J. Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 9 (12): 847 - 857, 2018

Changes of Water Retention in Rice Soil Amended with Organic Manures under Irrigation by Saline and Sodic Water

Enas M. Soliman
Soils Dept., Fac. Agric., Mansoura Univ., Mansoura, Egypt

ABSTRACT

The quality of irrigation water may affect soil water retention properties, especially in arid areas such as Egypt. Evaluate such an impact plays a vital role in the achieving of effective development of soil and water maintenance and management practices. Therefore, a field trial was performed to evaluate the effects of irrigation water qualities and organic manures amendment on the soil water potential as a limiting factor of crop production. The treatments consisted of all possible combinations of three types of organic manures (2 t fed^{-1} rice straw compost, 5 t fed^{-1} farmyard manure (FYM), and 2 t fed^{-1} rice straw compost + 5 t fed^{-1} FYM) beside the control and three types of irrigation water differed in salinity (EC) and sodicity (SAR_{Adj}), that were industrial wastewater, agricultural drainage water and freshwater. The investigated treatments influenced the shape of the soil-water characteristic curves (sorption and desorption) and had considerable effects on the aggregate stability as indicated by the patterns of hysteresis phenomena. The variation of irrigation water quality had the strongest effect on modifying soil properties, especially agricultural drainage water having the highest SAR_{Adj} then industrial wastewater with the highest EC. In addition, mixing compost with FYM is considered the best improver for soil irrigated with poor quality water under these experimental conditions.

Keywords: Soil water dynamic, soil retention properties, low quality water, organic manures.

INTRODUCTION

Nearly all Egyptian agriculture depends on irrigation water because of its arid climate. Unfortunately, Egypt's renewable water resources are limited only to its share of the 55.5 billion cubic meters of Nile water annually. It is therefore imperative to explore non-traditional water resources to meet the needs of agriculture, industry and the increasingly growing civilian needs with Egypt's massive population growth. Utilization of wastewater in irrigation can reduce the gap between existing water requirement and supply, as well as saving freshwater resources. Furthermore, many farmers utilize poor quality water because it is abundant and free, especially for irrigating rice crop during drought periods (Jeong *et al.* 2014). In addition, wastewater acts as an efficient fertilizer because of its content of plant nutrients such as nitrate, phosphates and organic matter (Gibbs *et al.* 2006 and Carlos *et al.* 2015). This practice by farmers will not disappear and it can't be negligent or dealt with by imposing a prohibition on its use (Scott *et al.* 2004).

Many researchers have shown that the rice crop is successfully cultivated under conditions of salt-affected soils and irrigation with poor quality water. Girdhar, (1988) observed that the rice plant gives a satisfactory yield even when the dissolved salts 20 to 25 dSm^{-1} in the upper layers. Furthermore, the high tolerance of rice to exchangeable sodium percentage (ESP) arises mainly because of its capacity to resistant and its need for a head of water on the field during the growing season. In additions, the high pH of sodic soils (caused by high SAR_{Adj} of irrigation water) reduced under continuous flooding. These advantages of rice plant due to the flooded system of agriculture which including conservation of standing water nearly during the growing season perform a significant depression in the root zone alkalinity and salinity by dilution and leaching of the dissolved salts.

The salinity of irrigation water has been shown to affect the physical and chemical properties of submerged rice soil. For example, Ragab (2000) found that soil salinity values increased with increasing irrigation water salinity and decreased soil water availability (increased soil water retention). The increasing of dissolved salts in irrigation water from 0.58 to 3.67 dSm^{-1} increased soil salinity from 1.87 to 24.83 dSm^{-1}. Thus, the accumulation of soil salts was widely related to the salt concentrations of irrigation water. Water quality for agricultural purposes is fixed based on the influence of water on the yield and the quality of the different crops, as well as, its effect on the characteristic changes in the paddy soil (Ayers and Westcot 1985).

The major problems occurred by soil salinization are lowering of osmotic potential (ψ_S) of the soil solution (which decreases the water availability for plants) and the toxicity of certain ions (Rhoades *et al.* 1992). When dissolved salts exist that are not uniformly distributed, osmotic effects occur. The soil water potential (ψ_w) tends to be lower where the concentration of the solutes is higher. Consequently, the presence of dissolved salts influences the water thermodynamic properties. In particular, dissolved salts minimize the vapor pressure of soil water (Hillel, 2004). Meantime, poor quality irrigating water leads to changes in the soil physical properties, such as water infiltration rate, permeability, hydraulic conductivity, structure, clogging of soil channels and pores for water flow (Tedeschi and Dell'Aquila, 2005), pH and nutrient availability for plants.

Primarily, the budget of soil water is impacted by soil water dynamics (infiltration, redistribution, hydraulic conductivity, percolation, evaporation, transpiration by plants), which are adjusted by the soil water potential ψw (the soil water energy state). Understanding of the (ψ_w) may be used to describe the hydraulic conductivity and distribution of solutes from the rhizosphere into the groundwater, as well as for planning alternative cropping systems based on the plant's response to water stress. Clearly, ψ_w is a significant parameter that can be applied to improve the irrigation water use efficiency (Timlin *et al.* 2001). The movement of water, its retention, and its availability are governed by physical and chemical properties of soil, irrigation water quality, crop type and its management. It provides an outstanding supply of water to plants between irrigation intervals to allow their continued survival, growth, and production. Soil water dynamic has a deciding role in the soil chemical and physical properties, microflora, and nutrient dynamics.

The soil water characteristic curve (SWCC) and the unsaturated hydraulic conductivity relationships are the most significant hydraulic functions of the studied soil. Fredlund *et al*. (1998) proved the ability of SWCC in unsaturated soil properties estimation. Also, the SWCC is considered an important function of soil relating the water content (θ) to its retention (ψ) and is a representation of the amount of water content in different pores under different soil water suctions. Furthermore, the SWCC is a main hydraulic property required for modeling water flow, irrigation management and many applications related to the water behavior predicting in the porous media (Warrick, 2002). This interprets why studies that model water flow and solute transport in the unsaturated zone are increasingly becoming an essential issue of water resources management and prevent groundwater contamination (Rumynin, 2011).

Hysteresis is evident that the two soil water characteristic curves do not follow the exact same reversible path. Soil moisture hysteresis plays a vital role in understanding the soil behavior as a porous system, as well as it provides us with an idea to soil moisture retention and release characteristics. In addition, it shown to significantly influence solutes transport and water flow under saturated conditions. The major causes of hysteresis phenomena produced by several physical and physicochemical mechanisms of soil aggregates collapse by water, such as (1) the contact angle variation at different drying and wetting cycles, (2) entrapped air in a recently wetted soil, (3) temperature, (4) shrinking and swelling, (5) ink-bottle effect because of non-uniformity in sizes and shape of both individual pores and interconnected pore networks and (6) physico-chemical dispersion as a result of osmotic potential upon wetting with low water salinity (Bachmann and van der Ploeg, 2002; Maqsoud *et al.* 2004 and Le Bissonnais, 2016).

To overcome the adverse effects for irrigating by low quality water, it should be added any soil improver *i.e.,* organic matter. Hence, the soil functional properties such as (soil structure, porosity, and hydraulic properties) are modified when integrating organic matter in it. In addition, it reduces the negative effects of low quality water and lowers the soil water potential values. Accordingly, the understanding of the relationship between water, soil, and plants is required essentially to fulfill the effective management of poor quality irrigation water resources and crop production, especially under puddled soil. The aim of this study was to demonstrate to what extent organic manuring can reduce the harmful effects of irrigation water salinity and sodicity on the soil water retention characteristics after rice cultivation under flooding conditions through testing of soil water potential state, hysteresis effect and some soil properties.

MATERIALS AND METHODS

A field experiment was conducted at the Res., Farm of Fac. Agric., Mansoura Univ., Mansoura, Dakahlia, Egypt, to evaluate the variation of water quality and organic manures on soil water retention properties of rice field. The soil was amended with three types of organic manures (M) (rice straw compost @ 2 t fed^{-1}, FYM @ 5 t fed^{-1}, and rice straw compost @ 2 t fed^{-1} + FYM @ 5 t fed^{-1}), and the rice crop was irrigated with three types of water quality have a different salinity and SAR_{Adj} (I) (untreated industrial wastewater, agricultural drainage water and freshwater). The experiment was laid out in strip plot design with three replications in plot size 5.5×2.25 m^2. A drain nearby the way out of Delta Company for Fertilizers and Chemical Industries, Talkha District, Dakahlia was the source of the industrial wastewater. While the agricultural drainage water was collected from an agriculture drain near Mit Khames Village, Mansoura District, Dakahlia. These waters were collected every five days and put in a polyethylene tank.

