Magnetically Treated Brackish Water New Approach for Mitigation Salinity Stress on Sunflower Productivity and Soil Properties under South Sinai Region, Egypt

Mahmoud H. Mahmoud[1], Sahar M. Ismail[2]; Amany A. Abd El-Monem[3] and Mohamed A. Elal Darwish[4]

ABSTRACT

Application of low quality irrigation water is compulsive in facing water scarcity. Magnetized water is an attractive approach to overcome this challenge as considered eco-friendly physical pretreatment of brackish water. The objectives of this study are to: i) Investigate and compare the effect of two different magnetic intensities for treating brackish water to alleviate water and soil salinity stresses on sunflower growth, yield production under constructed gated pipe and drip irrigation systems, and ii) Determine the changes in soil properties due to the application the magnetically treated brackish water in Ras-Sedr, South Sinai Governorate. The study was conducted at the Agricultural Experimental Station of Desert Research Centre, Research Station of Ras-Sedr region, Egypt. Two magnetized-brackish water (BW^1; with magnet gauss strength of 1200 and BW^2; with magnet gauss strength of 3850) and untreated brackish water were applied under gated pipe and drip irrigation systems. The two tested factors were laid out in split-plot design with three replications where the two irrigation systems and the three irrigation water-treatments were allocated in main and sub-plots, respectively. The results showed that concentration of soil soluble cations (Ca^{2+}, Mg^{2+}, K^+ and Na^+) and anions (Cl^-, HCO_3^- and SO_4^{2-}) at soil depths of 0–30, 30–60 cm was decreased when the soil treated by magnetized water compared to control and more decreasing occurred with higher magnetic strength. Also, the results showed that, the soil concentrations of available N, P, K as well as CEC, SAR, $CaCO_3$, bulk density and available micro-element contents in the magnetized-water treated soil were lower than those with non-magnetized irrigation water treatment at the two depths. Soil surface samples were investigated using Energy Dispersive X-ray spectral (EDX) and Scan electron microscope (SEM) images and specific surface area (SSA) analysis to identify the particular elements and their relation proportion for soil aggregations. Magnetized water treated-soil gave higher soil aggregations than control. Irrigation of sunflower plants with magnetically treated brackish-water under gated or drip irrigation systems led to improved Chlorophyll concentrations, accumulated dry matter in plant organs and macro-element contents in leaves at 60 DAS. The changes of dry weight in stem and leaf and plant height were significant ($LSD_{0.05}$). Seed and oil yield (%) also were improved significantly compared to the irrigation with BW under both irrigation systems. Average N, K and Ca contents in sunflower leaves increased with magnetized-BW^2 treatment under the both irrigation systems compared to those in BW^1 and control treatments. Plant height and plant seed and oil yields were significantly increased with both magnetized water treatments. It can be conclude that the irrigation with magnetized water could be a promising technique in the agriculture with soil and water under salt stress conditions using gated pipe or drip irrigation systems.

Key words: Magnetized water, brackish water, drip irrigation, gated irrigation, sunflower, soil characteristics, Ras-Sidr, seed and oil production.

INTRODUCTION

The agricultural crops commonly face different types of biotic and abiotic stresses. Among abiotic stresses, salinity is considered a widespread phenomenon in arid and semi-arid regions. Farmers face

---

DOI: 10.21608/asejaiqjsae.2019.50351

[1]Field Crops Research Department, Agricultural and Biological Research Division, National Research Center, 33 El Behouth St., (Former El-Tahrir St.) 12622 Dokki, Giza, Egypt.
E-mail: m_hozien4@yahoo.com
[2] Soil physics and chemistry Department, Water Resources and Desert Soils Division, Desert Research Center, 1 El-Mataria St., Cairo, Egypt. Email: dr.sahar.mohamedi@gmail.com
[3]Botany Department, Agricultural and Biological Research Division, National Research Center, 33 El Behouth St., (Former El-Tahrir St.) 2622 Dokki, Giza, Egypt. Email: amany.gouda5@yahoo.com
[4]Fertilizer Department, Agricultural and Biological Research Division, National Research Center, 33 El-Behouth St., (Former El-Tahrir St.) 12622 Dokki, Giza, Egypt. Email: madarwishnrc@yahoo.com

Received August 12, 2019, Accepted September 26, 2019

dwindling supplies of good quality water for irrigation and are forced to use low quality groundwater (Mostafazadeh-Fard, et al., 2009) and thus efficient use of available water resources including recycled water of low or medium salinity for irrigation is important. High soil and/or water salinity has adverse effects on the soil properties and agricultural production represented in severely deteriorates the soil physiochemical properties by destroying of the soil aggregates and structure (Loveland, et al., 1987). Therefore, Salinity is considered as the major environmental factor that prevents crops from realization their full yield potential. Therefore, new technologies are needed to reduce the rate of salt accumulation and improve the leaching of salts below the root zone of salt-sensitive agricultural crops as well as to conserve both the quantity and quality of water and considered as appropriate strategies have to be developed to avoid risk facing future water supplies. Magnetic treatment of saline irrigation water (MWT) is considered one of the most important and influential strategies for reducing of salt accumulation, economic, safe and promises to improve soil and water properties, which is reflected in improving crop productivity. This MWT application decreases the hydration of salt ions and colloids, having a positive effect on salt solubility, accelerated coagulation and salt crystallization and lowering of pH values, and dissolving of slightly soluble components such as phosphates, carbonates and sulfates (Hilai, 2000)**.** Moreover, the magnetic field interacts with the surface charges of particles in the fluid solutions, affecting the crystallization and precipitation of the solids. These processes are reported to effect the translocation of minerals in irrigated soil (Noran, et al., 1996) and also induced changes in mobility of nutrient elements in the root zone and make changes in the solubility of some soil components such as $CaCO_3$ and gypsum (Selim, 2008)**.** The magnetic effect causes the large aggregate water cluster becomes into smaller particles, making both water and nutrients more accessible to plants (Zhou et, 2000; Zhou, et al., 2008 and Zhou, et al., 2011). Many studies also reported that the use of magnetic technology have a positive effect on the germination, growth, maturity and productivity of different crops (Hozayn et al, 2016b). This is through its impact on processes of plant physiology (i.e., protein biosynthesis, cell reproduction, photochemical activity, respiration rate, enzyme activities, nucleic acid content, etc ...) as reported by Aladjadjiyan (2002); Vashisth, *et al.* (2010); Sadeghipour, *et al.* (2013); El-Sayed, *et al*. (2014) and Alderfasi, *et al.* (2016). From these studies, it appears that the influence of magnetically treated water depends upon the plant species, the pathway length in the magnetic field, and the water flow rate (Gabrielli et al, 2001)**.** Under Egyptian condition (Hozayn, et al., 2011; Hozayn, et al., 2013; Hozayn, et al., 2014; Hozayn, et al., 2015 and), it was reported by (Hozayn, et al., 2016a; and Hozayn, et al., 2016 b) that irrigation with magnetized water showed to improve the growth, metabolism, quality and productivity of tested crops (i.e., wheat, barley and maize, faba bean, lentil, chickpea, ground nut, mungbean, sunflower, canola, flax, sugar beet and potato). These increases ranged from 8.25 to 42.0%. Therefore, the main objectives of this study were to: i) Investigate the impact of two different of magnetic intensities for treating brackish water to alleviate water and soil salinity stresses on sunflower growth, yield production under constructed gated pipe and drip irrigation systems, and ii) Determine the changes in soil properties due to the application the magnetically treated brackish water in Ras-Sedr region, South Sinai Governorate.

MATERIALS AND METHODS

A field trial using sunflower (*Helianthus annuus* L.; Var., Sakha-53) was conducted at Agricultural Experimental Station of Desert Research Centre, Ras Sidr province, South Sinai Governorate, Egypt during summer season of 2017. The experimental area is located on the Gulf of Suez and the Red Sea coast (29º60'28" N latitude and 32º68'96" E longitude). It has a desert climate and the average annual temperature and rainfall in Ras-Sidr is 22.2 °C and 15 mm, respectively. The source of irrigation water is well. The investigated soil and irrigation water were analyzed before treatments applying according to Page *et al.,* (1982). Table (1) reveals that the soil of the experimental area was sandy loam, saline and poor in NPK and organic matter. Also, irrigation water was saline.

Treatments and cultivation methods: The tested treatments included two irrigation systems (gated and drip) and three irrigation water treatments [i) Brackish-water (BW), ii) Magnetic-BW^1; brackish water after magnetization by passing a water through three inch permanent static magnetic unit, 3850 Gauss (Delta Water Company, Industrial Zone-1, Alexandria, Egypt) and iii) Magnetic-BW^2; brackish water after magnetization by passing a water through three inch permanent static magnetic unit, 1200 Gauss (Magnetic-Technologies Company LLC PO Box 27559, Dubai, UAE). The two tested factors were laid out in split-plot design with three replications, where the two irrigation systems and the three irrigation water-treatments were allocated in main and sub-main plots, respectively. The soil was ploughed twice, ridged at 0.60 meter apart and divided into main and sub-main plots with an area of (15 m width x 4 m long) and (5 m width x 4m long), respectively. During seed bed preparation, 150 kg fed^{-1} superphosphate fertilizer (15.5% P_2O_5) was applied. Recommended rates of sunflower seeds (5 Kg fed^{-1};

Var., Sakha-53; obtained from Oil Research Department, Field Crop Research Institute, Agriculture Research Centre, Giza, Egypt) were sown in hills 20 cm apart at the third week of July, 2017. Gated pipe and drip irrigation started immediately after sowing and as plants needed during the period of experiment. Thinning was carried out after 21 days from sowing to secure one plants per hill on one side of the ridge. Nitrogen fertilizer as ammonium sulfate (20.60 N%) at the rate (45 kg N fed^{-1}) was added in four equal doses starting from 15 days after sowing till flowering. Potassium fertilizer at the rate of 50 kg fed^{-1} as potassium sulfate (48 % K_2O) was added after one month from sowing. The recommended agricultural practices for sowing sunflower was conducted according leaflet Agriculture Research Centre under this province conditions. The experimental layout is shown in Fig. 1.

