FACULTY OF AGRICULTURE

Minia J. of Agric. Res. & Develop.
Vol. (40), No. 2, pp. 175-196, 2020

IRRIGATION WITH MAGNETIZED WATER ENHANCES WATER AND FERTILIZER USE EFFICIENCY AND PEACH PRODUCTION UNDER ARID CONDITIONS

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Received: 28 September (2020)   Accepted: 25 October (2020)

ABSTRACT

Irrigation with magnetized water can be a propitious technology in agriculture under arid conditions. Field experiment was carried out to investigate impacts of magnetic treatment on irrigation groundwater quality and in turn impacts of magnetized water on irrigated sandy soil properties and peach crop production under desert conditions. Results of this study indicated that there were no significant changes in water suitability criteria for irrigation with magnetized water from unmagnetized significantly were observed by magnetic field treatment. However, irrigation with magnetized water increased water and fertilizer use efficiency and productivity and consequently increased peach crop yield over irrigation with unmagnetized water. Results of this significantly study showed that when sandy soil were irrigated with magnetized water, soil moisture content in root zone increased from 9.45% for control treatment to 12.03 % in the first 200 m irrigation distance from the magnetic field device. Moisture content in root zone was significantly decreased as the irrigation distances increased from 200 to 400 and 600 m distances. This indicates that the effect of magnetizing irrigation water decreases with increasing the irrigation distance from the magnetic device at the head of the field. It could be concluded that, using magnetic technology for groundwater treatment in arid regions would increase the possibility of using saline water for safe irrigation on the long-run.

Keywords: Magnetic water technology, Magnetized water, Suitability criteria.

1. INTRODUCTION

Water is the greatest imperative element on earth for human and living organisms. Water shortage is the lack of sufficient available water resources to meet water requirements within a country. Water shortage can occur through either physical water scarcity as a result of insufficient natural water resources or economic water scarcity, which happens because of poor management of the available water resources. In Egypt, the scarcity of water is initially physical scarcity because of limited water resources and moreover economic scarcity as a result of improper management of water resources (Omran and Negm 2020; Abd El-Azeim et al., 2020).

Irrigated agriculture is the principal consumer of freshwater in Egypt, agricultural activities in Egypt munches about 85% of the Nile water budget. What makes matters even worse, surface irrigation is the dominant irrigation system in the old Nile Valley and Delta lands with application efficiency less than 50% triggering large losses of this valuable resource to groundwater (Omran and Negm, 2020; Ouda et al., 2020). Under arid conditions, agricultural production is one of the chief elements contribute to the economic income and food security, despite the accompanying difficulties such as lack of water, low soil fertility, desertification, salinity and low crop yield. These difficulties can be relieved relatively using magnetic treatment of water technology. Extensive agricultural areas in Egypt have arid and semi-arid conditions and severe problems of salinization because of irrigation with low water quality along with poor drainage infrastructures, low soil fertility or nutrients availability. In this regard, irrigation with saline water is compelling farmers of arid areas to devise innovative technologies to reserve crop yield and quality while adopting to degradation natural resources (Hachicha et al., 2018; Ismail et al., 2020).

Among these approaches, research results have conveyed valuable impacts of magnetic field treatments in numerous agricultural circumstances. Irrigation with water magnetic treatment can enhance the root growth of various plant species (Turker et al., 2007). Definitely, studies reported by Esitken and Turan (2004) and Selim and El-Nady (2011) have reported an increase in number of flowers, early and total fruit yield of strawberry and tomatoes with the application of seed and irrigation water magnetic or electromagnetic field treatments. Consequently, food production must increase to meet population growth where feeding Egypt population of 104 million by 2020 is beyond mandates that farmable soil and water quality be restored and enhanced. Under the population increase pressure and food gap in Egypt, the need to reclaim additional soils coerces the country to use all unconventional resources of low-quality water (Abd El-Azeim et al., 2020). The use of saline or brackish water for irrigation in water scarcity areas requires transfer of the innovative technology and sustainable agricultural activities. There is a pressing need for a system technology e.g. magnetic field that can help in increasing productivity of such water (Mohamed, 2013; Abdelhafez et al., 2020).