The initial analyses of the experimental soil and irrigation waters are presented in Tables (1 and 2). The representative surface soil samples (0-20 cm) were collected from each plot (140 day after transplanting), air dried, grinded and passed through a 2 mm sieve. The different analysis of the studied soil before applying treatments and water samples were done by the standard methods describe by Piper (1950), U.S.S.L.S (1954), Black *et al.* (1965), Hesse (1971), Hillel (1980) and Singh (1980). The micronutrients and heavy metals in water samples were measured using Qtegra ISDS Data Processing Algorithms for ICAP 7000 Series ICP-OES (Ammann, 2007). In addition, the statistical analysis was done according to Panse and Sukhatme (1985).

Table 1. Initial values of some physical and chemical properties of the tested soil.

Physical properties	Value	Chemical properties	Value
Mechanical analysis		pH (in soil paste)	8.57
Sand (%)	11.69	EC dSm^{-1} (in soil paste extract)	0.65
Silt (%)	37.17	$CaCO_3$ (%)	1.03
Clay (%)	51.14	OM (%)	0.84
Texture class	Clayey	Soluble cations† (mmole L^{-1})	
SP (saturation %)	68.00	Na^+	3.48
FC (%)	32.00	K^+	0.80
WP (%)	15.00	Ca^{+2}	1.70
AW(%)	17.00	Mg^{+2}	0.90
Ks (m s^{-1})	5×10^{-5}	Soluble anions† (mmole L^{-1})	
ρb (Mg m^{-3})	1.14	CO_3^{-2}	0.00
ρs (Mg m^{-3})	2.19	HCO_3^-	0.23
Total porosity (%)	48.00	Cl^-	4.29
Air porosity (Ea%) at FC	30.25	SO_4^{-2}	1.89
Void ratio (e)	0.923	Available macro nutrients (mg Kg^{-1})	
		N	58.76
		P	12.34
		K	350.00

† Soluble cations and anions were determined in soil paste extract.

The soil water retention was estimated by the technique of soil water vapor pressure relationships (0.15 - 1.00 P/P_0) with two replicates according to Danielson (1980) and as used by Enas-Soliman (2008, 2013). The pF of hygroscopic water was calculated from the equation: pF = 6.5 + log (2 - log RH), where RH is the relative humidity in percent. The solutions of salts were used to obtain the different percentages of RH, which mentioned in Table (3) as described by Schofield and Botelho Da Costa (1935). All chemicals used in the present study were of AR grade and manufactured by Merck KGaA. This method was used to determine soil water characteristic curves (sorption and desorption) for each treatment.

Table 2. Analysis of the used irrigation water types.

Parameter		Mean Values†			Recommended Max. Concentration††
		Industrial Waste water	Agriculture drainage water	Fresh irrigation water	
pH		6.90	9.50	7.12	6.5-8.4
EC (dSm^{-1})		4.52	2.92	0.46	0-3
$SAR_{Adj.}$		8.71	20.79	1.72	6-24
RSC		0.00	3.00	0.00	1.25-2.50
SO_4^{-} (meq/l)		24.21	7.20	0.00	0-20
NO_3^-	Ppm	0.24	0.11	0.00	0-10
NH_4^+	Ppm	0.21	0.06	0.00	0-5
Zn	Ppm	2.56	0.20	0.01	2.0
Fe	Ppm	5.53	1.15	0.05	5.00
Cu	Ppm	0.22	0.06	0.00	0.20
Mn	Ppm	0.65	0.01	0.01	0.20
Pb	Ppm	6.86	2.07	0.02	5.00
Cd	Ppm	0.42	0.05	0.00	0.01
Ni	Ppm	0.36	0.10	0.00	0.20
Cr	Ppm	0.59	0.24	0.00	0.10
Co	Ppm	0.01	0.01	0.00	0.05
Sr	Ppm	0.98	0.14	0.00	0.10

† The mean values of the number of irrigation during the season.
†† Adapted from National Academy of Sciences (1972) and Pratt (1972).

Table 3. The saturated salts solutions and their relations to relative humidity and pF values.

Sat. solutions of salts	p/p_0†	RH (%)††	pF
LiCl	0.15	15	6.42
CrO_3	0.35	35	6.16
NH_4NO_3	0.65	65	5.77
NaCl	0.75	75	5.60
KCl	0.84	84	5.38
$NH_4H_2PO_4$	0.93	93	5.10
H_2O (distilled)	1.00	100	-

†p is the vapour pressure of saturated salts solutions, †p_0 is the vapour pressure of pure water and ††RH is the relative humidity (%).

The local and average degrees of hysteresis data were calculated according to the equation given by Lu and Khorshidi (2015): The local degree of hysteresis phenomena (D_{hi}) assess the hysteresis effect at a point (i) in the relative humidity (RH) or matric potential, it is defined as:

$$D_{hi} = (W_{di} - W_{wi})/W_{mi}$$

where w_{di} = water content (θ) at point (i) during desorption, w_{wi} = water content (θ) at point (i) during sorption, w_{mi} = average water content at the same point between the sorption and desorption states. Accordingly, to the local degree, the average degree of hysteresis (D_h) over the extent of RH or matric potential between point (j) and point (k) can be defined as:

$$D_h = \sum(W_{di} - W_{wi})/W_{mi}/(K - j) + 1$$

RESULTS AND DISCUSSION

To evaluate the suitability of water for irrigation, several criteria and certain effects on soil properties, especially retention properties must be investigated. Accordingly, the influence of different qualities of irrigation waters on the soil water characteristic curves pattern should be studied. The soil water potential (ψ_w) versus soil water content (θ) relationship is important for characterizing water release and retention of the soil and its hydraulic properties. Knowledge of the soil water content at different suction can allow us to assess the factors acting on soil moisture in all directions and to mark how far the moisture in a soil system is at equilibrium. These relations could be determined by the studying of soil water retention curve shape, where the curve is formed as a result of soil properties changes and it shows that as the water potential (ψ_w) decreases (becomes more negative), more and more soil pores become empty, and therefore the soil water content (θ) decreases.

The amount of water remaining in the studied soil at equilibrium is a function of the suction value, the pore sizes filled with water and the amount of water adsorbed to the reactive soil particles surfaces and its content of dissolved salts, consequently, it is a function of the matric (ψ_m) and osmotic (ψ_s) suctions.

1. Sorption Curve of Soil Water.

The relationship between the different vapor pressures expressed as pF values ranged between 6.5 and 3.5 and the percentage of gravimetric water content (θ_m%) of the rice soil is illustrated in Table (4) and Figs 1, 2, 3 and 4. Under high suctions (6.42 - 5 pF), the results show that the use of industrial saline wastewater (I_3) registered the highest mean values of maximum hygroscopic water (MHW) at most points of the sorption curve at all the treatments. However, the agricultural sodic drainage water (I_2) recorded the lowest mean values of MHW as compared to fresh water (I_1). These findings are obvious, whether rice soil treated with organic manures or not.

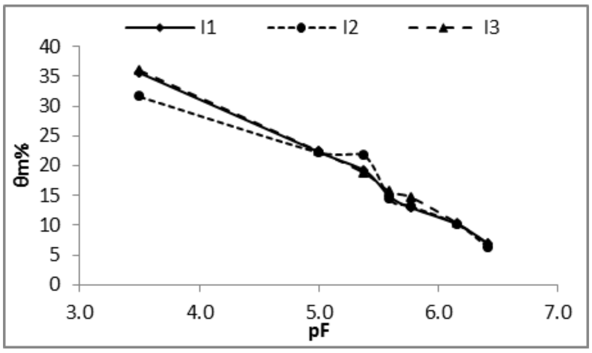

Fig. 1. The water sorption curves of rice soil as affected by irrigation water salinity and sodicity in the check manuring plots (without adding OM).

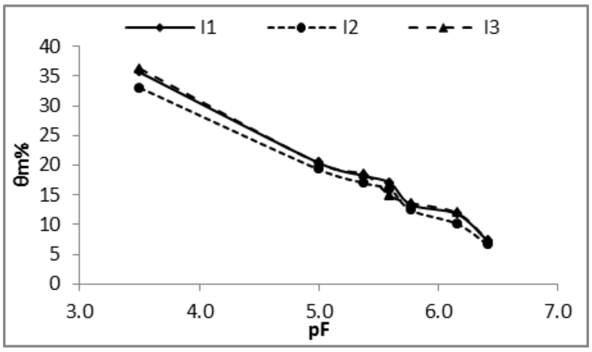

Fig. 2. The water sorption curves of rice soil as affected by irrigation water salinity and sodicity under amendment with straw rice compost.