Table 1. Mechanical, Chemical and physical analysis of soil and irrigation water before sowing

Parameter	Soil depth (cm) 0-30	Soil depth (cm) 30-60	Irrigation water
Soil physical properties			
Bulk density, g/cm^3	1.26	1.30	-
Particle size distribution			
Sand (%)	81.28	86.08	..
Clay (%)	10.67	6.33	..
Silt (%)	8.05	7.59	..
Texture	Sandy loam	-	..
Soil chemical properties			
pH (soil paste)	7.66	7.00	8.60
EC (dSm^{-1})	8.65	7.90	9.68
Organic matter (%)	1.70	1.23	-
Water soluble cations (mq/L) in soil extract			
Ca^{2+}	38.22	30.82	23.54
Mg^{2+}	27.44	22.00	24.48
Na^{+}	58.33	65.80	40.05
K^{+}	2.01	0.08	0.14
SAR	10.18	12.80	8.17
Water soluble anions (mq/L) in soil extract			
CO_3^{2-}	0.00	0.00	0.00
HCO_3^{-}	3.44	2.00	4.50
SO_4^{2-}	58.93	65.20	29.23
Cl^{-}	64.14	51.50	48.94

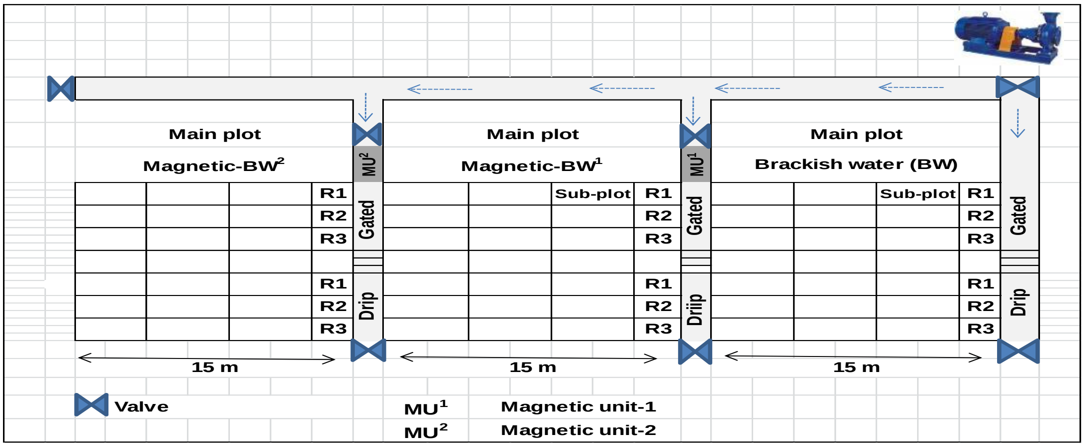

Fig.1. Layout and design of experiment

Data recorded:

Growth parameters: 60 days after sowing, ten plants were randomly taken from each plot to record plant height (cm), number of leaves/plant, accumulated dry matter of leaves, stem and the whole plant (g $plant^{-1}$).

Total Chlorophyll: Total Chlorophyll in leaves was determined using SPAD Chlorophyll meter (Chapman and Pratt, 1978).

Macro-elements contents in leaves: Macro-elements contents in dry leaves were determined according to Chapman and Pratt (1978). Total N content was determined by using Micro-Kjeldahl method. Potassium, calcium and sodium concentrations were determined using flame photometer (Genway model 3031) according to Sparks, 1996.

Yield and its components: At harvest date; the third week of October,2017; a random sample of ten plants was taken from each experimental unit to determine plant height (cm), head diameter (cm), head weight (g), head seed weight (g) and 100-seeds weight (g). Plants in the three inner ridges were harvested and their heads were air dried and threshed to calculate seed yield fed^{-1}.

Seed oil: Seed oil percentage was determined using Soxthelt apparatus according to AOAC (Jones, 2000) and oil yield kg fed^{-1} was calculated by multiplying seed yield by seed oil percentage.

Soil analysis: Field soil surface and subsurface samples at two depths (0 – 30 and 30 – 60 cm) were collected for analyses before and after the applied treatments (at harvest), air dried, passed through 2 mm sieve and analyzed for soil characteristics (pH, EC, concentrations of Na^+, Ca^{2+}, Mg^{2+}, K^+, Cl-, SO_4^{2-}, HCO_3^-, CEC, bulk density, $CaCO_3$, macro- and micro-nutrients) was determined according to standard methods (Konica Mo. 2012). The surface layers of studied soil from each treatment were characterized by SEM-EDX instrument (SEM, FEI NOVA NANO 450). The soil surface layers in the all treatments subjected to Transition Electron Microscope (TEM) image and Energy Dispersive X-ray (EDX) analysis to find the dimension of soil aggregates and to determine the elemental composition. Total soil surface area was also determined using the nitrogen adsorption isotherm and EBT approach (Brunauer, et al., 1938).

Data analysis: Data were statistically analyzed using F-test (Jones, 1955) and the least significant difference ($LSD_{5\%}$) test was used to compare among the means.

RESULTS

1- Influence of magnetic intensity on irrigation water quality:

The values of pH and EC of different irrigation water treatments before and after magnetic treatment are presented in Table 2. Magnetic treatment of brackish water led to reduce EC of all treatments and also a definite trend of decrease in pH values was noticed for all treatments. Concentrations of Cl^-, SO_4^{2+}, Na^+, Ca^{2+} and Mg^{2+}, were found to be higher in the brackish water (Table 1) and their concentrations were significantly decreased by affecting magnetic treatments (p 0.05).

Table 2. Analyses Irrigation water before and after applying of magnetized water treatments

Parameters	Brackish water (BW)	Magnetized-BW[1]	Magnetized-BW[2]
pH	8.60a	7.45b	6.82c
EC (dSm^{-1})	9.68b	8.32c	7.44d
Water soluble cations, meq L^{-1}			
Ca^{++}	30.54a	25.22b	22.34d
Mg^{++}	24.48b	22.53bc	20.64d
Na^+	40.05a	34.68c	31.48e
K^+	2.14b	2.02c	1.83f
SAR#	7.64a	7.11c	6.80f
Water soluble anions, meq L^{-1}			
CO_3^{--}	0.00	0.00	0.00
HCO_3^-	4.50bc	3.20cd	2.60e
SO_4^{--}	42.87ab	38.26c	33.41ef
Cl^-	48.94b	43.32d	39.24e

SAR = $Na^+/\sqrt{(Ca + Mg)/2}$

Note: Means in the same water treatment and same soil layer followed by the same letters (a, b, c, d, e, f) are significantly different (*P*>0.05) according to a protected LSD test.

The reduction in EC (8.32 and 7.44 dSm^{-1}), pH (7.45 and 6.82) and SAR (7.11 and 6.80) was noticed when the brackish water was exposed to magnetized-BW^1 and magnetized-BW^2 treatments, respectively, with compared to the control.

2- Influence of magnetized water treatments on soil properties after plant harvest under gated and drip irrigation systems:

a. Effect on soil ECe and soluble ions:

Application of magnetic brackish water and irrigation systems played an active role in improving of salt movement and leaching process. The EC (soil paste) was significantly (P> 0.05) and decreased by both magnetic treatments under the both irrigation systems compared with irrigated by non-magnetized water (Table 3). The data illustrated that significantly (P> 0.05) higher removal of salts was observed in gated irrigation system than those in drip irrigation system for both soil surface (00-30 cm) and subsurface layers (30-60 cm). However, EC was not significantly different in the two the depths (0–30 and 30–60 cm) using Magnetic-BW^2 treatment referred to stronger tension of magnetic field. As seen in Table 3, it is clear that the soil surface and sub-surface layers, Magnetic-BW^2 treatment was more effective on the decrease of soluble cation concentrations under the gated and drip irrigation systems, but there were significantly decrease in soluble cation concentrations under the gated irrigation system.

b. Effect on soil pH:

The results revealed that the soil pH of the soil surface layer (0 – 30 cm) decreased from 7.65 (for BW) to 7.40 and 7.12 after applying the magnetized-BW^1 and magnetized-BW^2 treatments, respectively, under gated irrigation system and this decrease was more than that in the drip irrigation system (7.52 and 7.35), respectively . The same trend was observed in the soil subsurface layer with the both two magnetized water treatments and irrigation systems (Table 3).

Table 3. Characteristics of soil samples that affected by brackish water and static-magnetic treatment of brackish water after sunflower harvest

Treatment		pH*	ECe*	Soluble cations and anions (meq/l)						
Irrigation system	Water treatment		(dS/m)	Ca^{++}	Mg^{++}	Na^+	K^+	Cl^-	HCo_3^-	$SO4^{--}$
		Depth, 0 - 30 cm								
Gated	Brackish water (BW)	7.65	8.25	16.30a	15.20b	50.21c	3.88b	45.22a	26.35bc	12.66
	Magnetized-BW^1	7.40	7.26	14.20b	13.30c	38.99bc	1.15d	43.22ab	19.60e	11.24
	Magnetized-BW^2	7.12	5.32	12.30bc	11.30e	24.15d	0.99f	31.55e	13.60f	10.50b
Drip	Brackish water (BW)	7.78	9.38	24.60a	14.10a	50.90b	3.02a	54.66ab	34.90a	7.43e
	Magnetized-BW^1	7.52	8.48	22.20c	13.60b	44.66e	2.84bc	45.92a	31.20b	10.04bc
	Magnetized-BW^2	7.35	7.32	22.60c	11.20c	46.30c	2.21c	41.55d	24.50c	8.45c
		Depth, 30 - 60 cm								
Gated	Brackish water (BW)	7.63	9.67	26.60a	22.45a	44.28b	3.15bc	54.60b	38.10a	5.65ab
	Magnetized-BW^1	7.42	7.62	20.52c	18.35b	40.66d	3.02c	44.66cd	28.40bc	4.42b
	Magnetized-BW^2	7.25	6.34	21.10cd	14.00d	39.60d	2.33b	36.20e	24.20c	3.65bc
Drip	Brackish water (BW)	8.11	8.14	22.60b	19.10a	40.20a	2.54ab	42.20b	35.30ab	4.12c
	Magnetized-BW^1	7.76	7.43	21.20bc	16.00c	38.65b	2.15b	40.12c	32.65c	3.28d
	Magnetized-BW^2	7.53	6.39	20.10e	13.30e	27.22c	2.41c	36.00f	25.20e	2.84f

*ECe and pH were determined in soil paste extract.

