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Benefits of Treated Rice Straw on Soil Hydraulic Properties under Saline-Sodic Irrigation Water

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ABSTRACT

Egypt is an arid country whose agricultural production depends entirely on irrigation, and it suffers from a severe shortage of fresh water resources. Reuse of agricultural wastewater is therefore inevitable, especially in the central and northern regions of the Egyptian Nile Delta. Recently, the addition of biochar is considered one of a climate-smart farming practice in sustainable agriculture. Therefore, a columns experiment was conducted at the laboratory of Soils Dept., Fac., Agric., Mansoura Unvi. to assess the role of treated rice straw on alleviating the adverse effects of irrigation by agricultural drainage water (low-quality water) on soil physical and hydraulic properties (water movement). The treatments of the experiment include two types of soil texture: (S_1) Clay loamy soil and (S_2) Loamy soil, two types of irrigation water: (I_1) Tap water and (I_2) Agricultural drainage water (severe salty and sodic) and two types of treated rice straw: (C_1) Rice straw compost (RSC) and (C_2) Rice straw compost biochar (RSCB), beside (C_0) Control. Results showed that applying both RSC and RSCB increased soil's resistance against negative effect of low-quality water, not only that, but it improves the soil physical and hydraulic properties. The addition of treated rice straw in particular RSCB caused an increase of the soil hydraulic properties i.e. saturated hydraulic conductivity (Ks), unsaturated hydraulic conductivity $K_{(\theta V)}$, specific fluid flux (q) and intrinsic permeability (k) as a result of the positive change in soil bulk density (ρb), mean pore diameter (d) and porosity (E). Based on these results, the two types of treated rice straw, especially RSCB could improve soil resistance against degradation caused by low-quality water irrigation through improving aggregation process, soil structure and water movement across soil matrix.

Keywords: treated rice straw, agricultural drainage water, soil texture, soil hydraulic properties, mean pore diameter.

INTRODUCTION

Egypt as one of the desert countries suffers a negative vicious cycle resulting from the terrible population pressure, lack of freshwater resources, climate change and the resulting desertification. This led to reducing the allocation of freshwaters for irrigation and other agricultural purposes (Allam and Allam, 2007). However, maintaining or rather increase agricultural productivity is very essential to face the food requirements of the continuing growth of the population (Asempa, 2010). Due to this fact, agricultural drainage water is often considered as viable options for using in the irrigation purposes although its negative impacts on plant growth (Kim *et al.,* 2008) and soil properties (Ould Ahmed *et al.,* 2007 and Feizi *et al.,* 2010).

Reuse of agricultural wastewater is therefore inevitable, especially in the central and northern parts of the Egyptian Nile Delta. Treating soil with organic materials, whether in the form of compost or biochar, is among the options/practices of modern sustainable agriculture (Fernandes *et al.,* 2019). The reuse of degraded agricultural drainage water in the irrigation purposes is constrained by many factors, the most important of all are quality and quantity. Reuse of low-quality water either agricultural drainage water or wastewater in the Nile-delta area of Egypt may be represents a main source of water, in particular for agricultural and irrigation purposes (El Bedawy, 2014).

Many studies have evaluated the effects of irrigation water salinity and sodicity on soil structure deterioration by clay dispersion and subsequent reduction in hydraulic conductivity (Frenkel *et al.,*1978; Grattan and Rhoades, 1990 and Mace and Amrhein, 2001). Soil-water interrelationships, or so-called "soil hydraulic properties", have many applications, including arid land use planning, irrigation support, and modeling strategic programs dealing with climate changes. Therefore, it should be the first criteria to be taken into account when assessing the impact of irrigation water quality on the "soil system", and also to assess the impact of agricultural practices that can be applied to mitigate the impact of low-quality water irrigation (Edelstein *et al.,* 2010).

Numerous investigations showed that soil water conductivity decreases with decreasing concentration of electrolytic solutes (salinity factor) or with increasing in sodium concentration (sodicity factor) of irrigation water (Agassi *et al.,* 1981). This is due to swelling and dispersion phenomena of colloidal 2:1 clay mineral particles, which are also affected by the ratios of cations present either in soil solution or on soil exchange complex (Hilell, 1980). Detachment and migration of clay particles during a flow may result in the clogging of soil pores. Where agricultural drainage water is applied to the soil for irrigation, the presence of monovalent cations promotes swelling, dispersion and clog soil pores. Saline water often has the opposite effect of preventing dispersion (Hilell,1980). Organic amendments have long been investigated for their positive impacts and effectiveness in enhancing soil properties such as hydraulic properties, aggregate stability and other chemical characteristics (Tejada *et al.,* 2009).

Therefore, the present research aims to use soil columns experiment to evaluate the positive effect of the addition of treated rice straw (compost or biochar) in conjunction with low-quality irrigation water to reduce or prevent deterioration of two alluvial soils properties, especially their hydraulic properties.

MATERIALS AND METHODS

A Columns experiment was conducted at the laboratory of Soils Dept., Fac., Agric., Mansoura Univ. Two-soil texture types were used as (1) clay loamy soil (from the farm of Fac., Agric., Mansoura Univ.) and (2) loamy soil (from Meet Khamis Village, Mansoura District, Dakahlia Governorate). These soils were air dried, grounded and passed through a 2 mm sieve. The primary physical and chemical properties of the studied soils were analyzed according to the standard methods of Piper, 1950; Richards, 1954; Black *et al.,* 1965; Jackson, 1967; Dewis and Freitas, 1970; Hesse, 1971 and Hillel, 1980). The agricultural drainage water was collected from drainage channel No.1, Aboazher Village, Sherbin District, Dakahlia Governorate. Table 1 show some physical and chemical properties of the experimental soils, while Table 2 show characteristics of the two irrigation waters.