Table 4. The Sorped water content of rice soil irrigated with saline and sodic waters and amended with different organic manures.

Treat.	Mean values of moisture content (θm%) at pF points						
	3.50	5.00	5.38	5.60	5.77	6.16	6.42
				Without adding OM (M_0)			
I_1	35.57	22.31	19.23	14.78	12.95	10.15	6.92
I_2	31.56	22.22	21.69	14.29	13.16	10.14	6.27
I_3	35.98	22.41	18.78	15.58	14.69	10.32	6.86
				Rice straw compost (M_1)			
I_1	35.62	20.39	18.23	16.98	13.34	11.76	7.19
I_2	33.02	19.29	16.98	15.87	12.41	10.10	6.54
I_3	36.26	20.33	18.51	14.84	13.63	11.93	7.35
				FYM (M_2)			
I_1	36.80	21.27	19.73	16.09	13.22	10.68	7.06
I_2	33.15	18.22	17.42	15.86	11.67	9.79	5.95
I_3	37.66	21.41	19.78	16.98	13.71	10.96	7.34
				Rice straw compost + FYM (M_3)			
I_1	37.80	21.25	19.45	16.13	13.73	11.13	7.19
I_2	33.82	19.66	18.23	15.40	12.41	9.60	6.74
I_3	39.70	22.16	20.64	15.99	13.76	11.23	7.44

I_1: freshwater, I_2: industrial saline wastewater and I_3: agricultural sodic drainage water.

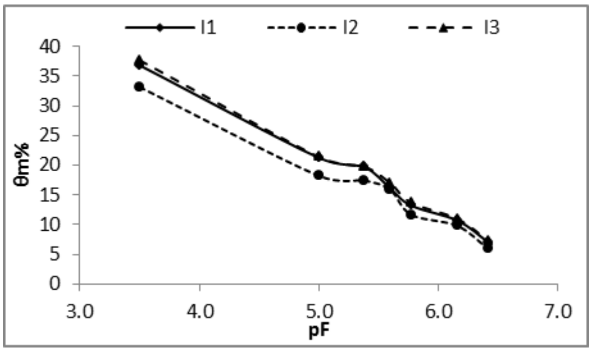

Fig. 3. The water sorption curves of rice soil as affected by irrigation water salinity and sodicity under amendment with farmyard manure (FYM).

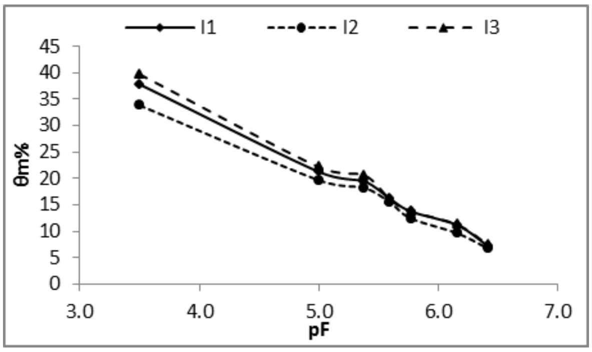

Fig. 4. The water sorption curves of rice soil as affected by irrigation water salinity and sodicity (under manuring with rice straw compost + FYM).

On the other hand, the application of organic manures as soil improvers have obvious effects, which caused increases in the mean values of MHW as compared with the values obtained in check manuring plots (without adding OM). This result demonstrates once again the importance of organic manuring in alleviating the hazardous effects of irrigation with poor quality water on soil properties and then the criteria of its water retention. The treatment M_3 (rice straw compost + FYM) is the best one where it increased the mean values of MHW at most points of pF curve, followed by application of FYM alone. These effects were clearer when using the industrial wastewater (I_3) then the fresh water (I_1). Whereas, the use of organic manures has a slight effect on mean MHW values of soil irrigated with agricultural drainage water (I_2). These results offered in Figs. 5, 6 and 7.

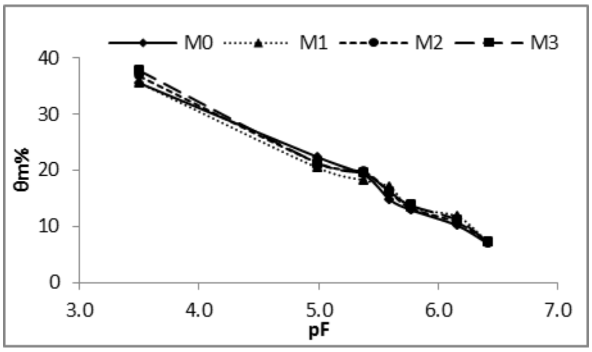

Fig.5. The water sorption curves of rice soil irrigated with fresh water as affected by the addition of organic manures.

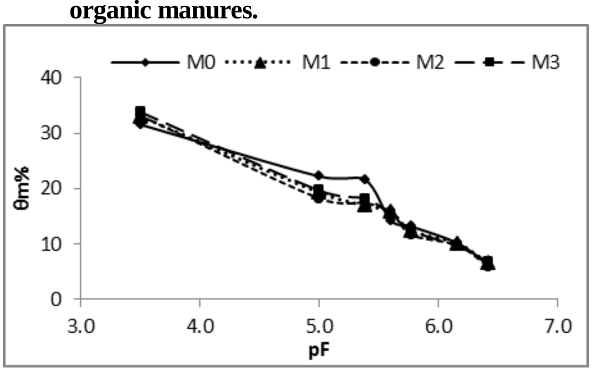

Fig. 6. The water sorption curves of rice soil as affected by the addition of different organic manures under irrigation with agriculture sodic drainage water.

The obtained data clearly shows that the salinity and sodicity (SAR_{Adj}) of the used irrigation waters have a great effect on changing the MHW values of sorption curve. The increase of salinity or decrease in sodicity (SAR_{Adj}) caused an increase in the mean values of MHW. The presence of dissolved salts in irrigation water may have the ability to absorb high amounts of soil water, especially industrial saline wastewater (I_3) with low Na^+ content. These results are confirmed by Hammad, (1985) who reported that soil soluble salts might arise from several sources, such as irrigation water and mineralization of organic matter. Consequently, these solutes increase the sorption of water and the moisture contents of the chernozem soil. Also, Enas-Soliman, (2013) and Hammad *et al.* (2013) concluded that the structural degradation of soils is a function of both low salinity and high sodicity.

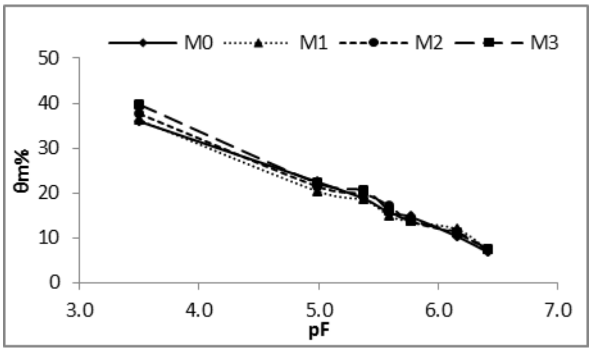

Fig. 7. The water sorption curves of rice soil as affected by the addition of organic manures under irrigation with industrial saline wastewater.

2. Desorption Curves of Soil Water.

These curves are adverse sorption curves, which aims to measure the desorption of retained water at different suctions of the rice soil as affected by irrigation water salinity and alkalinity and organic manure sources. These results are shown in Table (5) and Figs 8, 9, 10 and 11. The obtained results show that the irrigation with the agricultural sodic drainage water (I_2) registered the highest mean values in the quantities of the remained water at most points of the desorption curve as compared to the control (I_1) without adding organic manures or when using rice straw compost treatment, these results recorded at high suction of pF values (6.42 - 5). But this trend of remaining water (θm%) differed when the rice soil irrigated with the industrial salinity wastewater (I_3) and amended with FYM or rice straw compost + FYM treatments at only low suction (2.1 - 0.0 pF).

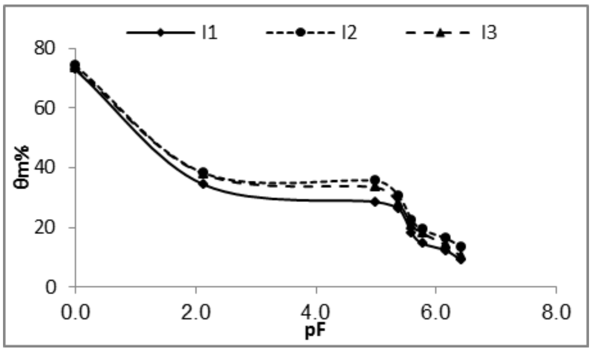

Fig. 8. The water desorption curves of rice soil as affected by irrigation water salinity and sodicity in the check manuring plots (without adding OM).