Note: Means in water treatments and different irrigation systems followed by the same letters (a, b, c, d, e, f) are significantly different (*P*>0.05) according to a protected LSD test.

c. Effect on Sodium Adsorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP):

Table 4 showed that SAR values were higher reduced in the soil subsurface layers than those in the soil surface layers treated by the two magnetized brackish water treatments under the two irrigation systems compared to non-magnetized treated water (brackish water). The soil ESP-SAR relationship equation can provide an easy, economic and brief methodology to estimate soil ESP. Estimation of ESP from the SAR of the saturated paste extract would be useful for characterization of sodic soils and provide information relative to their reclamation (Table 4).

d.Effect on Cation Exchange Capacity (CEC):

Table (4) shows that CEC can change with depth and magnetized water treatments where soil surface and sub-surface layers under the applied gated irrigation system had higher CEC for magnetized-BW^1 and magnetized-BW^2 treatments than those in applied drip irrigation system. But in any case, the CEC increasing was higher in the magnetized-BW^2 treatment in the two depths and under the two irrigation systems. It is clear that intensity of magnetic field and type of applied irrigation system played an important role in increasing of cation exchange capacity (CEC).

e. Effect on soil total calcium carbonate and bulk density:

As shown in Table 4, there was a decrease in the soil total calcium carbonate percent in soil (two depths) treated by magnetized water compared to control. Table (4) showed higher decrease in the total calcium carbonate of the soil surface and subsurface layers treated by magnetized-BW^2 treatment than that treated by magnetized-BW^1 treatment under the applied two irrigation systems. Therefore, both magnetized water treatments appeared higher decreasing rate values of total calcium carbonate under the applied gated irrigation system than those under drip irrigation system for the soil surface layer. The correlation of MTW with Soil bulk density was found. It cited by the data in the Table (4) insignificantly decrease in the soil bulk density and ranged from 1.41 to 1.29 g/cm^3 in the all treatments.

f. Effect of the macro-nutrients (N, P and K) contents in soils

The results in Table 5 revealed the effect of MTW on the soil macro nutrient levels after the harvest of sunflower plants. In general, low concentrations of available soil N for all treatments is found and it decreased with the both depths. Whereas, the concentration of P was significantly varied between the two depths. MTW increased available soil P contents at the two soil depths.

Table 4. Values of soil Cation Exchangeable Capacity (CEC), Sodium Adsorption Ratio (SAR) and calculated Exchangeable Sodium Percent (ESP) affected by magnetic treatments under two irrigation systems

Treatment		CEC, mole kg^{-1}soil	SAR*	ESP**	$CaCO_3$ (%)	Bulk density (g/cm^3)
Irrigation System	Water treatment		Depth, 0 – 30 cm			
Gated	Brackish water (BW)	38.50b	12.65ab	14.98a	18.33a	1.35a
	Magnetized-BW^1	42.00c	10.51b	12.77b	17.32ab	1.34a
	Magnetized-BW^2	48.20e	7.04e	9.20d	15.22c	1.32ab
Drip	Brackish water (BW)	41.36a	11.57b	13.86ab	19.32a	1.41b
	Magnetized-BW^1	43.12bc	10.55c	12.81a	18.58a	1.39ab
	Magnetized-BW^2	43.60c	11.27a	13.56b	17.22b	1.38bc
			Depth, 30 – 60 cm			
Gated	Brackish water (BW)	40.20b	8.94ab	11.16a	17.11b	1.31a
	Magnetized-BW^1	45.80c	9.26ab	11.48a	15.32bc	1.30a
	Magnetized-BW^2	49.00e	9.45c	11.68a	14.21c	1.29b
Drip	Brackish water (BW)	39.32c	8.81b	11.02a	18.33a	1.35b
	Magnetized-BW^1	43.80b	8.97c	11.19a	17.11ab	1.34b
	Magnetized-BW^2	46.30d	6.67f	8.82c	16.22c	1.32d

*SAR: Sodium Adsorption Ratio: $Na^+ / \sqrt{(Ca + Mg)/2}$ **ESP: calculated by equation 1.95 + 1.03 SAR (Mohsen, 2009).

Note: Means in water treatments and different irrigation systems followed by the same letters (a, b, c, d, e, f) are significantly different (*P*>0.05) according to a protected LSD test.

The increasing of available P was higher in the soil surface layers than that in the sub-surface layers under the two applied irrigation systems. An increase observed in soil available K, particularly under magnetically treated brackish water and appears to have played some role in improving salt tolerance sunflower plants.

g. Soil Available micro-nutrients (Fe, Mn, Zn and Cu) in soils:

MTW had positive effect on the availability of soil Fe, Mn and Zn after the harvest of sunflower plants (Table 5). This means that magnetically treated water significantly increases ($P > 0.05$) nutrient mobility in soil and enhances extraction and uptake by sunflower plants, but magnetic-BW^2 treatment was more efficient in the enhancement than magnetic-BW^1 treatment. As for Zn, there is clear that trend to not significantly increase in the treatments confirming occurrence high solubility of phosphate under the influence of the magnetic treatments, connected with Zn and formed as zinc phosphate. It showed clearly influence of the magnetic treatment on the increase in solubility of zinc phosphate. For Cu, its concentrations are negligible in the all treatments, but it observed that decrease of Cu concentration in the soils treated by magnetized water compared to control. This means that magnetically treated water increases nutrient mobility in soil and enhances extraction and uptake by sunflower plants.

h.EDX Spectral and SEM image analysis under gated irrigation system:

Soil surface layer samples were investigated using SEM/EDX. The main observations by optical microscopy and mainly SEM of soil aggregates are illustrated in Fig. 2 for the soil irrigated by brackish water, magnetic-BW^1 and magnetic-BW^2 under applied gated irrigation system. It reveals that circular disc-shaped micro crystals of $CaCO_3$ deteriorate slowly by a solid state transformation into bundles of $CaCO_3$ needles called aragonite in the case of soil treated by magnetized water treatments, whereas in control this transformation seems to be partial. The length of these crystals is bigger for both magnetized water compared to control treatment (Fig.2). In particular, under the applied gated irrigation system, the soil treated by brackish water (BW) treatment as observed by SEM image had variable soil miro-aggregate sizes (23.86 - 377.0 µm), soil treated by magnetic-BW^1 treatment had variable aggregate sizes (74.04 – 214.5 µm) and soil treated by magnetic-BW^2 were 64.81 – 376.4 µm.

This means that there has been an increase in size of soil aggregates when treated by magnetized water compared to the soil treated by brackish water. There are no significant differences between the two magnetically treated water treatments. On these soil aggregates, it observed by SEM images small crystallite forms (Fig. 2). As shown in Figure 3, SEM/EDX analysis revealed mainly oxygen, calcium, silicon and carbon.

Table 5. Soil available Nutrient (mg kg^{-1}) concentrations at the two depths affected by the two magnetized water treatments under the gated pipe and drip irrigation systems

Treatment		Available Nutrients (ppm)						
Irrigation system	**Treatment**	**N**	**P**	**K**	**Fe**	**Mn**	**Zn**	**Cu**
				00 – 30 cm				
Gated	Brackish water (BW)	3.20a	8.40e	52.00a	2.15a	2.65a	0.94b	0.55a
	Magnetic-BW^1	3.32a	11.20b	57.00b	2.66b	2.70a	0.93b	0.36c
	Magnetic-BW^2	3.60a	13.20d	62.00c	1.62d	1.52c	1.24c	0.54a
Drip	Brackish water (BW)	2.60c	6.80f	62.50a	4.55a	3.22a	0.68d	0.63d
	Magnetic-BW^1	3.01ab	11.90b	65.00b	2.99c	2.22ab	1.22b	0.24f
	Magnetic-BW^2	4.80a	13.90a	84.00f	1.55e	1.95c	0.94a	0.24f
				30 – 60 cm				
Gated	Brackish water (BW)	0.80c	2.10b	47.00b	3.25a	1.94a	1.17b	0.94a
	Magnetic-BW^1	2.10e	3.70a	55.00a	3.51b	1.33b	0.75c	0.54d
	Magnetic-BW^2	2.20e	3.80a	58.00c	2.90c	1.22ab	1.20b	0.62c
Drip	Brackish water (BW)	1.60d	3.20b	57.00b	4.21a	1.22a	1.14a	0.65c
	Magnetic-BW^1	3.50b	3.35c	٧1.00e	3.36b	1.14ab	1.33c	0.56b
	Magnetic-BW^2	3.60b	3.90d	75.00f	2.69ab	1.06c	1.24b	0.51d

Note: Means in water treatments and different irrigation systems followed by the same letters (a, b, c, d, e, f) are significantly different (*P*>0.05) according to a protected LSD test.

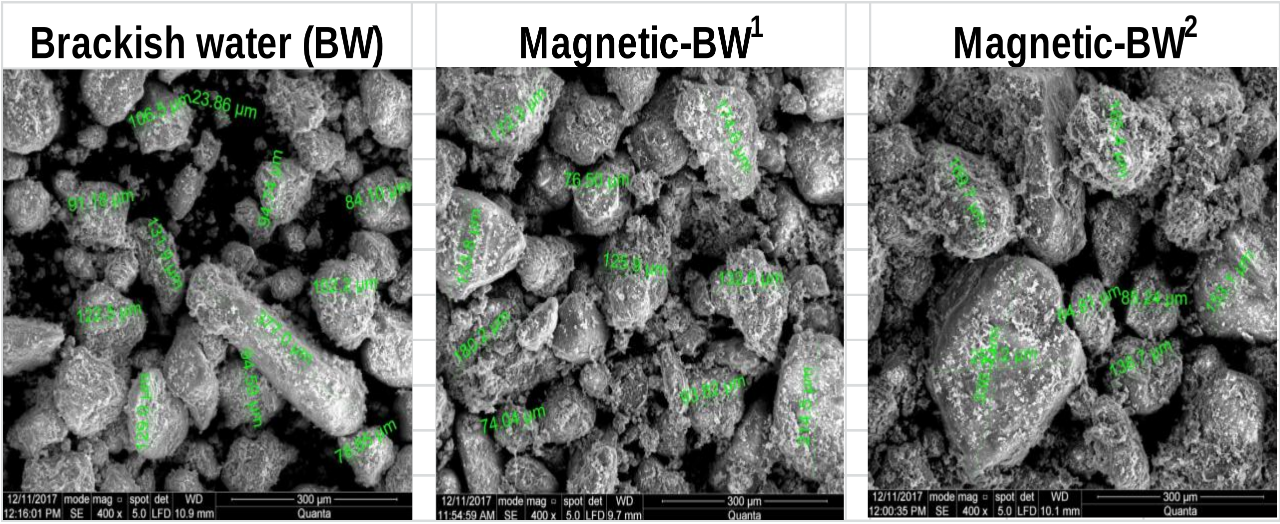

Fig. 2. SEM micrograph of soil irrigated by brackish water, magnetized-BW[1], and magnetized-BW[2] treatments under the applied gated irrigation system. The length of the white bar is 500 µm

Decreasing their ratios in the soil was observed for Magnetized -brackish water treatments compared to control and suggests that presence of hydrogen carbonate and possibly dissolved organic materials. The detection of Sulphur (S) and Calcium (Ca) suggested that the acicular and/or fibrous crystals identified as calcium sulphate (gypsum and/or anhidrite) and calcium carbonate. These crystal formations appeared sometimes mixed with magnesium and/or Calcium chlorides according to additional evidences by EDX in the all the treatments.

i.Effect on EDX Spectral and SEM image analysis under drip irrigation system:

The main observations by the SEM images of soil aggregates were described in the soil irrigated by brackish water, magnetic-BW[1] and magnetic-BW[2] treatments, respectively, under the applied drip irrigation system as shown in (Fig. 4). The soil treated by BW treatments as observed by SEM images had different aggregate sizes (58.2 – 192.4 µm), soil treated by magnetic-BW[1] treatment had variable aggregate sizes (68.22 – 155.2 µm) and soil treated by magnetic-BW[2] were ranged from 88.96 – 170.2 µm. This means that there has been more aggregation for smaller diameter of soil aggregates when treated by magnetized water under applied drip irrigation system compared to the soil treated by brackish water.