It is worth mentioning that the magnetized irrigation water had good effects on the availability of NPK all during fertilization season, entail the observed increases in the yield of apricot, grape and peach fruits. Thus, results indicated that the main beneficial of using magnetized water in irrigation were improving yield of these fruits by decreasing soil salinity and raising the efficiency of water productivity (Fanous et al., 2017). The availability of fresh water in the future for fruit agriculture in Egyptian desert sandy soils is difficult due to soil salinity concentration build-up with ground water irrigation at several regions. Now, many farms in the newly cultivated soils were irrigated with saline water from ground wells or treated sewage water, therefore the significance of physical treatment of saline water using magnetic devices become viable.

Therefore, the scientific aim of this work was to investigate the effects of magnetic field treatment on irrigation groundwater quality and in turn impacts of irrigation by magnetized groundwater on soil properties, efficiency on salt removal from saline sandy soil, the availability of main nutrients, as well as water productivity and the yield of peach. To achieve this aim, the objectives of the present work were as following to evaluate suitability of the magnetized groundwater for irrigation, soil moisture distribution, water use efficiency, soil physicochemical properties, peach crop yield and quality parameters.

2. MATERIALS AND METHODS

Field experiment was conducted at a private peach farm (Nahdet Egypt Farms) in Wadi Al Natrun district, Behera Governorate, Egypt, during the agricultural season 2016, on sandy soil irrigated with magnetized and unmagnetized groundwater. Study area and particulars of experimental procedures implemented, materials used and methods adapted during the course of the current research were as following:

2.1. Study area discerption and main water resources.

Depression of Wadi Al Natrun is located at roughly 110 km NW of Cairo as a part of the West Nile Delta of Egypt (longitudes, 30º 02´ and 30º 29´ E and latitudes, 30º 16´ and 30º 32´ N). The total area of Wadi El Natrun is 281.7 Km^2, extended in a NW-SE direction and 23 m below sea level. The underground water origin is seepage from the Nile stream, due to its proximity and low level. Wadi Al Natrun area considered as an extremely arid region where the mean annual rainfall is 41.4 mm, evaporation is 114.3 mm and temperature are 21ºC. The inland salt marshes of the Egypt's Western Desert are found in the form of Sabkhas around the lakes, springs and wells of Wadi Al Natrun (Azzazy and Marco, 2020).

2.2. Experimental design, procedures and treatments.

This research was carried out using randomized complete block design consisted of 24 plots with three replicates. The experimental design included two factors, the first was type of irrigation water including (magnetized and unmagnetized) and the second factor was involved drip irrigation distances i.e., 200, 400- and 600-meters distance. Dripper line 16mm drip lateral line contained one hundred GR-type emitters at 50 cm spacing with the water discharge at 4 Lh^{-1} every irrigation. The magnetic field treatment was applied using AQUA-PHYD treatment device provided by OAKWOODE company with a capacity range of 0.75 T (Tesla).

The magnetic field device was set up on the main source of irrigation groundwater directly from well water. Peach trees have been irrigated by magnetized water (MW) and unmagnetized water (UMW), at the beginning of December 2016 until fruit harvest, through a drip irrigation system with fertigation technique of NPK fertilizers. The drip laterals with drippers were placed at both sides of peach trees. In the meantime, micronutrients are fertilized using spray method. All fertilizers were applied in accordance with recommendations of Ministry of Agriculture, Egypt. The cultivation distance between peach trees are 5x5.

The irrigation took place according to the evapotranspiration in this region, viz. 2mm at December, January and February; 3 mm at March; 5mm at April, May, 7mm at June, July and August and 4mm at September, October and November. Prior to starting of the experimental procedures, magnetized and unmagnetized water samples were collected in three replicates and submitted for physicochemical analyses. Also, soil samples were collected in three replicates at 30-cm depth two times before irrigation and after fruit harvest and submitted for physicochemical analyses. At peach maturity and fruit harvest, three trees at the fixed irrigation distance examined were chosen at random and examined for peach growth and fruit yield quality characteristics. Water productivity was computed as mean fruit yield (kg) per water used (m^3) according to Larcher (1995).