Table 1. Some physical and chemicals properties of the experimental soils.

Soil characteristics		Soil type: Clay loamy soil	Loamy Soil
Particles size distribution	Sand (%)	31.76	36.40
	Silt (%)	38.69	41.92
	Clay (%)	29.55	21.68
Saturation Percentage, SP (w/w)		68.27	53.00
Field Capacity, FC (%)		34.14	26.50
Wilting Point, WP (%)		17.08	13.25
Available Water, AW (%)		17.08	13.25
Hydraulic conductivity (m day^{-1})		2.03	2.80
Bulk Density (Mg m^{-3})		1.10	1.25
Real Density (Mg m^{-3})		2.17	2.38
Total Porosity (%)		49.31	47.49
pH (in soil paste)		8.44	8.30
EC dSm^{-1} (in 1:2 extract)*		1.47	1.83
$CaCO_3$ (%)		0.38	4.05
OM (%)		0.96	0.55
Soluble Cations ($cmol_{(p+)}$ kg^{-1})	Ca^{+2}	0.36	0.80
	Mg^{+2}	0.32	1.10
	K^+	0.05	0.08
	Na^+	1.99	1.78
Soluble Anions ($cmol_{(p+)}$ kg^{-1})	CO_3^{-2}	N.D.	N.D.
	HCO_3^-	0.68	0.4
	Cl^-	0.56	0.56
	SO_4^{-2}	1.70	2.69
Available NPK (mg Kg^{-1})	Nitrogen (N)	54.49	27.47
	Phosphorus (P)	7.65	7.30
	Potassium (K)	282.35	246.93

*** Dellavalle, (1992).**

Table 2. Chemical analysis of the two irrigation waters

Parameter	Agricultural drainage water	Tap water
pH	8.50	7.20
EC(dSm^{-1})	3.12	0.43
$SAR_{Adj.}$	17.99	1.53
RSC	-4.51	-0.54
	Soluble Cations (mmol L^{-1})	
Ca^{+2}	4.60	1.24
Mg^{+2}	7.11	1.12
K^+	1.91	0.85
Na^+	16.75	1.34
	Soluble Anions (mmol L^{-1})	
CO_3^-	N.D.	N.D.
HCO_3^{-2}	7.20	1.82
Cl^-	15.4	2.08
SO_4^{-2}	8.60	0.40
Water Class*	Severe salty and sodic	Normal

***according to Ayers and Westcot (1985).**

The experiment involved 12 treatments representing all possible combinations between two texture types of an alluvial soil: (S_1) Clay loamy soil and (S_2) Loamy soil, two types of irrigation water: (I_1) Tap water and (I_2) Agricultural drainage water ,and two types of treated rice straw: (C_1) Rice straw compost (RSC) and (C_2) Rice straw compost biochar (RSCB), beside (C_0) control, with three replicates.

Mineral N, P and K fertilizers were applied as ammonium sulphate at 60 kg N fed^{-1}, calcium super phosphate at 30 Kg P_2O_5 fed^{-1} and potassium sulphate at 50 Kg K_2O fed^{-1}. To produce biochar, an amount of RSC (has a low salinity and low C/N ratio less than rice straw biochar) was placed into a stainless steel crucible and cover it by aluminum foil then burned inside a muffle furnace at 450°C for 2 h. After burning it was allowed the biochar to cool down in the absence of oxygen for a minimum of 16 h then it grounded and passed through a 0.2 mm sieve. Biochar was mixed thoroughly to obtain a fine granular consistency then it was mixed uniformly with the soil mass. Both RSC and RSCB were applied at rate of 4 ton fed^{-1}. The general properties of RSC and RSCB used in this study are shown in Table 3.

Table 3. Some characteristics of rice straw compost and rice straw compost biochar.

Parameter	Unit	Values: RSC	RSCB
C/N ratio	-	12:1	15:1
Bulk density (ρb)	Mg m^{-3}	0.63	0.46
Residual reaction pH (1:2)	-	8.00	7.38
Electrical conductivity (EC) 1:2	dSm^{-1}	4.00	4.70
Organic matter (O.M.)	per cent	20.17	23.45
Total nitrogen (N)	per cent	1.18	1.27

Thirty-six polyvinylchloride (PVC) cylinders with a diameter of 6 cm and a height of 50 cm were used. Each cylinder contained 880 g of the air-dry soil which thoroughly mixed with the treated rice straw (RSC or RSCB) to provide a homogeneous mixture and then saturated by irrigation waters. Each column had nylon mesh tied from the bottom and a fixed 15 cm height of irrigation water was added above the 30 cm of the studied soil. The nylon mesh kept soil in columns and permitted only moving of water without soil particles. Soil columns were placed in a rack with a funnel placed below each column to deliver water and leachate. Total volume of water was determined and analyzed (Fig1). In addition, irrigation waters movement and leachates speed were measured in a specific time. After studying the movement of water, columns were covered and left for 40 days for equilibrium. Each column was divided into two sections, section A (0-15cm) and section B (15-30cm).