This aggregation was higher in magnetic-BW[2] than magnetic-BW[1] treatments, due to high magnetic intensity 3850 gauss. It also observed on the soil aggregates treated by brackish water (control) presence high mainly oxygen, calcium, silicon and carbon. Decreasing their ratios in soil treated by magnetized water treatments compared to control suggests that presence of hydrogen carbonate and possibly dissolved organic materials (Fig. 5).

j. Effect on soil specific surface area

Determination of specific surface area, pore size distribution, total pore area and total pore volume by the analysis of BET nitrogen adsorption/desorption isotherms on soil meso-porous and macro-porous below a pore diameter of 2nm were carried out to provide quantitative specific surface area and pore size distribution information primarily for soil meso-porous and macro-porous. This technique characterizes pore size distribution independent of external area due to particle size of the sample (Table 6, Fig 6 and Fig. 7). The exposure of brackish water to the magnetic field and its application to the soil increased the total pore volume and surface area of the soil particles significantly in each of the gated and drip systems. On the other hand, the average diameter of the pores decreased in both treatments under the gated irrigation system. In contrast, the average diameter of the pores increased in both treatments under the drip irrigation system. It is notable, however, that the magnetized water treatments applied by gated irrigation were more effective in the measured properties of the pores compared to those in the drip (Table 6). Thus, this was reflected in both soil aggregations on the one hand (see SEM Images) and decreasing total soluble salts in the soil solution on the other hand (Table 2).

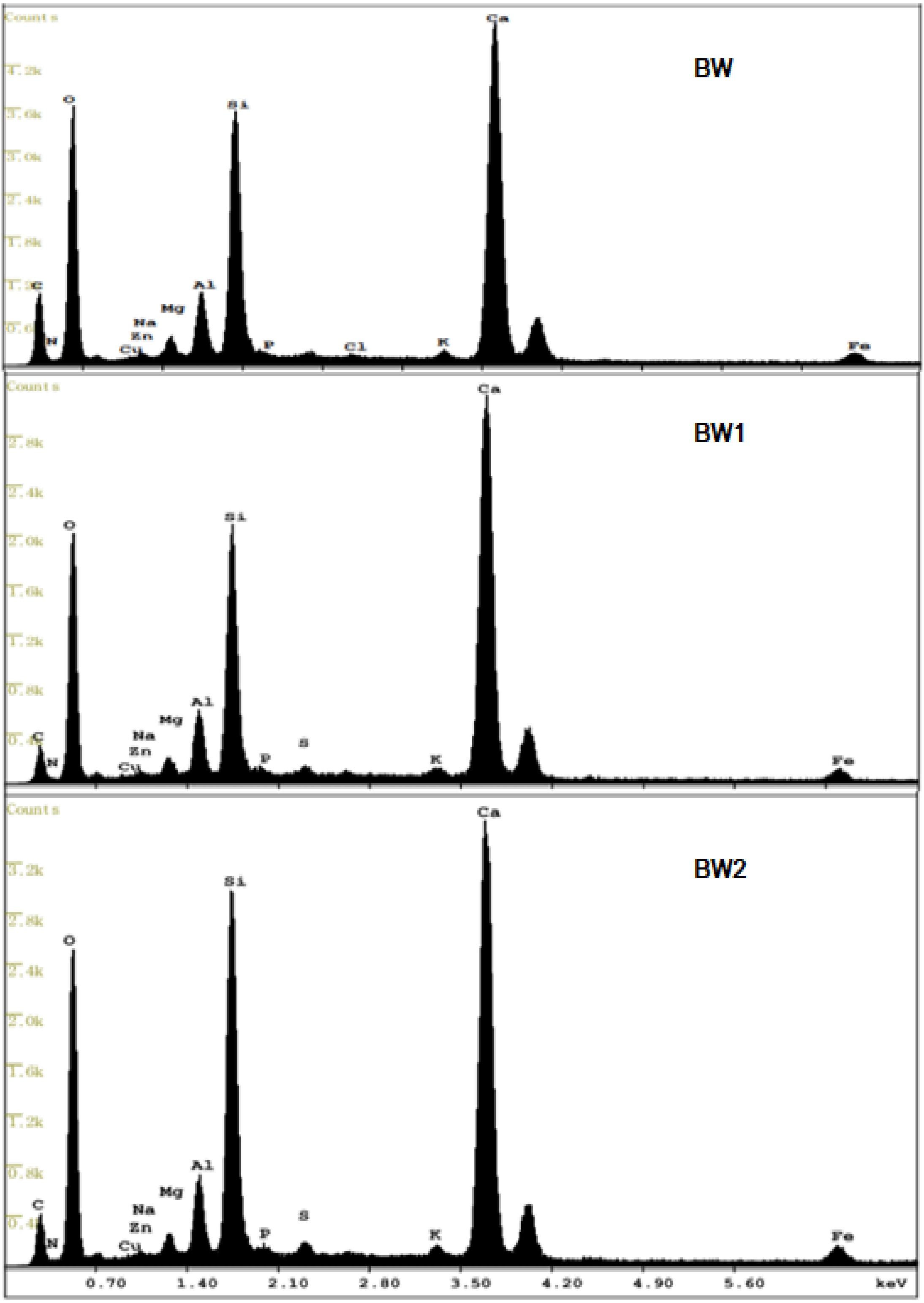

Fig. 3. Corresponding EDX-analysis spectra of soil irrigated by brackish water (BW), magnetized-BW[1] and magnetized-BW[2] treatments under the applied gated irrigation system

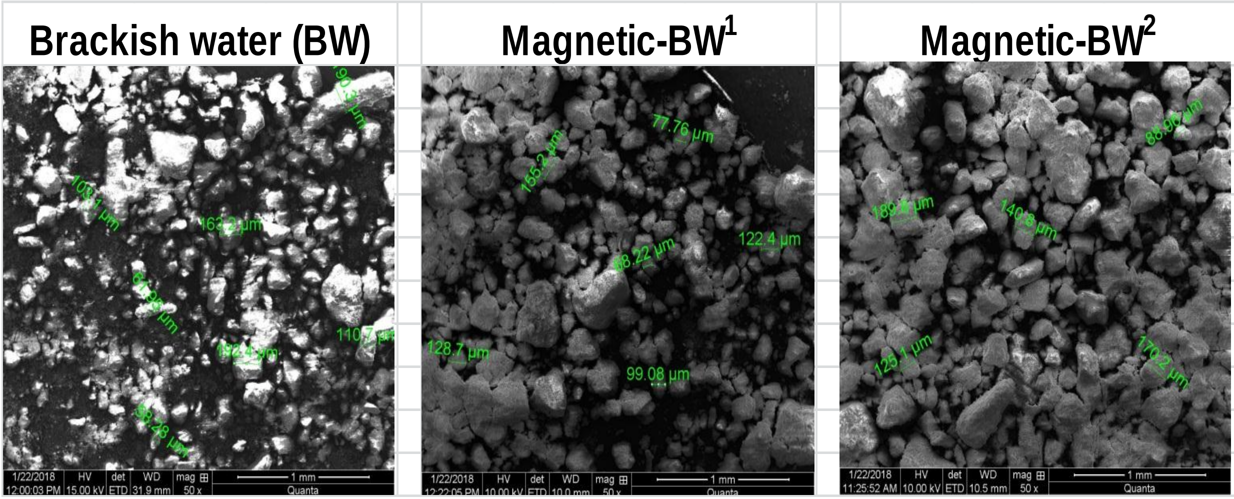

Fig. 4. SEM micrograph of soil irrigated by brackish water, magnetized-BW[1], and magnetized-BW[2] under the applied drip irrigation system. The length of the white bar is 500 µm

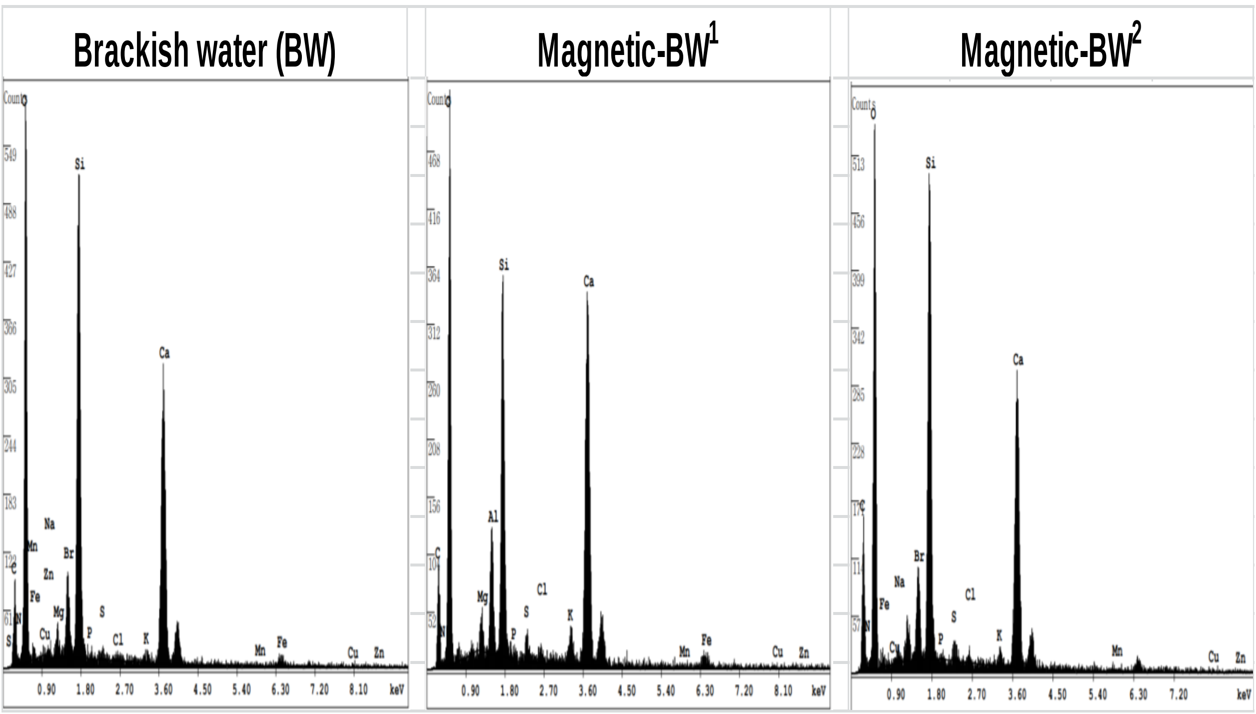

Fig. 5. Corresponding EDX-analysis spectra of soil irrigated by brackish water (BW), magnetized-BW[1], and magnetized-BW[2] treatments under the applied drip irrigation system