The data in Figs. 12, 13 and 14 reveal that the increasing of retained water of the rice soil at different suction values of desorption curve is correlated to irrigation by poor quality water, such as agricultural sodic drainage water (I_2) then industrial saline wastewater (I_3), especially when adding M_2 (FYM) or M_3 (compost + FYM) as compared to control (I_1).

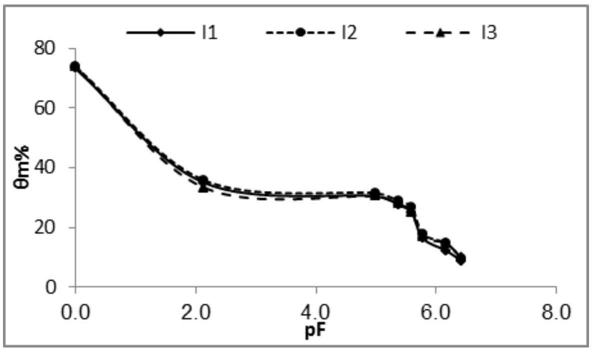

Fig. 9. The water desorption curves of rice soil as affected by irrigation water salinity and sodicity under amendment with straw rice compost.

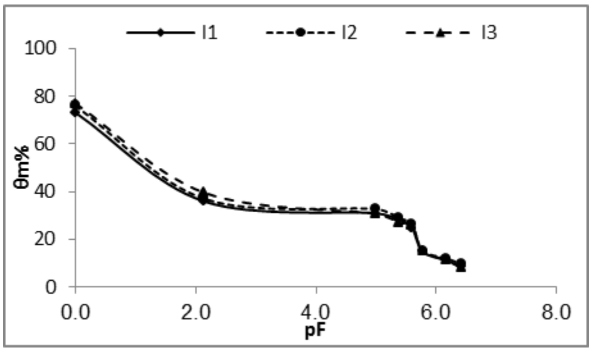

Fig. 10. The water desorption curves of rice soil as affected by irrigation water salinity and sodicity under amendment with farmyard manure (FYM).

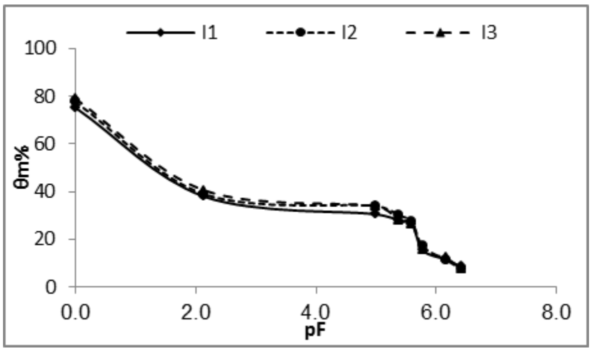

Fig. 11. The water desorption curves of rice soil as affected by irrigation water salinity and sodicity under manuring with rice straw compost + FYM.

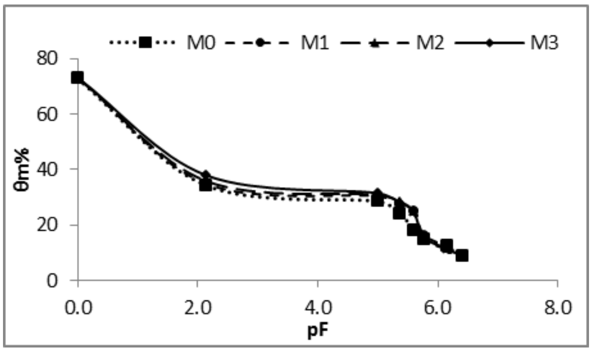

Fig. 12. The water desorption curves of rice soil irrigated with fresh water as affected by the addition of organic manures.

The quality of water refers to the degree of suitability for irrigation and it mainly depends on its physicochemical composition and nature of the dissolved salts. For matric potential below (-10 MPa), the only adsorption water can remain in the soil due to its surface hydration and cation hydration. Consequently, the soil water cannot flow as a liquid, and thus, evaporation and condensation are the sole transport mechanisms for water movement (Croney and Coleman 1961 and Richards 1965). According to He *et al*. (2015) field capacity (FC) for different soils increased with decreasing EC and increasing sodicity (SAR_{Adj}). Across all sodicity (SAR_{Adj}) values, the electrical conductivity (EC) greater than 4 dSm^{-1} was required to prevent swelling. Because of the high salt content and the presence of calcite in soil may have reduced the potential for water retention and may have lower FC.

Table 5. Desorpted water content of rice soil amended with different types of organic manures and irrigated with saline or sodic waters.

Treat.	Mean values of Moisture Content (θm%) at pF points							
	0.00	2.10	5.00	5.38	5.60	5.77	6.16	6.42
				Without adding OM (M_0)				
I_1	72.92	34.32	28.57	26.23	17.96	14.64	12.28	9.03
I_2	74.32	38.18	35.65	30.40	22.44	19.24	16.35	13.51
I_3	73.38	37.87	33.41	27.99	20.72	18.04	14.08	10.19
				Rice straw compost (M_1)				
I_1	73.31	34.96	30.47	27.52	24.84	16.42	12.28	8.88
I_2	74.02	35.79	31.49	28.69	26.77	17.83	14.75	9.72
I_3	73.98	33.34	30.41	27.93	24.92	16.91	14.69	9.87
				FYM (M_2)				
I_1	73.15	35.92	30.95	28.40	24.71	14.93	11.27	8.56
I_2	76.03	37.06	32.71	28.94	26.25	15.26	12.18	9.66
I_3	77.02	39.58	30.70	26.98	25.90	15.09	11.40	8.10
				Rice straw compost + FYM (M_3)				
I_1	75.23	38.00	30.54	27.97	26.44	15.48	11.56	8.47
I_2	77.66	38.98	33.96	30.13	27.27	17.14	11.43	7.64
I_3	78.99	40.56	33.95	27.91	26.62	15.54	12.21	7.57

I_1: freshwater, I_2: industrial saline wastewater and I_3: agricultural sodic drainage water.

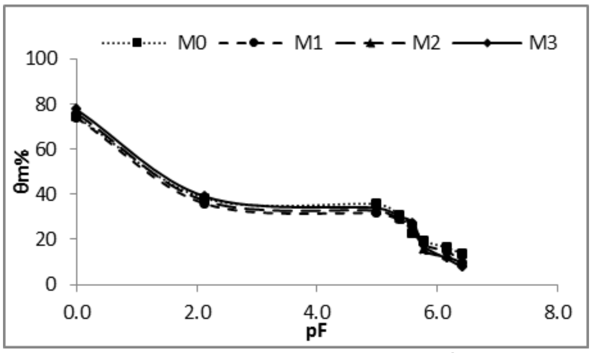

Fig.13. The water desorption curves of rice soil as affected by the addition of different organic manures under irrigation with agriculture sodic drainage water.

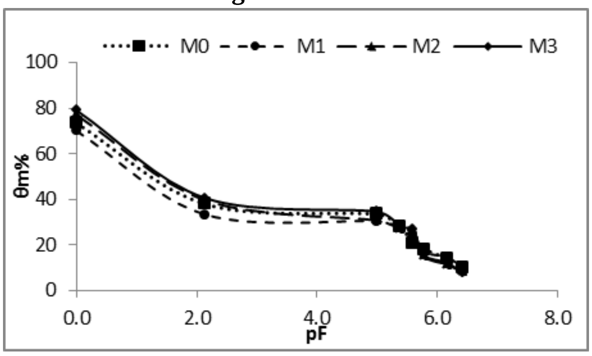

Fig. 14. The water desorption curves of rice soil as affected by the addition of organic manures under irrigation with industrial saline wastewater.

The regression equations of sorption and desorption curves of rice soil under submergence condition (Table 6) can be defined as:

$$\theta_{(di\ or\ Si)} = a\ \psi_w^2 - b\ \psi_w + c$$

Where $\theta_{(di)}$ is gravimetric water content at the point (i) during desorption, $\theta_{(Si)}$ is gravimetric water content at the point (i) during sorption, ψ_w is logarithm soil water (cm), a, b and c are fitting parameters illustrated in Table (6). The obtained data confirmed that there is a very strong negative correlation between soil water content (θ_m) and water potential (ψ_w) at all the treatments. Based on this finding, it can be concluded that the industrial saline wastewater can be used followed by the agricultural sodic drainage water instead of the freshwater. In addition, the users of these waters should add a high-quality organic matter to prevent soil degradation, especially when soil cultivated by rice crop.