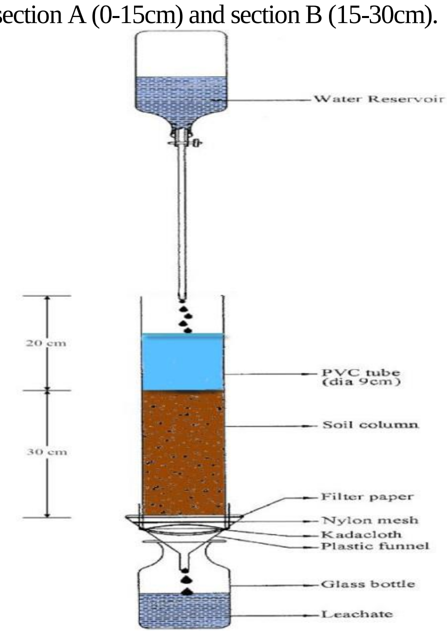

Fig. 1. Downward flow through a composite column

The saturated hydraulic conductivity (K_S) and the specific fluid flux (q) were measured by the constant head permeameter method in disturbed soil according to the equations of Singh, 1980.

$$q=\frac{Q}{AT}=Ks=\frac{\Delta H}{L}$$

The intrinsic permeability *(k)* m^2 calculated by the equation of Kirkham, (2005), $(k) = K\,S\,\eta/\rho\,g$, where K_S is the Darcy hydraulic conductivity (m day^{-1}), η is the dynamic viscosity ($Kgm^{-1}s^{-1}$), ρ is the fluid density, (kg m^{-3}), and g is the gravitational acceleration (ms^{-2}). Soil mean pores diameter (d µm) calculated by the equation of Dielman and De Ridder, (1972), $d = 6.177637\ \sqrt{Ks}$ (for water at 20°C).

The unsaturated hydraulic conductivity was calculated according to the equation of (Hillel, 1980).

$$K_{(\theta_v)} = K_s\,(\frac{\theta_v}{E})^m$$

Where $K_{(\theta V)}$ is unsaturated hydraulic conductivity (m day^{-1}) depending on θ_V, K_S is saturated hydraulic conductivity (m day^{-1}), θ_V is volumetric water content, E is the percentage of soil porosity and m is a constant equals to (2-4).

The experiment was conducted in a randomized complete block design and was analyzed using a three-way ANOVA, in addition to, the comparison of means and correlation coefficients was performed with Costat (v6.4).

RESULTS AND DISCUSSION

1. Soil chemical properties:

Data in Table 4 show the effect of treated rice straw, irrigation water types and alluvial soil textures on some soil properties (i.e. soil organic carbon, salinity, alkalinity and soluble sodium content).

Soil organic carbon (SOC):

At both layers (0-15 and 15-30 cm), soil organic carbon content increased with soil column depth except when using clay loamy soil irrigated with tap water. The mean values of SOC at the upper layer were greater in the $S_1I_2C_2$ treatment with 74.6% then $S_1I_1C_2$ treatment with 241.9% more than control, but at the lower layer SOC was greater in the $S_1I_2C_2$ treatment with 296.4% then $S_2I_1C_2$ treatment with 283.3%, as compared to control. Generally, the addition of RSCB increases the proportion of SOC in all the treatments due to its high content of organic carbon as compared to RSC. In additions, the organic carbon produced in biochar is very stable, addition of biochar to the soil has the potential to both improve soil quality and sequester carbon, which is important for mitigation of excessive carbon dioxide in the atmosphere (McHenry, 2009).

The using of treated rice straw caused a reduction of the soil pH, where, the high soil pH is assumed to increase losses of SOC through OM solubilization (Pathak and Rao, 1998). Furthermore, increased SOC content, in return, decreased soil bulk density, improved macro and meso porosity, and enhanced percent recovery of stable aggregates correspondingly, these results confirmed by (Mahmood-ul-Hassan *et al.*,2019).

Soil Salinity (EC):

The adding of treated rice straw on two soil textures irrigated by different quality water had a significant effect on changing the soil salinity. At the upper layer of clay loamy soil, EC values decreased with adding treated rice straw under both irrigation water types and increased at lower layer. On the other hand, salinity of loamy soil increased with adding treated rice straw irrigated by tap water only for both layer as compared to control. The addition of RSCB caused the highest positive effect on decreasing the salinity of clay loamy soil only at 0-15 cm depth, while it had not a clearly effect on decreasing soil EC at the other treatments.

Table 4. Some chemical properties of the studied soils as affected by adding treated rice straw and irrigation water types

Treat.	Mean Values							
	Upper Layer (0-15 cm)				Lower Layer (15-30cm)			
	SOC%	pH	EC (dSm^{-1})	S-Na (cmol kg^{-1})	SOC%	pH	EC (dSm^{-1})	S-Na (cmol kg^{-1})
	Clay Loamy Soil (S_1) + Tap Water (I_1)							
C_0	0.31	8.49	1.205	1.13	0.28	8.48	0.760	1.18
C_1	0.92	8.27	0.950	1.03	0.68	8.27	0.883	1.12
C_2	1.06	8.37	0.928	0.93	0.76	8.37	0.945	1.10
	Clay Loamy Soil (S_1) + Agriculture Drainage Water (I_2)							
C_0	0.63	8.70	1.320	1.40	0.55	8.71	0.852	1.46
C_1	0.99	8.32	1.193	1.35	1.12	8.39	1.209	1.44
C_2	1.10	8.23	1.114	1.32	2.18	8.23	1.116	1.34
	Loamy Soil (S_2) + Tap Water (I_1)							
C_0	0.24	8.36	0.857	1.25	0.30	8.41	0.900	0.88
C_1	0.59	8.10	0.990	1.11	1.14	8.15	1.036	0.99
C_2	0.70	7.99	0.997	0.97	1.15	8.03	1.050	0.98
	Loamy Soil (S_2) + Agriculture Drainage Water (I_2)							
C_0	0.42	8.51	1.000	1.24	0.44	8.59	1.051	1.37
C_1	0.86	7.96	0.988	1.29	0.94	8.13	1.048	1.26
C_2	0.95	7.97	1.052	1.20	1.04	8.09	1.052	1.17
LSD 5% S	0.039**	0.050**	0.024**	NS	0.060**	0.063**	0.033**	0.039**
LSD 5% I	0.039**	NS	0.024**	0.041**	0.060**	0.063*	0.033**	0.039**
LSD 5% C	0.047**	0.061**	0.029**	0.051**	0.074**	0.077**	0.040**	0.048**
LSD 5% S×I	0.055*	NS	0.034**	0.059**	0.085**	NS	0.046**	NS
LSD 5% S×C	0.067*	0.086*	0.041**	NS	0.104**	NS	0057**	NS
LSD 5% I×C	NS	0.086**	NS	0.072**	0.104**	0.109**	NS	0.068**
LSD 5% S×I×C	0.095**	0.122*	0.059**	NS	0.147**	NS	0.080**	0.096*

C_0: Without organic amendments, C_1: Rice straw compost (RSC), C_2: Rice straw compost biochar (RSCB), SOC:Soil organic carbon, S-Na: Soluble sodium.