2.3. Soil characteristics analysis.

Soil physicochemical properties of the experimental site must be characterized before and after irrigation with groundwater to protect these newly reclaimed soils from salinity build-up and soil degradation. Accordingly, soil samples were collected from soil surface at 0.0-20, 20-40 and 40-60 cm depth of each plot by excavating soil pits before and after irrigation with magnetized and unmagnetized groundwater. Soil samples were air dried, crushed, and sieved to pass through a 2.0 mm stainless steel sieve. Sieved soil samples were mixed thoroughly and a subsample was taken for soil analyses using standard methods as described by page et al., (1982). Some soil physicochemical properties before seasonal irrigation with magnetized and unmagnetized groundwater are illustrated in Table (1).

Table (1): Soil physicochemical properties of Wadi Al Natrun experimental site.

Particles Size Distribution (%)		Soil Profile Depth (cm)		
		0 – 20	20 - 40	40 - 60
Coarse Sand %		25.55	28.76	27.25
Medium Sand %		43.41	46.38	46.95
Fine Sand %		29.56	23.53	24.53
Silt + Clay %		1.48	1.33	1.27
Soil Texture		Sand	Sand	Sand
Field Capacity %		10.45	10.62	10.74
Wilting Point %		3.64	3.76	3.98
Available Water		6.81	6.86	6.76
Bulk Density (g cm^{-3})		1.55	1.58	1.57
Soil Chemical Properties:				
pH (1:2.5)		7.81	7.79	7.78
EC (1: 5) (dS m^{-1})		2.22	2.18	2.31
$CaCO_3$ g kg^{-1}		9.51	9.62	8.44
Soluble Anions ($mmol_c$ L^{-1})	(HCO_3^- + CO_3^{2-})	1.63	1.33	1.01
	CL^-	14.43	14.36	14.13
	SO_4^{2-}	5.98	5.79	5.68
Soluble Cations ($mmol_c$ L^{-1})	Ca^{2+}	7.98	7.68	7.58
	K^+	0.11	0.71	0.66
	Mg^{2+}	3.42	3.48	3.62
	Na^+	9.92	8.95	8.52
Sodium Adsorption Ration (SAR)		3.83	3.78	3.59

2.4. Groundwater quality analysis.

Magnetized and unmagnetized well water samples were analyzed according to Chapman and Pratt (1961). The chemical composition and criteria of groundwater samples before magnetic treatment are presented in Table (2).

2.5. General analytical procedures.

Details of analytical procedures implemented during the course of this experiment were as following:

2.5.1. Estimation of soil moisture distribution.

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According to Liven and Van Rooyen (1979) method of specifying soil moisture, the following formula equation was applied to measure the moisture: S.M.W = (W1- W2) *100/W2; Where: W1 = weight of the wet soil sample (g). W2 = weight of the oven dried soil sample (g) at 105 ^{0}C for 72 hours. By using "contouring program surfer", we obtained on contouring map for different moisture levels with depths.

Table (2): Chemical composition and criteria of irrigation water in Wadi Al Natrun experimental site.

Chemical Property		Groundwater
pH		7.81
EC (dS m^{-1})		2.48
Soluble Anions (mmolc L^{-1})	(HCO_3^- + CO_3^{2-})	2.82
	CL^-	17.63
	SO_4^{2-}	3.77
Soluble Cations (mmolc L^{-1})	Ca^{2+}	8.03
	K^+	0.07
	Mg^{2+}	2.10
	Na^+	14.03
Chemical criteria:		
Sodium Adsorption Ration (SAR)		6.24
Ca^{2+}/Mg^{2+} Ratio		3.82
Magnesium Hazard (M.H %)		20.73
Na^+/ Cl^- Ratio		0.80
Sodium percentage (Na^{1+}%)		58.19
permeability index (%)		65.02

2.5.2. Determination of water use efficiency.

The water that utilized in the season was calculated by the discharge emitter in the time of irrigation (2 hours) on the day (the irrigation was day after day) and the value of water is multiplied by number of irrigation days. According to Larcher (1995), the water use efficiency "WUE" was calculated as one of the indicators used to calculate the increase of the yield by the following equation: WUE Corn (Kg/m^3) = Total yield (Kg/fed.)/Total applied irrigation water (m^3/fed.)

2.5.3. Determination of fertilizer use efficiency.

According to Barber (1976), fertilizer use efficiency "FUE" was determined for the tested NPK variables by using the following equation: FUE (Kg/kg) = yield (Kg fed^{-1}) /Fertilizer applied (Kg fed^{-1}) for N (NUE), P (PUE) and K (KUE).

