse-textured soils or soils with large amounts of macro-pores, although the amount of biochar often required to enhance water retention is high and vary with soil type (Glaser *et al.*, 2002).

Conclusion

From the present results, biochar rate 3 kg was superior to the other treatments for water holding capacity (WHC), field capacity (FC), permanent wilting point (PWP), and led to a decrease infiltration rate (IR). The biochar rate 3 kg and irrigation rate100% FC were the highest for water holding capacity (WHC) and field capacity (FC). The interaction between water irrigation rates and biochar treatments was highly significant for all pore size classes. Mean effect of irrigation rate 100 % FC and biochar 1kg was highest for quickly drainable pores (QDP) and the ratio of air/water on other treatments. While the biochar rate 3 kg and irrigation rate of 50 % FC was highest for slowly drainable pores (SDP), fine capillary pores (FCP), and total drainable pores (TDP). Biochar rate 3 kg and 100 % FC of irrigation rate gave the highest water holding pores (WHP) and water storage pores (WSP**).**

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تأثير معاملات الري على بعض الخواص المائية للتربة الرملية تحت تأثير معدلات مختلفة من البيوشار

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** محطة البحوث الزراعية بالاسماعيلية- الاسماعيلية- مصر

أجريت تجربة حقلية في تربة رملية بمحافظة الإسماعيلية في مصر (خط العرض 30 ° 35 '30 "شمالاً ، خط الطول 32 ° 14' 50" شرقاً والارتفاع 3 أمتار فوق مستوى سطح البحر ، خلال موسم الشتاء 2020 / 2021 ، بهدف دراسة تأثير ثلاثة مستويات للري 50 و 75 و 100٪ من السعة الحقلية مع أربعة معدلات من الفحم الحيوي 0 ، 1 ، 2 ، و 3 كجم / م^2 على بعض الخواص المائية و التوزيع النسبي لمسام التربة.

أوضحت نتائج متوسط تأثير معدل الري أن استخدام معدل الري 100٪ من السعة الحقلية أعطى بشكل عام أعلى قيم للسعة التشبعية للتربة والسعة الحقلية ونقطة الذبول الدائمة ومؤشرات معدل التسرب مقارنة بالمعاملات الأخرى. تفوق معدل الفحم الحيوي (3 كجم / م^2) على المعاملات الأخرى حيث أدى الى زيادة للسعة التشبعية للتربة ، السعة الحقلية ، نقطة الذبول الدائمة ، وأدى إلى انخفاض معدل التسرب. بينما كان معدل الفحم الحيوي (3 كجم / م^2) ومعدل الري 100٪ من السعة الحقلية الافضل وأعطى أعلى القيم للسعة التشبعية للتربة والسعة الحقلية.

كان التفاعل بين معدلات الري ومعاملات الفحم الحيوي معنوياً لجميع فئات حجم المسام. كان متوسط تأثير معدل الري 100٪ من السعة الحقلية ومعدل الفحم الحيوي (1كجم / م^2) أعلى بالنسبة للمسام سريعة التصريف (QDP) ونسبة الهواء/ الماء من المعاملات الأخرى. بينما كان معدل الفحم الحيوي 3 كجم / م ^{2} ومعدل الري بنسبة 50٪ من السعة الحقلية أعلى للمسام القابلة للصرف البطيئ (SDP) والمسام الشعرية الدقيقة (FCP) والمسام الصرف الكلية (TDP). فيما يتعلق بمعدل الفحم الحيوي (3 كجم / م^2) و معدل الري 100٪ من السعة الحقلية أعطى اعلى القيم لمسام حفظ الماء (WHP) ومسام تخزين المياه (WSP).

التوصية: يمكن الاستنتاج أن أستخدام معدل الفحم الحيوي 3 كجم / م2 كان متفوقا على المعاملات الأخرى حيث أدى الى زيادة للسعة التشبعية للتربة ، السعة الحقلية ، نقطة الذبول الدائمة ، مسام حفظ الماء ، مسام تخزين المياه وأدى إلى انخفاض معدل التسرب.