Soil alkalinity (pH) and soluble sodium (S-Na):

There is a strong relationship between soil pH and soil Na^+ content. The obtained data illustrated that the reduction of (S-Na) content caused a reduction in soil pH as a result of the addition of treated rice straw. At both layers the (S-Na) and soil pH decreased significantly by adding the treated rice straw under different soil textures and irrigation water types. This means that the addition of organic amendments could alleviating the hazard of irrigation with saline water by decreasing the soil (S-Na) in particular when using RSCB. Biochar has the ability to adsorb the amount of Na^+, consequently, decrease the hazard of sodicity water, soil pH (to be less than 8.5) and the dispersion of soil particles, which in turn causes a poor soil structure with low aggregate stability and it has adverse effects on the soil water balance and plant development (Qadir and Schubert, 2002). Also, Sheldon *et al*., (2018) confirmed these results, where, the biochar amendments improve soil fertility by reduced transient sodium ions by adsorption and released mineral nutrients such as K, Ca and Mg into the soil solution.

To evaluate the effect of irrigation by saline water on the soil, it is necessary to know the chemical composition of this water (in particular, Na^+ concentration). Actually, Na^+ has the opposite effect of salinity on soils. While a high salt concentration (on condition of a low concentration of sodium salts) may usually increase flocculation and aggregation, saturation with Na^+ causes dispersion and collapse of soil structure. The soil texture, the content of organic matter and the irrigation water composition influence the flocculation and dispersion of colloidal particles (Qadir and Oster, 2004 and Ladeiro, 2012).

2. Physical properties:

Data in Table 5 show the effect of treated rice straw, irrigation water quality and soil textures on some soil physical properties i.e. bulk density (ρb), porosity (E) and mean pore diameter (d).

Table 5. Some physical properties of the studied soils as affected by adding treated rice straw and irrigation water types.

Treat.		Mean Values				d (μm) (0-30) cm
		Upper Layer (0-15) cm		Lower Layer (15-30) cm		
		ρb (Mg m^{-3})	E (%)	ρb (Mg m^{-3})	E (%)	
Clay Loamy Soil (S_1) + Tap Water (I_1)						
C_0		1.03	52.53	1.08	54.48	8.26
C_1		0.98	55.06	0.98	59.03	9.07
C_2		0.96	55.56	0.97	59.06	15.18
Clay Loamy Soil (S_1) + Agriculture Drainage Water (I_2)						
C_0		1.06	51.15	1.10	53.64	9.19
C_1		0.99	54.33	1.00	57.94	10.65
C_2		0.96	55.74	1.00	58.10	17.07
Loamy Soil (S_2) + Tap Water (I_1)						
C_0		1.33	43.98	1.36	42.72	8.65
C_1		1.22	48.69	1.27	46.79	9.07
C_2		1.14	52.14	1.12	52.91	9.99
Loamy Soil (S_2) + Agriculture Drainage Water (I_2)						
C_0		1.34	43.70	1.37	42.58	8.18
C_1		1.18	50.29	1.20	49.79	8.72
C_2		1.08	54.43	1.17	50.77	9.64
LSD 5%	S	0.017**	0.723**	0.032**	1.412**	1.266**
	I	NS	NS	NS	NS	NS
	C	0.020**	0.885**	0.040**	1.729**	1.551**
	S×I	0.024*	1.022*	NS	NS	NS
	S×C	0.029**	1.252**	0.056*	2.445*	2.193**
	I×C	NS	NS	NS	NS	NS
	S×I×C	NS	NS	NS	NS	NS

C_0: Without organic amendments, C_1: Rice straw compost, C_2: Rice straw compost biochar.

Soil bulk density (ρb) and porosity (E):

Bulk density was greater in loamy soil (varied from 1.08-1.37 Mg m^{-3}) than in clay loamy soil (varied from 0.96-1.10 Mg m^{-3}). Also, it was noticed that the (ρb) decreased significantly by adding treated rice straw, especially with RSCB. Under both irrigation water types, the bulk density values increased with depth as a result of decreased soil volume. It is well known that there is a reversible relationship between (ρb) and (E), thus, the soil porosity means values took the same trend reversely. The differences between the studied soils confirmed by (Hillel, 1982) who proved that increases silt or sand content in soil texture will increase soil bulk density and decreases total porosity, but increases the ratio of macro-porosity in total porosity.

At the upper layer of both soils, the lowest bulk density value was identified at I_2C_2 then I_1C_2 treatments. Meanwhile, at the lower layer, it was identified as I_1C_2 then I_2C_2 treatments as compared to control. But, the highest soil porosity in both soils and layers was recorded at I_2C_2 treatment as compared to control. Based on these results, the size of biochar particles is responsible for the changes of the soil bulk density and porosity. Głab *et al*., (2016) confirmed the mention results where any increase in the biochar size from 0.5 to 2 mm caused a decrease in soil bulk density and plant-available water and an increase in total porosity.