2.5.4. Sodium Adsorption Ratio (SAR).

Sodium Adsorption Ratio (SAR) was calculated by the following formula, where the concentrations are expressed in meq/L as reported in Richards (1954).

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{+2} + Mg^{+2}}{2}}}$$

2.5.5. Magnesium Hazard percentage.

Magnesium hazard values can be calculated by the following formula (where the concentrations are expressed in meq/L) (Szabolcs and Darab, 1964).

$$\text{Mg ratio} = \frac{Mg^{+2}}{(Ca^{+2} + Mg^{+2})} X100$$

2.5.6. Permeability Index

The Permeability Index was calculated according to Doneen (1964) by using the following formula, where the concentrations are expressed in meq/L.

$$Pi\% = \frac{(Na^{+1}\sqrt{Hco_3^{-1}})}{(Ca^{+2} + Mg^{+2} + Na^{+1})} X\ 100$$

2.5.7. Sodium Percentage

The percentage of sodium (% Na) was also commonly utilized for assessing the suitability of water quality for irrigation and was calculated using the following formula (Negm and. Armanuos 2017): (The concentrations of ions are expressed in meq/L)

$$Na\ \% = \frac{(Na^{+1} + K^{+1})}{(Ca^{+2} + Mg^{+2} + Na^{+1} + K^{+1})} X\ 100$$

2.6. Statistical analysis.

The obtained results were subjected to analysis of variance using the least significant difference (L.S.D.) test at 5% level of probability using the MSTAT-C v. 1.42 for completely randomized block design with three replicates. Significance of the differences was estimated and compared using Duncan test at 5% level of probability ($p < 0.05$).

3. RESULTS AND DISCUSSION

Results of this study were divided into two main aims; the first aim was to study impacts of the magnetic water treatment on the physicochemical characteristics of the magnetized groundwater qualities for irrigation. The second aim was to determine the application the impacts of irrigation with magnetized and unmagnetized groundwater on soil properties, water use efficiency and productivity and peach fruit quality and productivity. In particular, the results of this field study are presented under these main headings.

3.1 Effects of magnetic field treatment on irrigation groundwater quality.

Irrigation water quality was assessed mainly by pH, soluble salt content (EC), main soluble anions and cations, sodium adsorption ratio (SAR), Ca^{2+}/Mg^{2+} Ratio, Magnesium Hazard (MH%), $Na^{+}/\ Cl^{-}$ Ratio, Sodium percentage (Na%) and permeability index (%). Results of effects of magnetic field treatment on chemical composition and water suitability criteria for irrigation (Average of 30 groundwater samples during irrigation events) are presented in Table (3).

3.1.1. Effects of magnetic treatment on irrigation groundwater chemical composition.

Results of this research indicated that groundwater pH was significantly increased from 7.81 to 7.92 directly after magnetic field treatment (Table, 3). An increase in magnetized groundwater's pH was recorded up to 0.11 pH units compared to the non-magnetically treated distilled water (Hassan, 2015). Several researches informed changes in the pH of magnetized irrigation water, nevertheless these researches have displayed variable results. Water hydrogen ion activity (pH) is rarely a problem itself but it is an indicator of nutrient availability and solubility for plants. The main use of pH in a water analysis is for detecting an abnormal water, which may cause a nutritional imbalance or may contain toxic ions and as a result needs further appraisal

(Abd El-Azeim et al., 2020). The magnetic process can change the pH of water (Ageeb, et al., 2018). Irrigation water normal pH ranges from 6.5 to 8.4, therefore using Wadi Al Natrun water source in soil irrigation may not cause a nutritional inequality or soil pH sequential changes (Karkush, et al., 2019; Ben Hassan, et al., 2020). In general, it is imperative to evaluate irrigation water source and quality to determine its suitability for irrigation of plants so that avoid the occurrence of problems related to irrigation water quality.

Table (3): Effects of magnetic treatment on irrigation groundwater chemical composition and suitability criteria for irrigation.