3- Morphology characters of sunflower plants at 60 days from sowing:

Significant effects of irrigation systems, water treatments and its interaction treatments were recorded for plant growth parameters at 60 days after sowing, i.e., plant height (cm), leaves (no. plant^{-1}), accumulated dry matter of leaves, stem and total plant (g plant^{-1}) and total chlorophyll (Table 7). Given the differences between two irrigation systems, significant increases were obtained under drip compared to gated pipe irrigation system in all tested growth parameters (Table 6). The percent of increment reached to 7.83, 7.62, 28.79, 25.33, 26.03 and 5.33% in the mentioned growth parameters, respectively compared to the control.

Regarding water treatments, the same table revealed that irrigation with magnetized-BW^1 or magnetized-BW^2 treatments surpassed irrigation with brackish water in all tested growth parameters. The interaction between the two studied factors in Table 7 showed that irrigation with magnetized-BW^1 gave more values in all tested growth parameters under drip irrigation system, while magnetized-BW^2 treatment gave best values under gated pipe irrigation.

4- Macro-elements in sunflower plants at 60 days from sowing:

Table 8 showed an increase of the concentrations of N, K and Ca in plants irrigated with magnetized-BW^2 treatment under the both irrigation systems compared to control. Magnetized-BW^2 treatment had highest values for all the elements except Na under the applied gated and drip irrigation systems. The variation in leaf element levels that were demonstrated in the Table 8 showed highly enhancement of the crop products (Table 9), which were encouraged by applying magnetic field to the brackish irrigation water. In the Table (8), it showed statically significant differences between irrigation systems and water treatments for K and Ca concentrations. The plants irrigated with magnetized water recorded highest K/Na ratios in sunflower leaves (5.83 and 6.58) for magnetized-BW^1 and magnetized-BW^2 treatments, respectively, with compared control (4.28) under the applied gated irrigation system. While these ratios were 3.04 and 3.28 for magnetized-BW^1 and magnetized-BW^2 treatments, respectively, compared to the control (2.11) under the applied drip irrigation system.

5- Plant height and head parameters of sunflower plants at harvest:

Tables 9 and 10 revealed that the magnetized water treatments had significant effect on plant height, weight of seeds per head and total seed and oil yield. The plant height of sunflower at harvest was significantly influenced by magnetic treatments. The highest plant height was recorded in plants which received magnetized-BW^1 and magnetized-BW^2 (136.60 and 143.80 cm) treatments, respectively, compared to magnetic untreated brackish water (117.12 cm) under applied gated irrigation system. While, it recorded under the applied drip irrigation system as 140.97 and 132.25 cm for magnetized-BW^1 and magnetized-BW^2 treatments, respectively compared to control (122.35 cm). It observed that magnetized-BW^2 had highest values of plant height under the applied gated irrigation system while magnetized-BW^1 had highest values of plant height under the applied drip irrigation system. Our study reported that the magnetic treatment of saline water resulted in statistically significant increases in the total seed and oil weight yields as kg/fed of sunflower plants (Table 9).

Table 6. Values of specific surface area (BET) and pore size and volume analyses (BJH) for soil surface layers treated by brackish water (control), electrostatic magnetically treated water at two different tensions 1200 (Magnetized-BW^1) and 3500 Gauss (Magnetized-BW^2)

Depth and Irrigation system	Measurements	Control (BW)	Magnetized-BW^1	Magnetized-BW^2
Gated 0 – 30 cm	V_m (pore volume), $cm^3(STP)g^{-1}$	0.6502a	0.7526c	1.5850f
	a (surface area) m^2g^{-1}	2.8300a	3.2757b	6.8989e
	TPV (total pore volume) ($P/P_0 = 0.990$), m^3g^{-1}	1.0686b	1.1824ab	1.9034d
	Mean pore diameter, nm	15.105a	14.439b	11.036d
	Radius of pores, nm	1.6600a	1.6600a	1.2200e
	V_p, cm^3g^{-1}	1.0924a	1.2094b	1.9609f
	a_p, m^2g^{-1}	3.3226a	3.3226a	7.7875f
Drip 0 – 30 cm	V_m (pore volume), cm^3 (STP) g^{-1}	1.1381b	1.1938ab	1.3432c
	a (surface area), m^2g^{-1}	4.9534a	5.1959c	5.8463d
	TPV (total pore volume) ($P/P_0 = 0.990$), cm^3 g^{-1}	1.1973a	1.2757a	1.5374d
	Mean pore diameter, nm	9.6686b	9.8206ab	10.519c
	Radius of pores, nm	1.2200b	1.6600e	1.6600e
	V_p, cm^3 g^{-1}	1.1988a	1.2871b	1.5528d
	a_p, m^2 g^{-1}	5.0290a	5.4632c	6.1752e

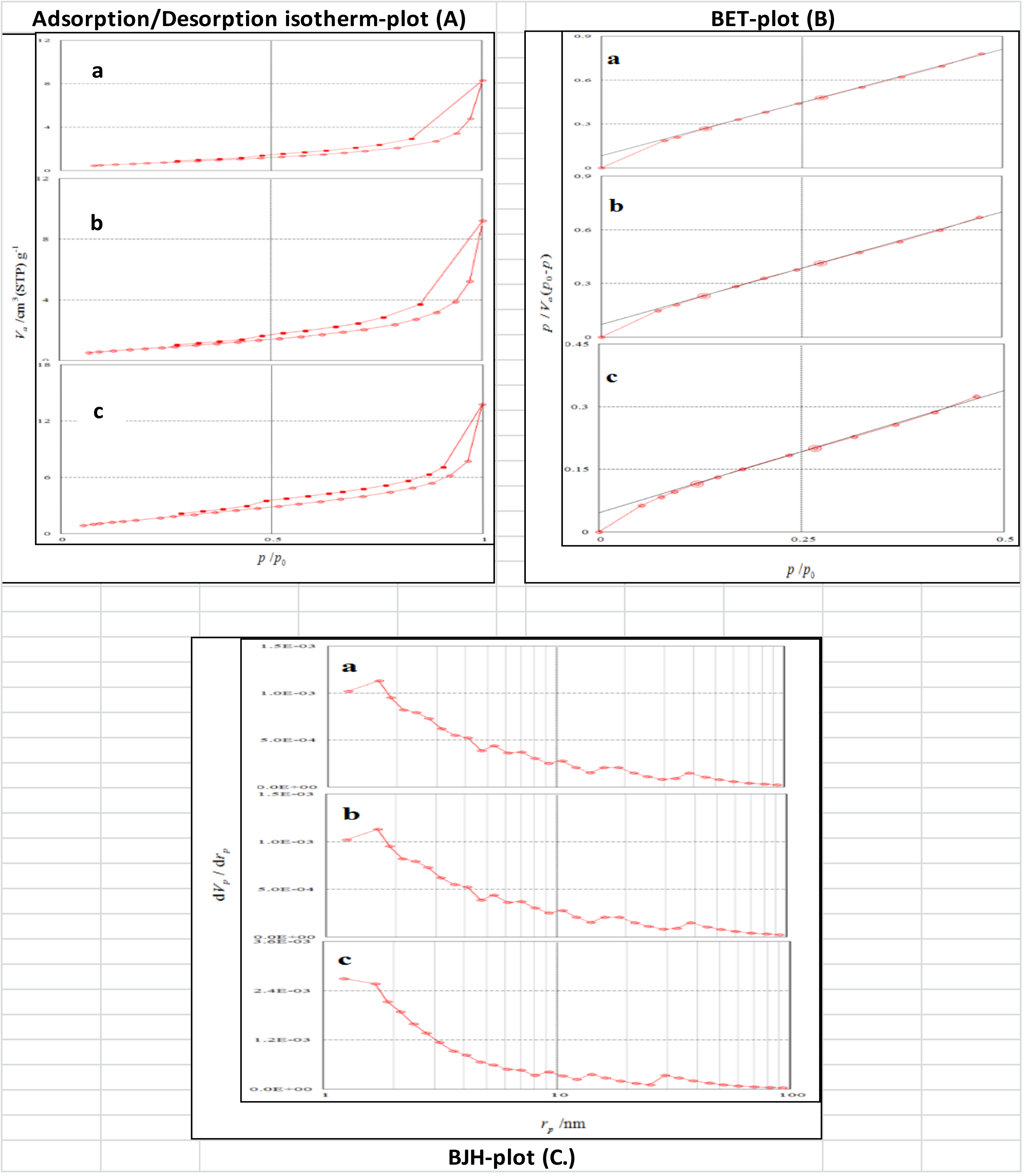

Fig. 6. (A) Water vapor adsorption/desorption isotherm for soil surface layers treated with brackish water (a); soil treated with magnetized-BW[1] (b) and soil treated with magnetized-BW[2] (c) treatments under gated irrigation system. (B) Analysis of BET nitrogen adsorption and desorption isotherms for soil surface layers treated with brackish water (a); soil treated with magnetized-BW[1] (b) and soil treated with magnetized-BW[2](c) treatments under gated irrigation system. (C) Pore size and volume analyses (BJH) for soil surface layers treated with brackish water (a); soil treated with magnetized-BW[1] (b) and soil treated with magnetized-BW[2] (c) treatments under gated irrigation system