Mean pore diameter of the soil (d):

The clay loamy soil (S_1) has a great ability to aggregate their particles more than that in loamy soil (S_2). Adding treated rice straw into clay loamy soil irrigated by different quality waters has a highly significant effect on increment the mean pore diameter. Application of RSCB (C_2) treatment recorded the highest mean value of mean pore diameter of the soil in particular at S_1I_2 then S_1I_1 treatments. These increases were at rates of 85.7 and 83.8% respectively as compared to control. Moreover, there is a high positive correlation (varied from 70 to 98) between soil mean pore diameter and the increases of soil organic carbon under all the treatments where it promotes to form the macro and meso-pore.

3. Soil hydraulic properties:

Saturated hydraulic properties (K_S):

Data in Table 6 show the effect of treated rice straw, irrigation water quality and soil textures on some soil hydraulic properties i.e. saturated hydraulic conductivity (K_S), specific fluid flux (q) and intrinsic permeability (k).

Data revealed that the addition of treated rice straw (RSC and RSCB) have a significant effect on the hydraulic conductivity (Ks), the specific fluid flux and the intrinsic permeability (k) in all the treatments as compared to control. Adding RSCB (C_2) recorded the highest mean values of the mention parameters at both soils irrigated by different quality water in most treatments. Moreover, the highest water movement appeared in the clay loamy soil (with RSCB amendment) and irrigated with agricultural drainage water or tap water by the rate of 239.1 and 243.8% respectively as compared to control. On the contrary, the loamy soil appeared a slight effect on the mean values of soil hydraulic properties (soil water movement) as compared to control and the increases in clay loamy soil.

The soil hydraulic properties may be increase by using agricultural drainage water than tap water because of its high salts content although it has high Adj $_{SAR}$. Na^+ excess reduces in particular the permeability in soils. The major problems occur when Na^+ excess is associated with a low salt concentration. Hence, Na^+ induces de-flocculation, an increase in soil bulk density and a higher micro and macro-pore volume ratio. The correlation between K_S and soil EC took a positive trend in all the treatments except in the upper layer of clay loamy soil which appeared a negative correlation. These results may be due to the effect of salts leaching from the upper layer to lower layer, especially in clay loamy soil (has low EC) as compared to loamy soil (has high EC).

These results prove the positive influence of treated rice straw such as rice straw compost and rice straw compost biochar in enhancement soil hydraulic properties (by increasing the soil organic carbon content and adsorption of some salts like Na^{+}), especially in clay loamy soil. The decrease in loamy soil water movement may be attributed to its specific content of soluble salts such as Mg^{+2} which take the same trend of Na^{+}. In addition, the OM content of loamy soil (0.55%) is less than clay loamy soil (0.96%). These results are in harmony with the finding of Hanson *et al.*, (1999) and Levy *et al.*, (1999), Hammad *et al.*, (2013) and Enas-Soliman (2018), they stated that the sodic soils are related with structural changes that greatly affect soils permeability. The high level of sodium in the soil leads to losses of structure that reduces the hydraulic conductivity.

Table 6. Hydraulic properties of the studied soils as affected by adding treated rice straw and irrigation water types.

Treat.	Mean Values		
	K_S (m day^{-1})	q (m day^{-1})	k (m^{2} ×10^{-12})
Clay Loamy Soil (S_1) + Tap Water (I_1)			
C_0	1.79	2.73	2.11
C_1	2.23	3.44	2.63
C_2	6.07	9.35	7.16
Clay Loamy Soil (S_1) + Agriculture Drainage Water (I_2)			
C_0	2.24	3.48	2.65
C_1	2.97	4.55	3.51
C_2	7.70	11.51	9.08
Loamy Soil (S_2) + Tap Water (I_1)			
C_0	1.97	3.05	2.32
C_1	2.16	1.96	2.55
C_2	2.64	2.03	3.11
Loamy Soil (S_2) + Agriculture Drainage Water (I_2)			
C_0	1.78	2.69	2.11
C_1	2.05	3.05	2.42
C_2	2.43	3.28	2.87
LSD 5% S	0.772**	1.175**	0.830**
I	NS	NS	NS
C	0.946**	1.440**	0.107**
S×I	NS	NS	NS
S×C	1.337**	2.036**	2.022**
I×C	NS	NS	NS
S×I×C	NS	NS	NS

C_0: Without organic amendment, C_1: Rice straw compost, C_2: Rice straw compost biochar,

Unsaturated hydraulic properties $K_{(\theta V)}$:

Figs. 2 and 3. illustrated that the addition of treated rice straw and irrigation water quality have a great effect on the mean unsaturated hydraulic conductivity values $K_{(\theta V)}$ of clay loamy soil more than in loamy soil. In addition, the treatment of RSCB (C_2) was the best one in increasing $K_{(\theta V)}$ under different moisture levels. The behasvior of water movement of unsaturated conditions is similar to its movement in saturated conditions under both of soil types, also, the hydraulic conductivity of unsaturated soil cannot generally be assumed to be constant. Rather, it is a variable which is predominantly a function of the degree of saturation (water content) or the matric and osmotic suctions of the unsaturated soil. Moreover, $K_{(\theta V)}$ is affected by the changing of soil properties.

These changes of soil properties as a results to irrigation with low-quality water affected on the porosity percentage, pore size distribution and mean pore diameter of both soils. Permanent wilting point (PWP) is mostly related with micro-porosity distribution of a soil when comparing with field capacity (FC). Increasing macro-porosity or decreasing micro-porosity in soil structure causes increases in soil hydraulic conductivity (Ahuja *et al.*, 1984). The addition of treated rice straw into the studied soils especially RSCB irrigated by low-quality water increased the soil macro-pores consequently increased both hydraulic conductivity types.