Water Property			
Water Chemical Properties:		Wadi Al Natrun	
		Unmagnetized Water	Magnetized Water
pH		7.81a *	7.92b
EC (dS m^{-1})		2.48a	2.49a
Soluble Anions (mmolc L^{-1})	$(HCO_3^- + CO_3^{2-})$	2.82	2.80
	CL^-	17.63	17.65
	SO_4^{2-}	3.78	3.84
Soluble Cations (mmolc L^{-1})	Ca^{2+}	8.03	8.05
	K^+	0.07	0.06
	Mg^{2+}	2.10	2.12
	Na^+	14.03	14.06
Water Suitability Chemical Criteria for Irrigation:			
Sodium Adsorption Ratio (SAR)		6.24a	6.24a
Ca2+/Mg2+ Ratio		3.82a	3.80a
Magnesium Hazard (M.H %)		20.73a	20.85a
Na+/ Cl- Ratio		0.80	0.80
Sodium percentage (Na%)		58.19a	58.13a
permeability index (%)		65.02a	64.92b

* Figures followed by the same letters through entire rows are insignificantly different (p>0.05).

Concerning total dissolved salts and electrical conductivity, irrigation water chemical analysis of the investigated groundwater showed insignificant differences of total dissolved salts (1589 to 1594 mg L^{-1}) and electrical conductivity (2.48 to 2.49) between magnetized and unmagnetized water, respectively. Although, these rates were much higher than those of the Nile water (TDS, 186 mg L^{-1} or E.C, 0.258 dS m^{-1}) (Abd El-Azeim et al., 2020). Concerning salinity problems in relation to irrigation water quality, as described by Ayers and Westcot (1994), the electrical conductivity for irrigation water was in the range of

0.7 to 3 which lies under the degree of restriction on use "Slight to Moderate", indicating that using such irrigation water may augment salinity problem of the investigated soil in the future. Variations in E.C and TDS between magnetized and unmagnetized irrigation waters are mainly affected by magnetic field treatment and recharging and exploitation different rates through the irrigation season (Ageeb, et al., 2018).

It was found that the magnetic treatment does affect the TDS and pH of different solutions according to the magnetizer used. The effect of the magnetizer was to increase insignificantly TDS but significantly increased pH of water. These effects hinge on the time of exposure to the magnetic field and magnetic field strength (Abobatta, 2019). The results of this study showed that magnetized water plays an important role in soil soluble salts in comparison to normal groundwater resulting in increased removal of salts from the investigated sandy soil. Commonly, when water is subjected to magnetic field, the water molecules will arrange in a mode of one direction caused by relaxation bonds. At that time the bond angle decreases to less than 105º leading to decrease in the consolidation degree between water molecules, and increase in size of molecules (Omran and Negm 2020). Accordingly, the viscosity of magnetic water is less than viscosity of normal water. This change in water molecules composite causes a change in permeability pressure, surface tension, pH and electric conduction (Abobatta, 2019; Da Silva et al., 2019). In addition, water becomes more volatile as a result of magnetic processing due to the weakening of the hydrogen bonds between its molecules causing more solvent power of magnetized water (Guo, et al., 2012; Karkush, et al., 2019). Fanous et al., (2017) assumed that the decrease in soil pH is owing to the effect of magnetic field treatment on soil organic matter where it releases relatively more organic acids in rhizosphere.

Unmagnetized or magnetized groundwater samples under investigation in general have Na/Cl ratios that are lower than one (unmagnetized = 0.795 and magnetized = 0.796), implying little effect of sodium and chloride in both samples. Soluble sodium toxicity in soil solutions is dissimilar to chloride toxicity being not easily diagnosed. Chloride content is very important for groundwater suitability for irrigation purposes where chloride ions are toxic and most plants are very sensitive for chloride in irrigation water. In addition, chloride ions are very strongly absorbed by plants compared to other ions and certain plants have the ability to accumulate chlorides even from water with low chloride content (Atta et al., 2007).