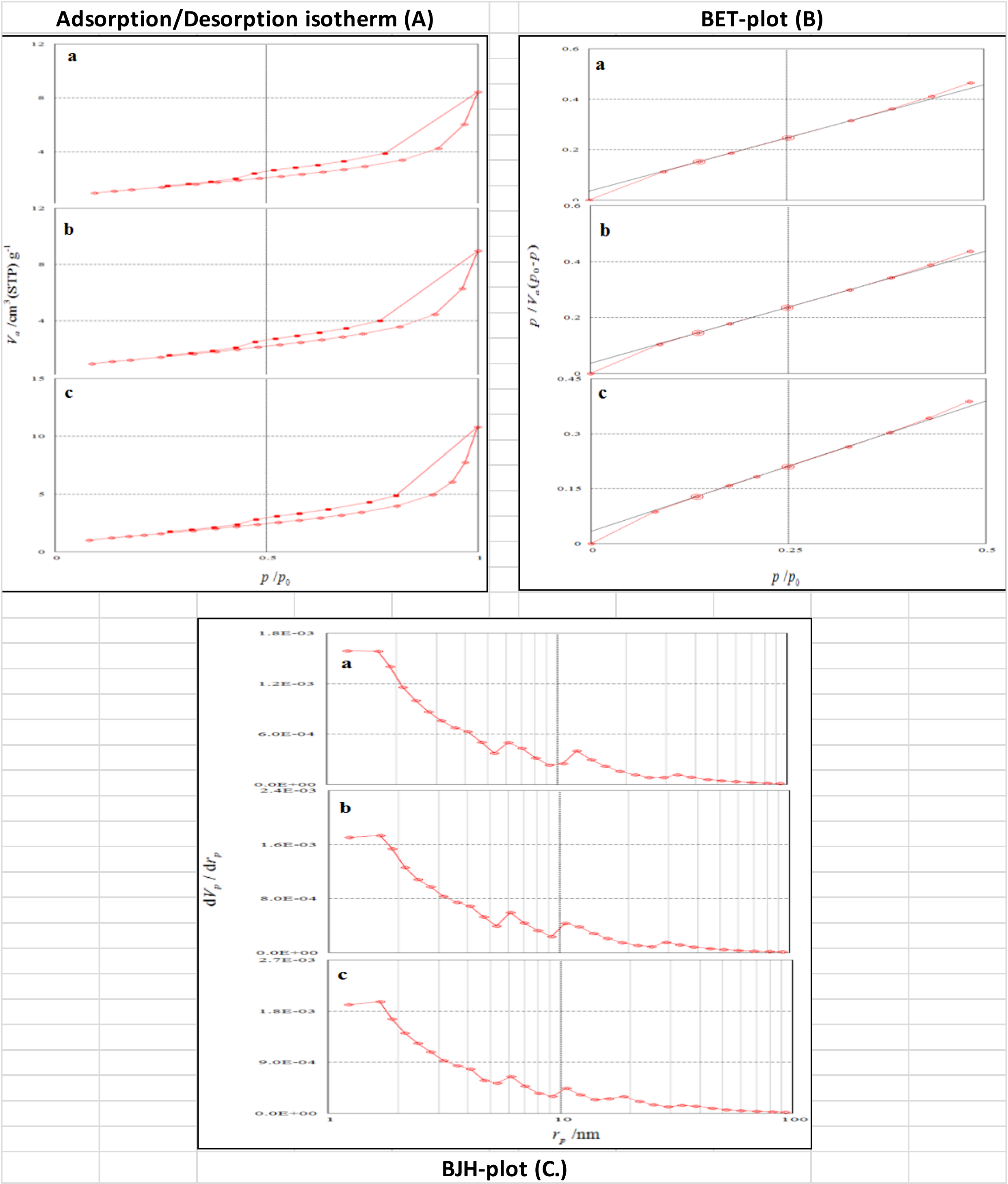

Fig. 7. (A) Water vapor adsorption/desorption isotherm for soil surface layers treated with brackish water (a); soil treated with magnetized-BW[1] (b) and soil treated with magnetized-BW[2] (c) treatments under drip irrigation system. (B) Analysis of BET nitrogen adsorption and desorption isotherms for soil surface layers treated with brackish water (a); soil treated with magnetized-BW[1] (b) and soil treated with magnetized-BW[2] (c) treatments under drip irrigation system. (C) Pore size and volume analyses (BJH) for soil surface layers treated with brackish water (a); soil treated with magnetized-BW[1] (b) and soil treated with magnetized-BW[2] (c) treatments under drip irrigation system

Table 7. Plant height, leaves number per plant, dry mater biomass of plant organs and leaf chlorophyll content (at 60 days) as affected by different magnetized waters under applied the gated and drip irrigation systems

Treatment		Plant height (cm)	Leaves (no. plant^{-1})	Dry matter (g plant^{-1})			Total chlorophyll (SPAD)
Irrigation system	Water type			Leaves	Stem	Plant	
Gated	Brackish water (BW)	98.40	23.00	19.70	85.01	104.71	37.70
	Magnetic-BW^1	108.20	24.00	24.81	96.69	121.50	39.30
	Magnetic-BW^2	113.40	25.60	28.55	108.00	136.56	40.59
Drip	Brackish water (BW)	102.00	23.60	24.13	103.20	127.33	39.71
	Magnetic-BW^1	126.67	27.53	35.59	134.10	169.69	42.47
	Magnetic-BW^2	116.40	27.00	34.38	125.80	160.18	41.68
F test		*	ns	*	***	***	*
$LSD_{5\%}$		8.69	ns	1.26	5.28	6.37	0.94
Irrigation system	Gated	106.67b	24.20b	24.35b	96.57b	120.92b	39.20b
	Drip	115.02a	26.04c	31.37a	121.03d	152.40e	41.29a
F test		*	**	*	**	**	**
Water type	Brackish water (BW)	100.20a	23.30a	21.91a	94.11a	116.02b	38.71a
	Magnetic-BW^1	117.43c	25.77b	30.20d	115.39d	145.60e	40.88c
	Magnetic-BW^2	114.90b	26.30c	31.46e	116.90e	148.37f	41.13d
F test		***	**	***	***	***	***
$LSD_{5\%}$		6.14	1.38	0.89	3.73	4.50	0.66
$CV_{\%}$		4.17	4.15	3.50	2.57	2.73	1.23

Table 8. Macro-element concentrations in sunflower leaves as percent at 60 days irrigated by magnetized low quality water under the applied gated and drip irrigation systems

Treatment		Macro-elements in leaves (%) at 60 days after sowing				
Irrigation system	Water type	N	K	Mg	Na	Ca
Gated	Brackish water (BW)	1.88	1.84	0.22	0.43	1.53
	Magnetic-BW^1	2.18	2.10	0.25	0.36	1.76
	Magnetic-BW^2	2.30	2.37	0.26	0.36	1.62
Drip	Brackish water (BW)	1.92	1.18	0.30	0.56	3.21
	Magnetic-BW^1	2.29	1.37	0.35	0.42	3.60
	Magnetic-BW^2	2.47	1.38	0.37	0.45	3.63
F test		*	*	Ns	*	*
$LSD_{5\%}$		0.89	0.83	0.18	1.23	0.86
Irrigation system	Gated	2.12a	2.10a	0.24b	0.38a	1.64a
	Drip	2.23a	1.31b	0.34b	0.48a	3.48c
F test		Ns	*	Ns	Ns	**
Water type	Brackish water (BW)	1.90a	1.51b	0.26a	0.49c	2.37a
	Magnetic-BW^1	2.24c	1.74c	0.30a	0.41b	2.68c
	Magnetic-BW^2	2.38b	1.87d	0.31a	0.39a	2.62bc
F test		*	*	Ns	Ns	*
$LSD_{5\%}$		0.87	1.13	0.65	0.29	1.05

Data point out that the highest seed and oil yields were 789.81, 831.56, 287.09 and 305.86 kg/fed for the plants that received magnetized-BW^1 and magnetized-BW^2 treatments compared to control (633.23 and 210.79 kg/fed), respectively, under the applied gated irrigation system at increasing rates 24.72, 31.32, 36.19 and 45.10 %. While under drip irrigation system, the data of highest seed and oil yields recorded 704.29, 735.18, 251.63 and 262.56 kg/fed for magnetized-BW^1 and magnetized-BW^2 compared to control (621.62 and 199.38 kg/fed), respectively, at increasing rates 13.30, 18.26, 26.20 and 31.68 %, respectively.

It was observed that the seed and oil yields increased by increasing the force of magnetic treatment (magnetized-BW^2). Data in Table (10) tabulated that yield of sunflower seeds and oil were increased significantly due to the interaction between irrigation systems and water type during growing season.

Table 9. Main effects of irrigation by magnetized low quality water on Plant height (cm) and head parameters of sunflower under the applied gated and drip irrigation systems after harvest

Treatment		Plant height (cm)	Head parameters			100-seed weight (g)
			Diameter (cm)	Weight (g)	Seed weight (g)	
Gated pipe	Brackish water (BW)	117.12	15.32	108.74	61.89	7.45
	Magnetic-BW[1]	136.60	16.50	120.55	84.26	8.38
	Magnetic-BW[2]	143.80	17.23	113.90	90.22	8.51
Drip	Brackish water (BW)	122.35	15.43	90.56	60.23	7.60
	Magnetic-BW[1]	140.97	17.52	110.93	72.04	8.71
	Magnetic-BW[2]	132.25	16.92	109.09	76.45	8.09
F test		**	**	**	***	**
$LSD_{5\%}$		8.75	0.23	6.75	5.42	0.13
Irrigation system	Gated pipe	132.51a	16.35a	114.40a	78.79b	8.11a
	Drip	131.85b	16.62a	103.53c	69.58a	8.13a
F test		*	ns	***	**	Ns
Water treatment	Brackish water (BW)	119.73a	15.38a	99.65b	61.06a	7.52a
	Magnetic-BW[1]	138.78c	17.01b	115.74c	78.15b	8.55d
	Magnetic-BW[2]	138.03c	17.08b	111.50b	83.34d	8.30c
F test		**	**	***	***	***
$LSD_{5\%}$		10.15	0.18	5.85	6.21	0.19

Fig. 8. Sunflower plants morphology under the gated pipe and drip irrigation systems after magnetization treatments

Table 10. Effects of magnetized low quality irrigation water on Seed oil content and Seed and oil yield (kg fed^{-1}) under the applied gated and drip irrigation systems