3. Hysteresis Phenomena.

While both sorption and release of soil water (for each investigated treatment) gives a continuous curve, but the two curves will not be conformable. At the equilibrium of moisture content under the studied soil, the water content is greater in drying (desorption) than in wetting (sorption). This equilibrium with the state of soil water and accordingly to the direction of the process leading up to it is called hysteresis.

Figs 15-26 show a typical soil water characteristic curve (SWCC) at high suctions and explains the hysteresis effect in the soil water equilibrium relationship. The difference in path diameter of pore leads to deviations in the wetting and the drying path of the soil system. Accordingly, to the above mention causes, the hysteresis effect produces a different area between the two curves of soil moisture as a result of the irrigation water quality and soil improvers. The greatest area between moisture curves (A_h) forms when irrigating rice soil by agricultural sodic drainage water (I_2) followed by industrial saline wastewater (I_3) which recorded A_h values of 84.88 and 72.98 respectively, without adding any organic manures as compared to control (64.84). The treatment in which rice straw compost was combined with the FYM (M_3) turned out to be the best one in decreasing the A_h values for rice soil irrigated with freshwater (I_1M_3) then the industrial saline wastewater treatment (I_3M_3) as illustrated in the Table (7).

Table 6. The fitting parameters and correlation of sorption and desorption equations of soil water for each tested treatment.

Treat.	Sorption Curve				Desorption Curve			
	r	a	b	c	r	a	b	c
Without adding OM (M_0)								
I_1	- 0.995	-0.552	4.445	57.990	- 0.947	0.770	13.543	69.261
I_2	- 0.963	-1.878	-9.835	20.229	- 0.940	0.525	11.515	70.469
I_3	- 0.998	-0.617	3.796	56.815	- 0.949	0.419	11.132	69.602
Rice straw compost (M_1)								
I_1	- 0.994	-0.009	9.284	68.086	- 0.936	0.576	12.079	69.065
I_2	- 0.996	-0.237	6.511	58.610	- 0.933	0.594	12.043	69.754
I_3	- 0.994	0.376	13.29	78.079	- 0.926	0.835	13.546	69.643
FYM (M_2)								
I_1	- 0.996	-0.247	7.634	66.477	- 0.937	0.418	11.182	68.892
I_2	- 0.991	-0.199	7.055	60.090	- 0.935	0.490	11.902	71.632
I_3	- 0.996	-0.149	8.745	69.982	- 0.953	0.407	11.860	73.114
Rice straw compost + FYM (M_3)								
I_1	- 0.997	0.046	10.734	74.709	- 0.945	0.414	11.498	71.153
I_2	- 0.996	-0.318	6.072	58.890	- 0.936	0.249	10.676	72.898
I_3	- 0.996	0.124	12.163	80.703	- 0.948	0.292	11.322	74.650

I_1: freshwater, I_2: industrial saline wastewater and I_3: agricultural sodic drainage water.

The results of the average degree of hysteresis (D_h) pointed out that there is a very slight variation between organic manure treatments, as well a weak variation between irrigation water types for each organic manure treatment. The highest value of (D_h) recorded by using agricultural sodic drainage water (I_2). This trend may be attributed to utilizing of the same soil texture and the effect of low quality water on changing soil aggregates (size and arrangement), porosity, and pore size distribution. Also, Levy *et al.* (2003) and Levy and Mamedov, (2013) confirmed that the soil aggregates wetted with freshwater were more stable because this water reduced the effect of differential swelling on aggregate slaking during its wetting. In additions, soil puddling for rice planting under flooding conditions caused some changes in pore size distribution and porosity of the rice soil. The process of soil puddling usually takes place under water content between field capacity (θ_{FC}) and saturation (θ_{SP}). Therefore, water movement and retention under saturated and unsaturated conditions are extremely affected by puddling. Puddling decreased transmission pores (pores > 30 µm) by about 83% and increased storage pores (pores of 0.6-30 µm) and residual pores (<0.6 µm) by 7% and 52%, respectively (Sharma and De Datta, 1985 and Bakti *et al.* 2010). Destroying non-capillary pores in puddled soil usually decrease water retention for potential above (-0.01 MPa). Thus, an ideal soil profile of a puddled rice soil consists of (1) a muddy layer with a small hardness of water flow (2) a ponded water layer, (3) a compacted cruel layer with a sizable resistance to water flow and (4) non-puddled subsoil with high-saturated conductivity and having an unsaturated flow of water (Gupta *et al.* 1984).

The results of soil pH, salinity, permanent wilting point (PWP), available water (AW), and its relationships are shown in Table (7). It confirmed the aforementioned results of soil moisture curves and hysteresis phenomena. Generally, the irrigating rice soil by (I_2) increases the mean values of all the previous parameters except AW as compared to control (I_1). The decreasing in AW may be due to the increases of both moisture content at FC and PWP because of irrigation water composition. On the other hand, the using of (I_3) decreases the mean values of soil pH at all the treatments and increases the moisture at PWP in all the treatments except M_1 (compost), the mean values of the AW decreases at (I_3M_0) and (I_3M_1) treatments, but it increases in (I_3M_2) and (I_3M_3) treatments by 21.32 and 3.74% respectively, as compared to control (I_1).

Table 7. Some soil parameters of rice soil and hysteresis phenomena at harvest stage.

Treat.	EC† (dSm^{-1})	pH††	θ_{FC} (mass %)	θ_{PWP} (mass %)	AW (mass%)	Area of Hysteresis (A_h)	D_h of Hysteresis
Without adding OM (M_0)							
I_1	1.395	8.61	34.32	20.96	13.36	72.98	1.0253
I_2	3.042	8.85	38.18	26.37	11.81	84.88	1.0361
I_3	4.608	8.30	37.87	25.24	12.63	64.84	1.0170
Rice straw compost (M_1)							
I_1	1.830	8.72	34.96	23.50	11.46	63.65	1.0267
I_2	4.253	8.96	35.79	24.65	11.14	66.36	1.0344
I_3	4.662	8.63	33.34	22.47	10.86	63.17	1.0210
FYM (M_2)							
I_1	1.630	8.65	30.95	24.29	11.63	63.00	1.0169
I_2	3.072	8.90	32.71	25.28	11.78	63.11	1.0323
I_3	4.175	8.51	30.70	25.48	14.11	62.51	1.0195
Rice straw compost + FYM (M_3)							
I_1	1.707	8.59	30.54	25.16	12.84	61.08	1.0185
I_2	3.064	8.80	33.96	27.44	11.54	61.11	1.0282
I_3	4.246	8.56	33.95	27.24	13.32	59.61	1.0195

† in soil paste †† in soil paste extract. I_1: freshwater, I_2: industrial saline wastewater and I_3: agricultural sodic drainage water.

Data in Table (8) illustrate a very strongly positive correlation between (pH, A_h) and (pH, D_h) at all treatments, while, it shows a strong negative correlation between EC and A_h at M_2 (FYM) and M_3 (compost + FYM) treatments.

These results indicate that the high SAR_{Adj} in irrigation water has a negative effect on soil porosity and structure, and hence soil hysteresis phenomena. This explanation of data confirmed with Ayers and Westcot, (1985).

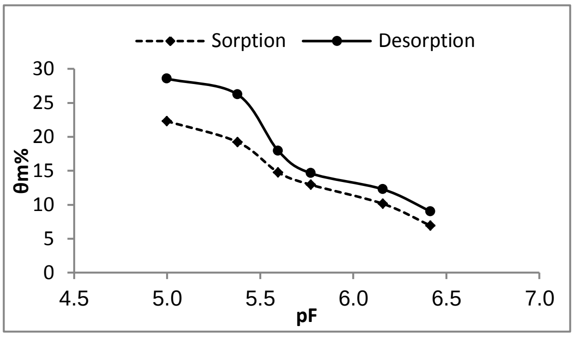

Fig. 15. Hysteresis effect of rice soil for I_1M_0 treatment.

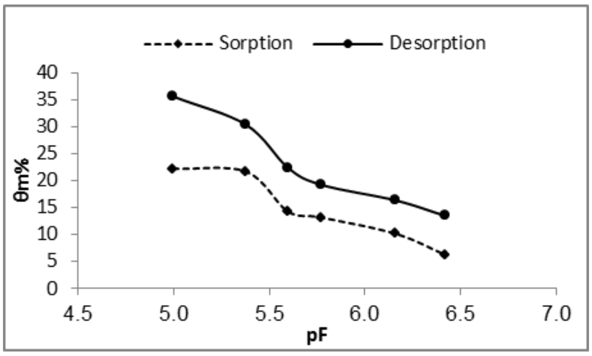

Fig. 16. Hysteresis effect of rice soil for I_2M_0 treatment.