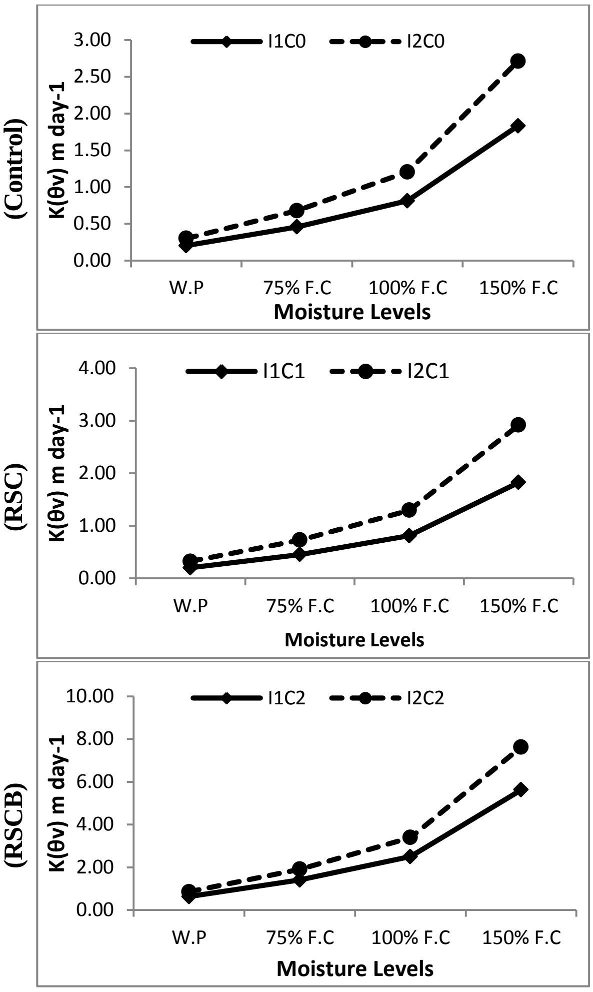

Fig. 2. Unsaturated hydraulic conductivity of clay loam soil as affected by adding treated rice straw under irrigation water types.

The results of soil physical and chemical properties confirmed the trend of soil hydraulic properties (water movement). The increasing of soil water movement was attributed to some reasons: (1) reducing the number of soil pores consequently soil porosity, (2) increasing the BD of soil, (3) increment the mean pore diameter (soil pore size) and (4) clogging the small pores and the change to massive form of structure, thus increasing the hydraulic conductivity and the soil ability to drain excess water. Correlation coefficients in Table 7 proved the mention effects of soil physical and chemical properties and its relation to hydraulic properties. These results were confirmed with Hillel, (1980) who found that the hydraulic properties were obviously affected by the structure as well as by texture, being greater if the soil is highly porous, fractured, or aggregated than if it is tightly compacted and heavy. Soil hydraulic properties depend not only on total porosity but also primarily, on the sizes of the conducting pores.

Generally, during the irrigation period, large amounts of soluble salts and low quantities of exchangeable Na^{+} favour the state of aggregation of clay particles, thus ensuring a good structural status and free circulation of air and water along the soil. However, the first irrigation, especially in the top layer, leaching processes causes solute transportation towards the lower layer of the soil column. Because of various physical, chemical, and biological processes, the hydraulic properties may change as water permeates and flows through the soil (Quirk, 1986).

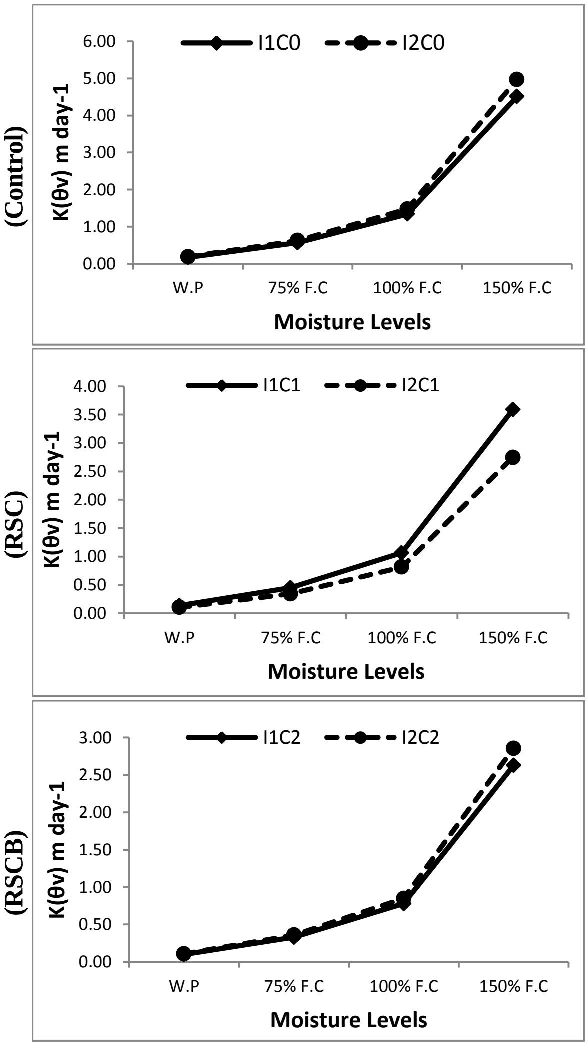

Fig. 3. Unsaturated hydraulic conductivity of loam soil as affected by adding treated rice straw under irrigation water types.

Table 7. Correlation values between some physical and chemical properties of the studied alluvial soils as affected by adding treated rice straw and irrigation water types.