Treatment		Seed oil (%)	Yield (Kg fed^{-1})	
			Seed	Oil
Gated pipe	Brackish water (BW)	33.29	633.23	210.79
	Magnetic-BW^1	36.34	789.81	287.09
	Magnetic-BW^2	36.79	831.56	305.86
Drip	Brackish water (BW)	32.08	621.62	199.38
	Magnetic-BW^1	35.73	704.29	251.63
	Magnetic-BW^2	35.70	735.18	262.56
F test		**	***	***
LSD $_{5\%}$		0.92	39.18	18.35
Irrigation system	Gated pipe	35.48b	751.53b	267.91b
	Drip	34.50a	687.03a	237.86a
F test		**	**	**
Water type	Brackish water (BW)	32.69a	627.43a	205.08b
	Magnetic-BW^1	36.04b	747.05c	269.36d
	Magnetic-BW^2	36.25c	783.37e	284.21e
F test		***	***	***
LSD $_{5\%}$		0.81	43.49	15.47

DISCUSSION

Much attention is being paid in recent years to achieve of the sustainable agriculture; therefore, many materials and therapies were applied such as using saline water electromagnetic treatment to resolve the harmful effects of soil/water salinity, improve soil physical and chemical characteristics, increase water preservation as well as provide mineral nutrients. Depending on this background, the present study examines the substantial reduction in the electrical conductivity and soil pH using saline water electromagnetic treatment. The results of this study showed that magnetized water plays an important role in increasing the leaching of large quantities soluble salts, decreasing the soil pH, and dissolving at the both depths slightly soluble salts such as carbonates, phosphates and sulfates. Variations in concentrations of macro-elements (N, P and K), Na, Ca and Mg in soils irrigated with electromagnetically treated water compared to those in brackish water were observed where electromagnetic water treatment slows down the movement of minerals, likely due to the effect of acceleration of crystallization and precipitation processes of solute minerals. This will lead to lower soil profile salt concentrations and better soil conditions for plant growth. These results were in agreement with the view of Hilai *et al.*, 2002. The reduction in EC and pH were more conspicuous at the higher intensity of magnetic field (Magnetized-BW^2). These results were in accordance with Maheshwari and Grewal, 2009 who stated that the use of magnetically treated irrigation water reduced soil pH. This reduction in soil pH was due to the effect of magnetic field on organic matter in the soil where it releases relatively greater part of organic acids in rhizosphere. Soils that have SAR values of 13 or more may be characterized by an increased dispersion of organic matter and clay particles, reduced saturated hydraulic conductivity (K_{sat}) and aeration and a general degradation of soil structure (Mohsen, et al., 2009). It is clear from our findings that magnetized water treatments did not allow degradation of soil structure and reduced soil alkalinity especially in the second depth (30 – 60 cm). Our data confirmed that decreasing rates of total $CaCO_3$ referred to the effect of magnetized water on dissolution of $CaCO_3$ in soil solution (Kney and Parson, 2006). Capability of magnetically treated water to re dissolve old lime scale deposits was observed and reported by our SEM-EDX images (Mostafazadeh-Fard et al., 2011). It can be concluded that the weak interaction between the magnetic fields and the hydrogen bonds is amplified to the breaking point by resonance. This confirms the hypothesis of the complex-formation in soil solution with ion of formerly dissolved minerals from the soil by forming micro crystals which move with the water in soil (Xiao Feng, 2008). This confirms our data that increasing nanometer pores of soils treated by magnetized brackish water played an important role in holding and binding an important part of the ions within these pores, which was clearly reflected in the low electrical conductivity of the saturated soil especially in the surface layer, thus improving the agronomic parameters of sunflower plants in both treatments. This is the first time that a magnetic water effect has been recorded on agricultural soil pores. We found that magnetized water especially magnetized-BW^2 treatment under the gated and drip irrigation systems plays an important role in increasing the P availability of the soil as well as an increase in soil available K. Electromagnetic treatment of saline water may be influencing desorption of K from soil adsorbed on colloidal complex, and thus increasing availability K to plants, resulting in an improved plant growth and productivity. Indeed, in the our study, an increase in the soil available K of magnetically treated saline waters irrigation, especially Magnetized-BW^2 treatment under the two irrigation systems appeared to have played a role in improving salt tolerance of sunflower. We recorded increases in the percentage of nutrients such as phosphorus, potassium, magnesium and zinc in the plant organs in corresponding with Maheshwari and Grewal (2009) mentioned that plants absorb more water of MTW than non-treated, consequently, they uptake more nutrients as a result of water molecules of MTW are minute and small and is reflected on the yield and Hozayn *et al* (2013) reported that irrigation with magnetized-water improved clearly growth of some field crops i.e., wheat, flax, faba bean, lentil, sugar beet, chick-pea. Electromagnetic treatment may be assisting to reduce the Na toxicity at cell level by detoxification of Na, either by restricting the entry of Na at membrane level or by reduced absorption of Na by plant roots. Alternatively, the reduction of Na concentration in of sunflower may be associated with dilution of salts when they were irrigated with electromagnetically treated saline water. The better growth of crop plants due to magnetic treatment was ascribed to easy entry of water to the cell membrane of plants resulting from the availability of minerals in soil through increased solubility of salts and minerals required for cell division and elongation during the plant growth (Barefoot and Reich, 2002) and activation of ions and polarization of dipoles in the living cells (Afshan, et al., 1999), but the irrigation systems with water type had significantly effect on the plant height (Table 8). Hilal and Helal (2003) clarified that the magnetically treated water has been utilized to improve productivity conditions of desert soils with high salinity and calcification, where higher yields were obtained for tomato, pepper, maize and wheat. Increase of soil magnesium as result applied magnetically brackish water have encouraged the formation of chlorophyll particle, thereby increasing of the chlorophyll concentration in leaves and thus supplying the seeds the required food for production of seed and oil yields (Tables 9 and 10). This increase in the seed and oil production referred to apply magnetized brackish water under gated irrigation rather than drip irrigation system are in correspondence with that obtained by Reina, *et al* (2001) who found a significance increase in the rate of water absorption accompanied with an increase in total mass of lettuce with the increase of magnetic intensity.

CONCLUSION

Results from the current study showed beneficial effects of magnetically treated saline water on soil and plants. The magnetically treatment of saline water plays an important role in the protection of sunflower crops against the adverse effects of salt stress. Compared with the control treatment, the magnetic treatment of irrigation water tends to change soil pH, EC, available P and extractable K measured at the crop harvest date and resulted in statistically significant increases in the seed and oil yields. Application of this technology can be recommended to farmers, it will be critical to clearly understand the mechanisms and processes that affect plant yield when they are irrigated with magnetically treated water, to identify the limits of the operating requirements and to evaluate its effectiveness under field conditions.

SIGNIFICANCE STATEMENT

The study discovered that, magnetized water and irrigation systems played a significant role on the improvement of sunflower production in terms of seed and oil yields. In this study, sunflower production significantly affected by magnetic intensity and irrigation system. This study will help the researchers to uncover the critical areas of desert soils with high salinity and calcification to apply suitable magnetization for saline and irrigation system to improve sunflower yielding conditions.

ACKNOWLEDGEMENT

This work funded through National Campaigns Program (project no.1340; entitled Applications of magnetic technology for correcting underground brackish water and improving field crops and water productivity in Sinai region) by Academy of Scientific Research and Technology, 101 Elkasr Eleny St., Cairo, Egypt.

REFERENCES

Afshan, N., J. Yasir, UH. Zia, M. Iqbal, RA. Ahmad, I. Ashraf, and R. Ahmad. 1999.Enhancement in the germination, growth and yield of okra (*Abelmoschus esculentus*) using pre-sowing magnetic treatment of seeds. *Indian J. Bioch. and Biophys.* 49: 211-14.

Aladjadjiyan, A. 2002. Study of the Influence of Magnetic Field on Some Biological Characteristics of *Zea mays*. *J. Central Europ. Agric.* 3 (2): 89-94.

Alderfasi, A.A., N.A. Al-Suhaibani, M.M. Selim and B.A.A. Al-Hammad.2016. Using Magnetic Technologies in Management of Water Irrigation Programs under Arid and Semi-Arid Ecosystem. *Adv. Plants Agri. Res*. 3 (4): 00102.

Barefoot, R.R. and C.S. Reich. 2002 The Calcium Factor: The Secret of Health and Youth. 5th ed. South Eastern, PA: Triad Marketing.

Brunauer, S., P.H. Emmett and E. Teller. 1938. Adsorption of Gases in Multi-Molecular Layers. *J.the Am. Chem. Soc.* 60: 309–19.

Chapman, H.D. and P.F. Pratt. 1978. Methods of Analysis for Soils, Plants and Waters. *Univ. California Div. Agric. Sci*. Priced Publication, Oakland.

El-Sayed, H.E., SA. 2014. Impact of Magnetic Water Irrigation for Improving the Growth, Chemical Composition and Yield Production of Broad Bean (*Vicia faba* L.) Plant. *Am. J. Exp. Agric*. 4 (4): 476-96.

Gabrielli, C., R. Jaouhari, G. Maurin and M. Keddam. 2001. Magnetic water treatment for scale prevention. *Water Res.* 35: 3249–59.

Hilai, M. and M.Hilai. 2000 Application of magnetic technologies in desert agriculture. I- germination and seedling emergence of some crops in a saline calcareous soil. *Egypt. J. Soil Sci.* 40 (3): 413-22.

Hilai, M.H., S.M. Shata, A.A. Abdel-Dayem and M.M. Hilai.2002. Application of magnetic technologies in desert agriculture. III. Effect of magnetized water on yield and uptake of certain elements by citrus in relation to nutrients mobilization in soil. *Egypt J. Soil Sci.* 42: 43–55.

Hilal, M.H. and M.M. Helal. 2003. Application of magnetic technologies in desert agriculture. Seed germination and seedling emergence of some crops in a saline calcareous soil. In: Proc. II Int. Conf. Impact of Electromagnetic Fields in the Agricultural Environment. Agrolaser. 8–10.Lublin, Poland.

Hozayn, M., A.M. Salama , A.A. Abd El-Monem and A.F. Hesham. 2016b. The impact of magnetized water on the anatomical structure, yield and quality of potato (*Solanum tuberosum* L.) Grown under newly reclaimed sandy soil. *Res. J. Pharm. Bol. Chem. Sci*. 7(3): 1059 – 72.

Hozayn, M., A.A. Abd El- Monem, T.A.E. El-wial and M.M. El-Shater.2014. Future of magnetic agriculture in arid and semi-arid regions". *Series A. Agronomy*. LVII: 197 – 204.

Hozayn, M., A.A. Abd El-Monem, A.M.S. Abdul Qados and H.M. Abd El- Hameed. 2011. Response of some food crops for irrigation with magnetized water under greenhouse condition". *Austr. J. Basic Appl. Sci*. 5(12): 29 – 36.