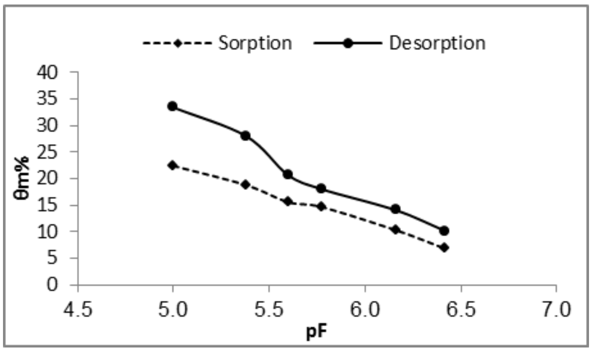

Fig. 17. Hysteresis effect of rice soil for I_3M_0 treatment.

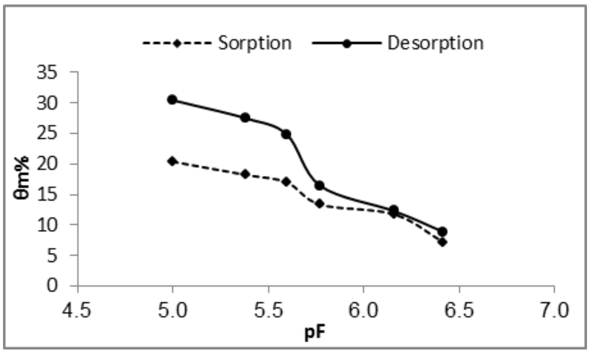

Fig. 18. Hysteresis effect of rice soil for I_1M_1 treatment.

They proved that the increasing Na^+ in irrigation water allows soil dispersion and destroying of its structure, but only if Na^+ exceeds Ca^{+2} by more than a ratio of (3:1). Like a relatively high Na^+ content (>3:1) causes in a severe water permeability problem due to soil dispersion and the pores clogging, associated with the decreasing in water salinity. Furthermore, the θ_{PWP} and θ_{FC} correlated strongly with the soluble salts (EC) of irrigation water at all treatments except rice straw compost treatment M_1.

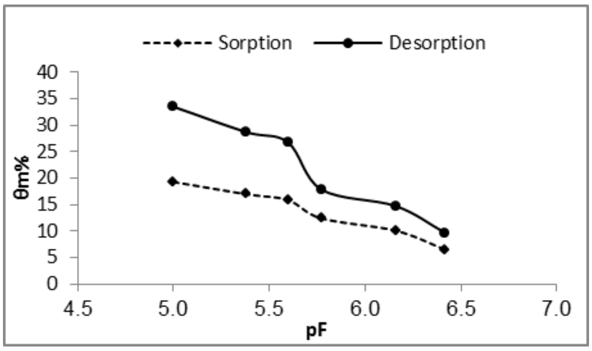

Fig. 19. Hysteresis effect of rice soil for I_2M_1 treatment.

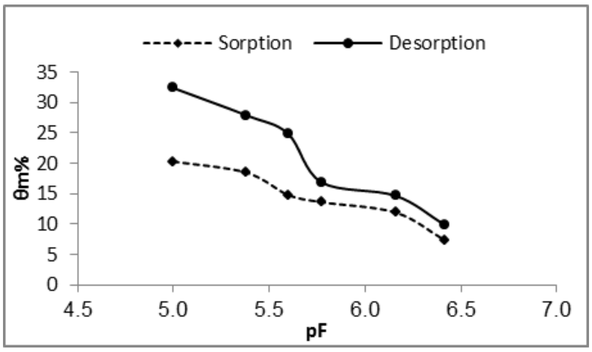

Fig. 20. Hysteresis effect of rice soil for I_3M_1 treatment.

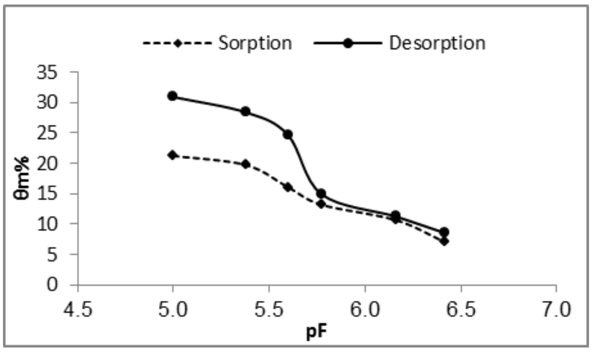

Fig. 21. Hysteresis effect of rice soil for I_1M_2 treatment.

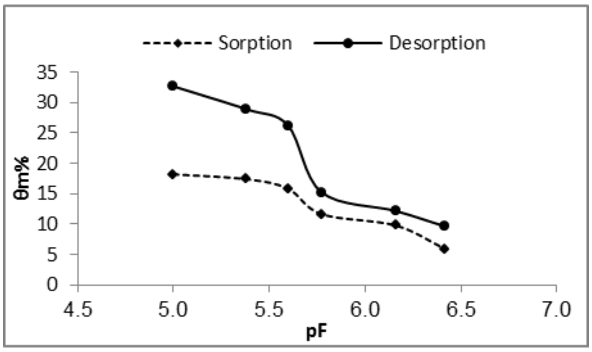

Fig. 22. Hysteresis effect of rice soil for I_2M_2 treatment.

The soil water dynamic alteration was predictable where salinity and sodium are involved. The irrigated soil may have less shrinking and swelling and less drying and wetting and these are both important physical processes for the creation of soil water dynamic and structure (Mamedov, 2014). Generally, the variation in the soil water content percentages under different water suction may be due to one or more of the following factors: (1) irrigation water quality [salinity and sodicity (SAR_{Adj})], (2) soil structure and pore size distribution and (3) quality of organic fertilizers.

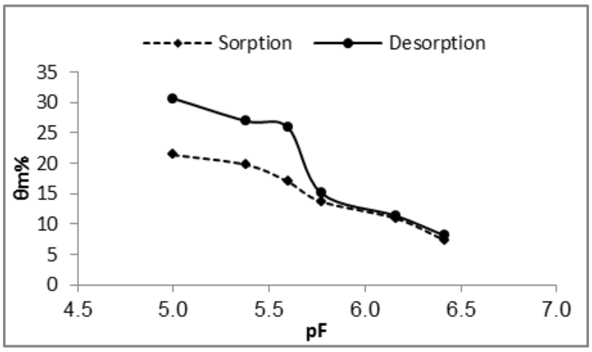

Fig. 23. Hysteresis effect of rice soil for I_3M_2 treatment.

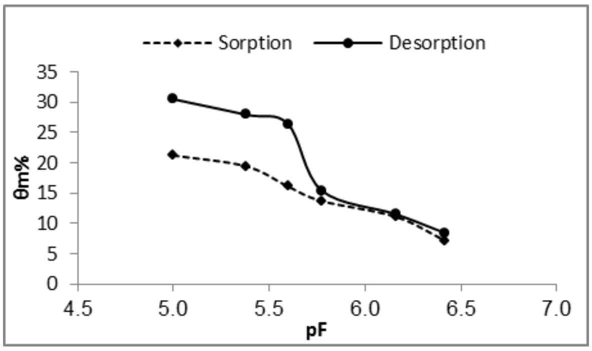

Fig. 24. Hysteresis effect of rice soil for I_1M_3 treatment.

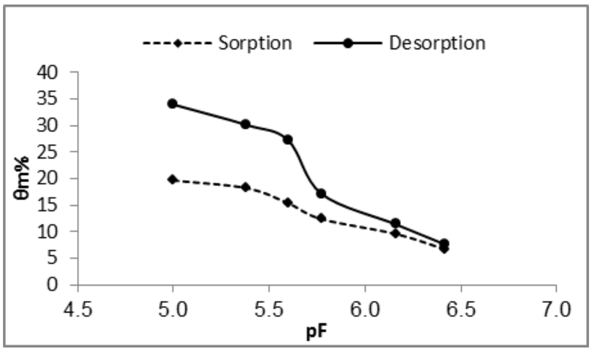

Fig. 25. Hysteresis effect of rice soil for I_2M_3 treatment.