Upper Layer (A)	Correlation	Lower Layer (B)	Correlation
Clay Loamy Soil (S_1) + Tap Water (I_1)			
E, OC	1.00**	E, OC	0.99**
d, OC	0.72**	d, OC	0.70**
K_S, OC	0.71**	K_S, OC	0.69**
K_S, EC	-0.63*	K_S, EC	0.81**
K_S, S-Na	-0.92**	K_S, S-Na	-0.77**
Clay Loamy Soil (S_1) + Agriculture Drainage Water (I_2)			
E, OC	1.00**	E, OC	0.79**
d, OC	0.80**	d, OC	0.98**
K_S, OC	0.77**	K_S, OC	0.97**
K_S, EC	-0.86**	K_S, EC	0.38
K_S, S-Na	-0.89**	K_S, S-Na	-1.00**
Loamy Soil (S_2) + Tap Water (I_1)			
E, OC	0.98**	E, OC	0.81**
d, OC	0.87**	d, OC	0.75**
K_S, OC	0.86**	K_S, OC	0.73**
K_S, EC	0.75**	K_S, EC	0.78**
K_S, S-Na	-0.97**	K_S, S-Na	0.68**
Loamy Soil (S_2) + Agriculture Drainage Water (I_2)			
E, OC	0.97**	E, OC	1.00**
d, OC	0.87**	d, OC	0.87**
K_S, OC	0.89**	K_S, OC	0.89**
K_S, EC	0.83**	K_S, EC	0.46*
K_S, S-Na	-0.54*	K_S, S-Na	-0.98**

CONCLUSION

According to the finding of this investigation, the application of treated rice straw (compost and biochar) has been proved to be superior treatments in resistance of soils to the adverse effect of low-quality water by increasing the macro-pores and hydraulic conductivity (saturated and unsaturated) and enhancement soil properties for agricultural proposes.

REFERENCES

Agassi, M.; I. Shainberg and J. Morin (1981). Effect of electrolyte concentration and soil sodicity on infiltration rate and crust formation1. Soil Sci. Soc. Am. J. 45(5):848-851.

Ahuja, I.R.; J.W. Namey; R.E. Green and D.R. Nielsen (1984). Macro-porosity to characterize spatial variability of hydraulic conductivity and effects of land management. Soil Science Society America Journal 48: 699–702.

Allam, M. N., and G. I. Allam (2007). "Water Resources in Egypt: Future Challenges and Opportunities". Water International, 32(2), 205-218.

Asempa (2010). The Battle of the Nile, North-East Africa. Africa Confidential, 51(17), 6-8.

Ayers, R.S. and D.W. Westcot (1985). Water Quality for Agriculture. FAO irrigation and drainage papers No. 29. Rome, Italy.

Black, C.A.; D.D. Evans; L.E. Ensminger; J.L. White and F.E. Clark (1965). "Methods of Soil Analysis". Part 1 and 2. Amer. Soc. Agron. Inc. Pub., Madison, USA.

Dellavalle, N.B. (1992). Determination of specific conductance in supernatant 1:2 soil: water solution. In "Handbook on Reference Methods for Soil Analysis". Soil and Plant Analysis Council, 44-50.

Dewis; J and F. Feritas (1970). "Physical and Chemical Methods of Soil and Water Analysis". FAO, Rome, soil Bulletin, No. 10.

Dielman, P.J and N.A. De Ridder (1972). Elementary ground water hydraulic. Drainage Principle and Application Pub. 16, 1-153 LLRI, Wageningen, The Netherlands.

Edelstein, M.; Z. Plaut and M. Ben-Hur (2010). Water salinity and sodicity effects on soil structure and hydraulic properties. Advan. in Horti. Sci. 24 (2): 154-160.

El Bedawy, R. (2014). Water Resources Management: Alarming Crisis for Egypt. J. Management and Sustainability, 4 (3).

Enas, M. Soliman (2018). Changes of water retention in rice soil amended with organic manures under irrigation by saline and sodic water. J. Soil Sci. and Agric. Eng., Mansoura Univ., 9 (12):847-857.

Feizi, M.; M.A. Hajabbasi and B. Mostafazadeh-fard (2010). Saline irrigation water management strategies for better yield of safflower *(Carthamus tinctorius L.)* in an arid region. Aust. J. Crop Sci., 4: 408-414.

Fernandes J. D.; L.H.G. Chaves; J.S. Mendes; I.B. Chaves and G.A. Tito (2019). Alterations in soil salinity with the use of different biochar doses. Revista de Ciências Agrárias, 42(1): 89-98.

Frenkel, H.; J.O. Goertzen and J.D. Rhoades (1978). Effects of clay type and content,exchangeable sodium percentage, and electrolyte concentration on claydispersion and soil hydraulic conductivity. Soil Sci. Soc. Am. J. 42(1):32-39.

Głab, T.; J. Palmowska; T. Zaleski; K. Gondek (2016). Effect of biochar application on soil hydrological properties and physical quality of sandy soil. Geoderma, 281, 11-20.

Grattan, S.R. and J.D. Rhoades (1990). Irrigation with saline ground water and drainagewater. In: Tanji, K.K., (Ed.), Agricultural salinity assessment and management,manuals and reports on engineering practices, ASCE, New York, pp. 432-449.

Hammad, S.A.; T. M. El - Zehery and Enas M. Soliman (2013). Modeling of saturated hydraulic conductivity and mean soil pore diameter in an alluvial loamy soil. J. Soil Sci. and Agric. Eng., Mansoura Univ., 4 (3):299-307.

Hanson, B.; S.R. Grattan and A. Fulton (1999). "Agricultural Salinity and Drainage". Oakland: Univ. of California, Division of Agric. and Natural resources. Irrigation Program. Pub. 3375.

Hesse, P.R. (1971). "A Text Book of Soil Chemical Analysis". John Murry (publishers) Ltd, 50 Albermarle Street, London.

Hillel, D. (1980). "Introduction of Soil Physics". Academic Press, Orlando, Florida, USA.

Hillel, D. (1982). Introduction to soil physics. Academic Press, Inc. San Dieoga, California.