Hozayn, M., A.A. Abd El-Monem, R.E. Abd El-Raouf, M.M. Abdalla. 2013. Do Magnetic Water Affect Water Use Efficiency, Quality and Yield of Sugar Beet (*Beta vulgaris* L.) Plant under Arid Regions Conditions?. *J. of Agron*.12 (1): 1-10.

Hozayn, M., M.M. Abdalla, A.A. Abd El-Monem, A.A. El-Saady and M.A.Darwish. 2016. Applications of magnetic technology in agriculture, a novel tool for improving crop productivity (1): Canola. *Afr. J. Agric. Res*. A. 11(5): 441 – 49.

Hozayn, M., H.M.S. El-Bassiouny, A.A. Abd El-Monem, M.M. Abdallah. 2015. Applications of magnetic technology in Agriculture, a novel tool for improving crop productivity (2). Wheat. *Int. J. Chem. Tech. Res*. 8 (12): 759 – 71.

Jones, B.J., Jr. Laboratory guide for conducting soil tests and plant analysis. AOAC Int. Handbook: CRC Press. Boca Raton, London, NEW York, Washington: D.C.2000.

Jones, L. V. 1955. Statistics and research design. Annual Review of Psychology. 6:405-430.

Kney, A.D., S.A. Parsons. 2006. A spectrophotometer-based study of magnetic water treatment: Assessment of ionic vs. surface mechanisms. *Water Research.* 40 (3): 517-24.

Konica, M.O. Chlorophyll Meter SPAD-502Plus - A lightweight handheld meter for measuring the chlorophyll content of leaves without causing damage to plants. 2012 http://www.konicaminolta.com/instruments/download/catalog/color/pdf/spad502plus_e1.pdf. Accessed. 13 Apr.

Loveland, P. J., J .Hazelden, R.G. Sturdy. 1987.Chemical Properties of Salt-Affected Soils in North Kent and Their Relationship to Soil Instability. *J. Agric. Sci.* 109 (1): 1-6.

Maheshwari, B., H.S. Grewal. 2009. Magnetic treatment of irrigation water: its effects on vegetable crop yield and water productivity. *Agric. Water Manage*. 96: 1229 – 36.

Mohsen, S.P., R. Majid, G.K. Borzo. 2009. Prediction of Soil Exchangeable Sodium percentage based on Soil Sodium Adsorption Ratio. *American-Eurasian, J. Agric. & Environ. Sci.* 5(1): 01-04.

Mostafazadeh-Fard, B., M. Khoshravesh, S.F. Moousavi, A.R. Kiani. 2011. Effects of magnetized water on soil chemical components underneath trickle irrigation. *J. Irrigation Drainage Eng*. 135: 32– 38.

Mostafazadeh-Fard, B., H. Mansouri, S.F. Mousavi, M. Feizi. 2009. Effects of different levels of irrigation water salinity and leaching on yield and yield components of wheat in an arid region. *Journal of Irrigation and Drainage Engineering, American Society of Civil Engineering*. 135: 32–38.

Noran, R., R. Shani, I. Lin. 1996. The effect of irrigation with magnetically treated water on the translocation of minerals in the soil. *Magn. Electr. Sep*. 7: 109 – 22.

Page, A.L., D.R. Miller, E.d. Keeney. 1982. Methods of soil analysis, 2. Chemical and microbiological properties; 2rd ed. New York.

Reina, F.G., L.A. Pascual, I.A. Fundora. 2001. Influence of a stationary magnetic field on water relations in lettuce seeds". Part II: Experimental Results. *Bio electromagnetic.* 22:596–602.

Sadeghipour, O., P. Aghaei. 2013. Improving the Growth of Cowpea (*Vigna unguiculata* L. Walp.) by Magnetized Water. *J. Bio. Envir Sci*. 3 (1): 37-43.

Selim, M.M. 2008, Application of magnetic technologies in correcting underground brackish water for irrigation in the arid and semi-arid ecosystem. *The 3rd Int. Conf. on Water Resources and Arid Environments, 1st Arab Water Forum*. 11-21.

Sparks, L.D. 1996. Methods of Soil Analysis, Part – 3: Chemical Methods. Soil Science Society of America, USA: Soil Science Society of America.

Vashisth, A., S. Nagarajan. 2010. Effect on Germination and Early Growth Characteristics in Sunflower (*Helianthus annuus*) Seeds Exposed to Static Magnetic Field. *J. Plant Physiol*. 167 (2): 149-56.

Xiao Feng, P., D. Bo. 2008. Investigation of changes in properties of water under the action of a magnetic field. *Sci. China Ser. G Phys. Mech. Astron.* 51: 1621–32.

Zhou, K.X., G.W. Lu, Q.C .Zhou, J.H. Song, S.T. Jiang, H.R . Xia. 2000. Monte Carlo Simulation of Liquid Water in a Magnetic Field. J. Appl. Physic. 88 (4): 1802-5.

Zhou, R., I. Hotta, A.M. Denli, P. Hong, N. Perrimon, G.J. Hannon. 2008. Comparative analysis of argonaute-dependent small RNA pathways in Drosophila. *Mol. Cell*. 32(4): 592-99.

Zhou, Y., Y. Zhang, J. Li, X. Meng, J. Zhao, H. Wei, L. Zhou. 2011. Antibacterial and antioxidant activities of the endophytic fungi from medicinal herb *Trillium tschonoskii*. *African J. of Microb. Res.* 5(27): 4917-21.

الملخص العربي

تخفيف الإجهاد الملحى باستخدام المياه المعالجة مغناطيسيا تحت نظامين رى وتأثيره على خواص التربة وإنتاجية عباد الشمس فى منطقة جنوب سيناء – مصر

محمود حزين محمود، سحر محمد إسماعيل، أمانى عطية عبد المنعم، محمد عبد العال درويش

أصبح إستخدام مياه الرى منخفض الجودة فى مواجهة ندرة المياه موضوع غاية فى الأهمية. المياه الممغنطة هى طريقة جذابة للتغلب على هذا التحدى باعتبارها معالجة فيزيائية مبدئية للمياه المالحة وصديقة للبيئة. وقد قام عديد من الباحثين بدراسة استخدام المياه الممغنطة فى الزراعة إلا أنه لم يتم دراسة مقارنة تأثير قوتين مغناطيسيتين مختلفتين لمغنطة المياه المالحة تحت تأثير نظامين رى مختلفين على الخصائص الكيميائية للتربة وإنتاجية البذرة والزيت لعباد الشمس. تتلخص أهداف هذه الدراسة فى ١) إختبار ومقارنة تأثير شدتين مختلفيتين لمعاملة المياه المالحة لتخفيف الجهود الملحية للتربة والمياه على نمو وإنتاجية عباد الشمس تحت نظامى رى مبوب وتنقيط و٢) تحديد التغيرات فى حصائص التربة الراجع إلى استخدام مغنطة مياه الرى منخفضة الجودة فى رأس سيدر– محافظة جنوب سيناء. أجريت هذه الدراسة بالمحطة التجريبية البحثية برأس سيدر التابعة لمركز بحوث الصحراء جنوب سيناء، مصر. تم تطبيق معاملات مياه الممغنطة بقوة مغناطيسية ١٢٠٠ جاوس (BW1) والمياه الممغنطة بقوة مغناطيسية ٣٨٥٠ جاوس وكنترول (مياه مالحة غير ممغنطة) تحت ظروف إستخدام نظامى رى مبوب وتنقيط. تم وضع المعاملات تحت الدراسة فى تصميم قطاعات منشقة مع ثلاثة مكررات حيث خصص نظامى الرى كقطع أرضية رئيسة والثلاثة معاملات للمياه المالحة كقطع أرضية فرعية أوتحت رئيسية على التوالى. وقد أظهرت النتائج أن تركيز الكاتيونات الذائبة(كالسيوم، مغنيسيوم، بوتاسيوم وصوديوم) والأنيونات (الكلوريد والبيكربونات والكبريتات) الذائبة بالتربة على أعماق صفر – ٣٠، ٣٠ –٦٠ سم تناقصت عندما عوملت التربة بالمياه الممغنطة مقارنة بالكنترول بل وزاد التناقص مع المياه الممغنطة بقوة مغناطيسية أعلى. أيضا أظهرت النتائج أن التركيزات المتاحة للنيتروجين والفوسفور والبوتاسيوم بالتربة وكذلك السعة التبادلية الكاتيونية ونسبة الصوديوم المدمص وكربونات الكالسيوم الكلية والكثافة الظاهرية ومحتويات العناصر الصغرى المتاحة فى الأرض المعاملة بالمياه الممغنطة كانت أقل من نظيرتها فى مياه الرى المالحة غير الممغنطة بعمقى التربة. تم فحص عينات التربة السطحية للتحليل العنصرى باستخدام الأشعة السينية متشتتة الطاقة(EDX) والميكروسكوب الإلكترونى (SEM) وتحاليل مساحة السطح النوعى (SSA) للتعرف على العناصر الخاصة بها ومدى

تجمعات حبيبات التربة . فقد أعطت التربة المعاملة بالمياه الممغنطة تجمعات أعلى لحبيبات التربة فى المعاملتين مقارنة بالكنترول. رى نباتات عباد الشمس بالمياه الممغنطة سواء تحت نظامى الرى بالتنقيط أو المبوب أدى إلى تحسين تركيزات الكلوروفيل والمادة الجافة المتراكمة فى الأعضاء النباتية ومستويات العناصر الكبرى فى الأوراق عند ٦٠ يوم. وكانت تغيرات الوزن الجاف فى الساق والاوراق وارتفاع النبات معنوية (أقل فرق معنوى عند ٠,٠٥). وقد لوحظ أيضا تحسن فى إنتاج البذرة والزيت (%) بشكل معنوى مقارنة بالرى بمياه مالحة غير ممغنطة تحت كلا نظامى الرى. إزداد متوسط محتويات النيتروجين والفوسفور والكالسيوم فى أوراق عباد الشمس مع المعاملة BW^2 تحت نظامى الرى بالمقارنة بنظيراتها فى معاملات BW^1 والكنترول. إزداد إرتفاع النبات وانتاجية البذرة والزيت معنويا نتيجة كلا المعاملتين بالمياه الممغنطة. يمكن الإستنتاج بأن إستخدام المياه الممغنطة فى الزراعة كآلية واعدة تحت ظروف الإجهاد الملحى للتربة والمياه تحت نظم رى مبوب أو تنقيط.