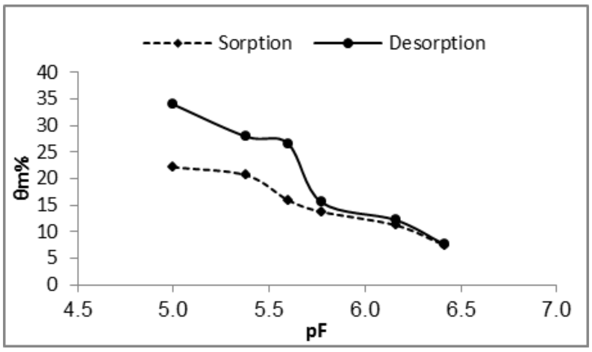

Fig. 26. Hysteresis effect of rice soil for I_3M_3 treatment.

Table 8. The obvious relationships between soil water parameters.

Parameter	Correlation (r)	Regression equation
	Without adding OM (M_0)	
WP & EC	0.76**	$\theta_{WP} = -1.2471EC^2 + 8.8186EC + 11.083$
FC & EC	0.84**	$\theta_{FC} = -0.7923EC^2 + 5.8599EC + 27.688$
pH & A_h	0.98**	$A_h = 42.41pH^2 - 690.89pH + 2877.6$
pH & D_h	0.99**	$D_h = 0.0331pH^2 - 0.5336pH + 3.1629$
	Rice straw compost (M_1)	
WP & EC	-0.10	$\theta_{WP} = -2.0495EC^2 + 12.943EC + 6.679$
FC & EC	-0.31	$\theta_{FC} = -2.2403EC^2 + 13.97 EC + 16.898$
EC & A_h	0.25	$A_h = -3.149EC^2 + 20.274EC + 37.095$
pH & A_h	0.99**	$A_h = 18.056pH^2 - 307.93pH + 1375.9$
pH & D_h	0.99**	$D_h = -0.0947pH^2 + 1.7063pH - 6.6519$
	FYM (M_2)	
WP & EC	0.96**	$\theta_{WP} = -0.1977EC^2 + 1.6124EC + 22.191$
FC & EC	0.96**	$\theta_{FC} = 0.5903EC^2 - 1.9884EC + 37.595$
EC & A_h	-0.72	$A_h = -0.2437EC^2 + 1.2222EC + 61.655$
pH & A_h	0.87**	$A_h = -7.8462pH^2 + 138.14pH - 544.84$
pH & D_h	0.87**	$D_h = 0.2056pH^2 - 3.5461pH + 16.31$
	Rice straw compost + FYM (M_3)	
WP & EC	0.85**	$\theta_{WP} = -0.7286EC^2 + 5.1562EC + 18.484$
FC & EC	0.98**	$\theta_{FC} = 0.2426EC^2 - 0.4354EC + 38.035$
EC & A_h	-0.84**	$A_h = -0.5085EC^2 + 2.4483EC + 58.383$
pH & A_h	0.61*	$A_h = -203.57pH^2 + 3540.2pH – 15329$
pH & D_h	0.98**	$D_h = 0.3313pH^2 - 5.716pH + 25.669$

*** Correlation is significant at the 0.05 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).**

The using of different qualities of irrigation water, organic manures and their interactions significantly influenced the grain and straw yields of rice crop (Table 9). The use of freshwater registered the highest mean values of grain and straw yield of rice crop, followed by the irrigation of agricultural sodic drainage water and finally industrial saline wastewater. The irrigation with industrial saline wastewater caused a decrease in grain and straw yield of rice crop by 49.35 and 21.41% respectively as compared with freshwater. While, the irrigation with agricultural sodic drainage water caused a decrease in grain and straw yield of rice crop by 26.39 and 9.85% respectively, less the control (I_1). The addition of compost + FYM at the proposed doses in this study induced increase in grain yield of about 47.52% over the control (I_1), but the addition of FYM recorded the highest straw yield (34.27%) over the control (I_1). The data of grain yield indicate that the treatment compost + FYM recorded the highest mean values for grain yield 5416 kg fed^{-1} under using of freshwater followed by FYM then compost + FYM under using of agricultural drainage water. Furthermore, the results of straw yield indicate that the treatment FYM which irrigated by freshwater recorded the highest mean values for straw yield (4913 kg fed^{-1}) followed by compost + FYM treatment then the soil which amended with compost + FYM and irrigated by agricultural drainage water. The industrial wastewater had a harmful effect on grain and straw yield, especially without adding organic manures, the treatment compost + FYM was the less harmful treatment for grain and straw yield, which caused a decrease by 45.86 and 17.70% in grain and straw respectively, less the control (I_1). These results agree with the data obtained by Yağdı *et al.* (2000) and Begum *et al.* (2011) where they reported that the toxicity of heavy metals minimized plant growth and its production. Furthermore, the reduction of yield was 30% of rice crop as a result of the irrigating by industrial wastewater (Yongguan *et al*. 2001).

Table 9. Grain and straw yields of rice crop as affected by irrigation water salinity and sodicity and organic manuring.

Treat.	Yield (kg fed^{-1})							
	Grain				Straw			
A: Irrigation (I)								
I_1	4519				4599			
I_2	3326				4146			
I_3	2289				3614			
F - Test	**				**			
LSD 5%	181				91			
B: Manures (M)								
M_0	2782				3446			
M_1	3684				4273			
M_2	2942				4627			
M_3	4104				4133			
F - Test	**				**			
LSD 5%	25				13			
C: Interaction (I×M)								
	M_0	M_1	M_2	M_3	M_0	M_1	M_2	M_3
I_1	4050	4195	4415	5416	3509	4162	4913	4609
I_2	2782	2520	3704	4292	3375	3662	4250	4296
I_3	1508	2111	2604	2932	2453	3556	3655	3793
F - Test	**				**			
LSD 5%	184				92			

CONCLUSION

Sodium (Na^+) content and soluble salt concentrations of irrigation water were found to be two important chemical factors influencing SWCC (sorption and desorption), an indicator of soil water dynamic. It has been found that SWCC generally increased as sodicity (SAR_{Adj}) increased and salinity (EC) decreased. In addition, if drainage removes soluble salts from rice soil that have a SAR_{Adj} greater than (5), the SWCC may increase and thus decreases the rate of water movement and increases hysteresis effect. The increasing of soluble salts and sodium content in the soil as a result of irrigation water qualities and additions of organic manures absorbs a lot of water and increases the osmotic potential (ψ_S) consequently increases the soil water potential (ψ_w) (decreases the energy of soil water) and decreases water availability for the plant. Furthermore, it has a harmful effect on soil porosity and structure. Accordingly, the use of poor quality irrigation water should be considered and adjusted to soil properties and conditions, such as soil salinity, calcium carbonates, sodium content, water holding capacity, and texture. The low quality water might be used in irrigation as long as it was treated with some improvers and adsorbent materials in addition to organic manures. Furthermore, the investigation needs more study, especially the changes in soil water dynamic because of different agricultural practices under variation of soil texture and structure combined with irrigation water types.

REFERENCES

Ammann, A.A. (2007). Inductively coupled plasma mass spectrometry (ICP MS): a versatile tool. J. Mass Spectrom., 42(4):419-427.

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

Bachmann, J. and van der Ploeg R.R. (2002). A review on recent developments in soil water retention theory: interfacial tension and temperature effects. J. Plant Nutr. Soil Sci., 165(4):468-478.

Bakti, L.A.A.; Kirchhof G. and So A.H.B. (2010). Effect of wetting and drying on structural regeneration of puddled soil. Proc. of 19th World Congress of Soil Science, Soil Solutions for Changing World, 1-6 Aug., Brisbane, Australia.

Begum, R.A.; Zaman M.W.; Mondol A.T.M.A.I.; Islam M.S. and Hossain M.F. (2011). Effects of textile industrial waste water and uptake of nutrients on the yield of rice. Bangladesh J. Agric. Res., 36(2):319-331.

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

Carlos, F.S.; Marafon A.J.; Andreazza R.; Anghinoni I.; Tedesco M.J. and Camargo F.A.d.O. (2015). Electrochemical changes and nutrient dynamics in the solution of soil with rice irrigated with treated industrial leachate. Rev. Bras. Ciênc. Solo 39(2):466-474.

Croney, D. and Coleman J.D. (1961). Pore pressure and suction in the soils. Proc. Conf. on Pore Pressure and Suction in Soils, British National Society of the International Society of Soil Mechanics and Foundation Engineering, at the Institution of Civil Engineers, March 30-31, Butterworths, London. UK.

Danielson, R.E. (1980). "Soil Physics Laboratory Manual". Dept. Agron., Colorado State Univ., Fort Collins.