Jackson, M. L. (1967). "Soil Chemical Analysis" .Advanced Course. Dept., of Soils, Univ., of Wise., Madison 6, Wishensin, U.S.A.

Kim, H.; J.M. Fonseca; J. Choi; C. Kubota and D.Y. Kwon (2008). Salt in irrigation water affects the nutritional and visual properties of romaine lettuce *(Lactuca sativa L.)*. J. Agric. Food Chem., 56, 3772–3776.

Kirkham, M.B. (2005). "Principles of soil and plant water relations". Elsevier Academic Press. USA.

Ladeiro, B. (2012). Saline Agriculture in the 21st Century: Using Salt Contaminated Resources to Cope Food Requirements. J. Botany (2012), 7.

Levy, G.J.; A. Rosenthal; J. Tarchitzky; I. Shainberg and Y. Chen (1999). Soil hydraulic conductivity changes caused by irrigation with reclaimed waste water. J. Environ. Qual., 28(5):1658-1664.

Mace, J. and C.A. Mrhein (2001). Leaching and reclamation of a soil irrigated withmoderate SAR waters. Soil Sci. Soc. Am. J. 65 (1), 199.

Mahmood-ul-Hassan M.; E. Rafique and A. Rashid (2013). Physical and hydraulic properties of aridisols as affected by nutrient and crop-residue management in a cotton-wheat system. Acta Scientiarum. Agronomy. Maringá, 35(1):27-137.

McHenry, M.P. (2009). Agricultural bio-char production, renewable energy generation and farm carbon sequestration in Western Australia: Certainty, uncertainty and risk. Agric. Ecosyst. Environ., 129, 1-7.

Ould Ahmed, B.A.; T. Yamamoto and M. Inoue (2007). Response of drip irrigated sorghum varieties growing in dune sand to salinity levels in irrigation water. J. Appl. Sci., 7, 1061-1066.

Pathak, H. and D.L.N. Rao (1998). Carbon and nitrogen mineralization from added organic matter in saline and alkali soils, Soil Biol. Biochem., 30, 695–702.

Piper, C.S. (1950). "Soil and Plant Analysis". Inter Science Publisher Inc. New York.

Qadir, M. and J.D. Oster (2004). Crop and irrigation management strategies for saline-sodic soils and waters aimed at environmentally sustainable agriculture. Sci. Total Environ., 323, 1-19.

Qadir, M. and S. Schubert (2002). Degradation processes and nutrient constraints in sodic soils, Land Degrad. Dev., 13, 275–294.

Quirk, J.P. (1986). Soil permeability in relation to sodicity and salinity. Philosophical Transactions of the Royal Society London, Series A, Mathematical and Physical Sciences. 316 (1537): 297–317.

Richards, L.A. (1954). "Diagnosis and improving of Saline and Alkaline Soils". U.S.S., Laboratory Staff. Agric. Handbook, No.60.

Sheldon, A; N.W. Menzies; H.B. So and R. Dalal (2004). The effect of salinity on plant available water. Super Soil 2004: 3rd Australian, New Zealand Soils Conf., 5-9 December, Univ. Sydney, Australia.

Singh, R.A. (1980). "Soil Physical Analysis". Kalyani Publishers, New Delhi, India.

Tejada, M.; M. Hernandez and C. Garcia (2009). Soil restoration using composted plant residues: Effects on soil properties. Soil and Tillage Res., 102 (1), 109-117.

فوائد قش الأرز المعالج على الخواص الهيدروليكية للتربة تحت مياه ري ملحية صودية

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مصر دولة جافة يعتمد إنتاجها الزراعي بالكامل على الري، وتعاني نقصًا شديدًا في موارد المياه العذبة. لذلك فإن إعادة استخدام المياه العادمة الزراعية أمر لا مفر منه، خاصة في المناطق الوسطى والشمالية من دلتا النيل المصرية. في الآونة الأخيرة، تعتبر إضافة البيوشار واحدة من ممارسات الزراعة الذكية للمناخ في الزراعة المستدامة. لذلك أجريت تجربة أعمدة في معمل قسم الأراضي، كلية الزراعة، جامعة المنصورة لتقييم دور قش الأرز المعالج في التخفيف من التأثير الضار للري بمياه الصرف الزراعي منخفضة الجودة علي الخصائص الفيزيائية والهيدروليكية للتربة (حركة الماء). تضم المعاملات تربتين رسوبيتين (طينية طميية، وأخري طميية)، ونوعين من مياه الري (ماء الصنبور العادي وماء صرف زراعي شديد الملوحة والقلوية) ونوعين من قش الأرز المعالج (كمبوست قش الأرز وبيوشار كمبوست قش الأرز) بجانب الكنترول. بينت النتائج أن إضافة كل من كمبوست وبيوشار كمبوست قش الأرز زاد من قدرة التربة علي مقاومة التأثير السلبي للري بمياه منخفضة الجودة ليس هذا فحسب, بل أيضًا حَسن من الخواص الفيزيائية والهيدروليكية للتربة. أدي إضافة المخلفات العضوية خاصة بيوشار كمبوست قش الأرز زيادة في الخواص الهيدروليكية للتربة، مثل (التوصيل الهيدروليكي المشبع, التوصيل الهيدروليكي غير المشبع, كثافة تدفق الماء, والنفاذية الذاتية) كنتيجة للتغير الإيجابي في كثافة التربة الظاهرية، ومتوسط قطر المسام والمسامية. بناءًا على هذه النتائج، يمكن لنوعي قش الأرز المعالج خاصة بيوشار كبوست قش الأرز تحسين مقاومة التربة ضد التدهور الناتج من الري بمياه منخفضة الجودة من خلال تحسين عملية تجمع الحبيبات، والبناء الأرضي، وحركة الماء خلال نظام التربة.