Enas, M. Soliman (2008). Soil fertility and water potential as affected by the quantity additions of some chemical fertilizers. M.Sc. Thesis, Soils Dept., Fac. Agric., Mansoura Univ., Mansoura, Egypt.

Enas, M. Soliman (2013). Water potential and movement of salts and some nutrients in soil. Ph.D. Thesis, Soils Dept., Fac. Agric., Mansoura Univ., Mansoura, Egypt.

Fredland, D.G.; Fredland M.G. and Wilson G.W. (1998). Estimating unsaturated soil properties using a knowledge base systems, Proc. of 2nd Inter. Conf. on Unsaturated Soils, 27-30 Aug., Beijing, China.

Gibbs, P.A.; Chambers B.J.; Chaudri A.M.; McGrath S.P. and Carlton-Smith C.H. (2006). Initial results from long-term field studies at three sites on the effects of heavy metal-amended liquid sludges on soil microbial activity. Soil Use Manag., 22(2):180-187.

Girdhar, I.K. (1988). Effect of saline irrigation water on the growth, yield and chemical composition of rice crop in a saline soil. J. Indian Soc. Soil. Sci., 36(2):324-329.

Gupta, R.; Kumar P.S. and Singh T. (1984). Soil management to increase crop production. A Consolidated Report 1967-82. ICAR, New Delhi.

Hammad, S.A. (1985). Water potential and salts movement in soils. Ph.D. Thesis, Fac. Soils, Moscow Univ., Moscow, Soviet Union.

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

He, Y.; DeSutter T.; Casey F.; Clay D.; Franzen D. and Steele D. (2015). Field capacity water as influenced by Na and EC: Implications for subsurface drainage. Geoderma 245-246:83-88.

Hesse, P.R. (1971). "A Textbook of Soil Chemical Analysis". John Murry Ltd., 50 Albermarle St., London, UK.

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

Hillel, D. (2004). "Introduction to Environmental Soil Physics". Academic Press, Elsevier Science, USA.

Jeong, H.; Jang T.; Seong C. and Park S. (2014). Assessing nitrogen fertilizer rates and split applications using the DSSAT model for rice irrigated with urban wastewater. Agric. Water Manag., 141:1-9.

Le Bissonnais, Y. (2016). Aggregate stability and assessment of soil crustability and erodibility: I. Theory and methodology. Eur. J. Soil Sci., 67(1):11-21.

Levy, G.J. and Mamedov A.I. (2013). Soil susceptibility to deformation in different agricultural management practices: assessment from water retention curve characteristics at low suction. Catena Verlag, Advances in Geoecology 42:129-147.

Levy, G.J.; Mamedov A.I. and Goldstein D. (2003). Sodicity and water quality effects on slaking of aggregates from semi-arid soils. Soil Sci., 168(8):552-562.

Lu, N. and Khorshidi M. (2015). Mechanisms for soil-water retention and hysteresis at high suction range. J. Geotech. Geoenviron. Eng., 141(8):1-10.

Mamedov, A.I. (2014). Soil water retention and structure stability as affected by water quality. Eurasian J. Soil Sci., 3(2):89-94.

Maqsoud, A.; Bussiere B.; Mbonimpa M. and Aubertin M. (2004). Hysteresis on the water retention curve: A comparison between laboratory results and predictive models. 8-15 p. Proc. 57th Can. Geotech. Conf. and the 5th joint CGS-IAH Conf. 24-27 Oct., Québec City. The Canadian Geotechnical Soc., Richmond, BC.

National Academy of Sciences and National Academy of Engineering (1972). Water quality criteria report. US Environmental Protection Agency, Washington D.C.

Panse, V.G. and Sukhatme P.V. (1985). "Statistical Methods for Agricultural Workers". ICAR Publications, New Delhi. India.

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

Pratt, P.F. (1972). "Quality Criteria for Trace Elements in Irrigation Waters". California Agri., Exteriment Station. Univ., California, USA.

Ragab, A.A.M. (2000). Physical properties of some Egyptian soils. Ph.D. Thesis, Soils Dept., Fac. Agric. Cairo Univ., Giza, Egypt.

Rhoades, J.D.; Kandiah A. and Mashali A.M. (1992). "The Use of Saline Waters for Crop Production". FAO irrigation and drainage papers No. 48. Rome, Italy.

Richards, B.G. (1965). "Measurement of the Free Energy of Soil Moisture by the Psychrometric Technique Using Thermistors", Buttersworth & Company (Australia) Limited.

Rumynin, V.G. (2011). "Subsurface Solute Transport Models and Case Histories". Springer, New York.

Schofield, R. K. and Botelho Da Costa J.V. (1935). The determination of the pF at permanent wilting and at the moisture equivalent by the freezing point method. Trans. 3rd Inter. Congr. Soil Sci., 6-10 p. 30 july-7 Aug., Oxford, England,.

Scott, C.A.; Faruqui N.I. and Raschid-Sally L. (2004). Waste water use in irrigated agriculture: Management challenges in developing countries. 1-10 p. In Scott *et al.*, (ed.) "Wastewater Use in Irrigated Agriculture: Confronting the Livelihood and Environmental Realities". CABI Publishing, Wallingford, UK.

Sharma, P.K. and De Datta S.K. (1985). Puddling influence on soil, rice development and yield. Soil Sci. Soc. Am. J., 49(6):1451-1457.

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

Tedeschi, A. and Dell'Aquila R. (2005). Effects of irrigation with saline waters, at different concentrations, on soil physical and chemical characteristics. Agric. Water Manag., 77(1-3):308-322.

Timlin, D.; Pachepsky Y.; Walthall C. and Loechel S. (2001). The use of a water budget model and yield maps to characterize water availability in a landscape. Soil Tillage Res., 58(3):219-231.

US Salinity Laboratory Staff (1954). "Diagnosis and Improvement of Saline and Alkali Soils". US Dept., Agric. Handbook 60, Washington, D.C. USA.

Warrick, A.W. (2002). "Soil Physics Companion". CRC Press LLC.

Yağdı, K.; Kaçar O. and Azkan N. (2000). Heavy metal contamination in soils and its effects in agriculture. Ondokuz Mayıs Üniversitesi, Ziraat Fakültesi Dergisi 15(2):109-115.

Yongguan, C.; Seip H.M. and Vennemo H. (2001). The environmental cost of water pollution in Chongqing, China. Environ. Dev. Econ., 6(3):313-333.

تغيرات الشد الرطوبي في أرض الأرز المسمدة بالأسمدة العضوية والمروية بمياه ملحية وصودية

إيناس مصطفى سليمان
قسم الأراضي ـ كلية الزراعة ـ جامعة المنصورة ـ المنصورة ـ مصر

يلعب تقييم آثار جودة مياه الري، على صفات الشد الرطوبي بالتربة وثبات الحبيبات المُركبة في المناطق القاحلة مثل مصر، دورًا حيويًا في تطوير ممارسات صيانة وإدارة التربة وكفاءة استخدام مياه الري. لذلك أجريت دراسة حقلية لتقييم آثار ملوحة وصودية مياه الري والتسميد العضوي على الجهد الرطوبي بالتربة باعتباره أهم عامل مُحدد لإنتاجية المحاصيل. واشتملت الدراسة علي إثنا عشر معاملة تمثل كل احتمالات التفاعل بين ثلاثة أنواع من مياه الري مختلفة في ملوحتها (EC) وصوديتها (SAR_{Adj}) وهي: مياه الصرف الصناعي غير المعالجة، مياه الصرف الزراعي، والمياه العذبة مع ثلاثة أنواع من الأسمدة العضوية هي: كمبوست قش الارز بمعدل 2 طن ف$^{-1}$، سماد بلدي بمعدل 5 طن ف$^{-1}$، كمبوست قش الأرز بمعدل 2 طن ف$^{-1}$ + سماد بلدي بمعدل 5 طن ف$^{-1}$ بجانب معاملة الكنترول. وقد تبين من نتائج الدراسة أن كل المعاملات تحت الدراسة عدلت من شكل منحنيات الشد الرطوبي (الترطيب والتجفيف) وكان لها تأثير كبير علي ثبات الحبيبات المُركبة وفقًا لظاهرة عدم الارتداد. أيضا كان لاختلاف جودة مياه الري تأثير قوي في تغيير خصائص التربة، خاصة مياه الصرف الزراعي الصودية (عالية SAR_{Adj}) ثم مياه الصرف الصناعي الملحية (عالية EC). بالإضافة إلى ذلك، اتضح أن خلط كمبوست قش الأرز مع السماد البلدي بالمُعدلات المقترحة في الدراسة يُحسن معايير الجهد الرطوبي للتربة المُروية بمياه ذات نوعية رديئة.