Bicarbonate plus carbonate concentrations in unmagnetized and magnetized groundwater were in the range of 2.80 – 2.82 $mmol_c$ L^{-1} which lies under the degree of restriction on use "Slight to Moderate", indicating that using such water in peach irrigation may cause white scale formation problem on leaves or fruit when sprinklers are used or emitters blockage when drip irrigation is used. Results of this study indicated that, although there was no superficial plant toxicity happened, drip emitters were subjected to deposits accumulating near small openings, resulting in some emitters blockage. Research data

agree with that reported by Hachicha et al., (2018); Ben Hassan, et al., (2020). One technique nowadays to avoid or exact a deposit problem is to use magnetized groundwater and drip irrigation method to reduce soluble salts in the plant root zone. The physical treatment technology of water by a magnetic field with very low intensities and frequency, give rise to restructure adjusted water able to dissolve and transport salts. Water treatment with electromagnetic field permits irrigation with brackish water without any harmful influences on crops (El-Gindy, et al., 2018; Ismail et al., 2020).

3.1.2. Effects of magnetic treatment on suitability of chemical criteria of water for irrigation.

Sodium adsorption ratio (SAR) value of both magnetized and unmagnetized groundwater was the same (6.24) indicating no change after applying magnetic field treatment (Table, 3). Irrigation water magnetized or unmagnetized SAR value (6.24) lies under the degree of restriction on use "None" implying that using such water in peach irrigation may not cause a sodium toxicity or soil infiltration problems in the investigated sandy soil as designated by Ayers and Westcot (1994). Hachicha et al., (2018) stated that implementation of physical treatment technology of water by a magnetic device, license to recreate a structure of natural and optimized water in its ability to dissolve soil salts and transport nutritious minerals. Magnetic irrigation water treatment allows irrigation with saline water without any detrimental impacts on crops.

Soil productivity is reported to be low on high magnesium soils or on soils being irrigated with high magnesium water due to a magnesium-induced calcium deficiency caused by high levels of exchangeable magnesium in soils albeit infiltration problems may not be evident. The general conclusions based on previous literature review is that the relative order of deleterious effects of soluble cations concentrations in irrigation water upon soil properties of soil main cations is Na> K> Mg> Ca (Smith et al., 2015; Ben Hassan et al., 2020).

It is important to assess irrigation water source to determine its suitability for irrigation of plants so as to avoid the occurrence of problems related to irrigation water quality. Calcium role in crops appears to reduce possible toxicities due to other ions such as Na^+ and Mg^{2+} in the root zone environment. If the Ca^{2+} / Mg^{2+} ratio is near or less than 1, the uptake and translocation of Ca^{2+} from a soil-water to above-ground parts of a crop are diminished due to antagonistic effects of high magnesium or competition for absorption sites to such an extent that less calcium is absorbed. Natural water contains particles charged in the form of positive and negative ions. Taking into account this fact, various studies related to the effectiveness of the magnetic field (MF) on the calcium carbonate precipitation in the presence of different ions were done (Hotysz, et al., 2003).

Results of this study showed that magnesium hazard index increased insignificantly from 20.73% to 20.85 % after magnetic field treatment. According to magnesium hazard index, investigated magnetized or unmagnetized groundwater are suitable for irrigation where irrigation water with magnesium hazard greater than 50 % is considered unsuitable and very dangerous on most agricultural crops and cultivated lands. In addition, high levels of Mg^{2+} in irrigation water increase magnesium hazard index due to increased exchangeable Na^{+} in irrigated soils and this might cause damage for soil structure and affects crop yields and soil quality by increased alkalinity.

It is known that sodium and chloride are some of the most undesirable ions in soil as they have very strong negative impact on plant growth and yield and this is particularly true with peach trees which are unusually sensitive to salinity, chloride, and sodium when compared to other fruit species. To escape sodium and chloride accumulation most growers periodically use low salt content water to leach salts below root zones, where Cl^{-} concentrations exceed 10 mg L^{-1} lies under degree of restriction on use " Severe " implying that using such water in the plant's irrigation may cause a Chloride toxicity problem as described by Ayers and Westcot (1994). In the case of chloride toxicity problem related to irrigation water quality, chloride concentration increased from 17.63 to 17.65 after using magnetic treatment. This value was more than 10.0 mg L^{-1} which lies under the degree of restriction on use "Severe", indicating that using this groundwater magnetized or not for plant irrigation may cause an increasing chloride toxicity problem. In addition, Na concentrations exceeded 9 mg L^{-1} lies under the degree of restriction on use " Severe " implying that using such water in peach farming irrigation may cause a sodium toxicity problem as described by Ayers and Westcot (1994). As well as in the case of sodium toxicity problem related to irrigation water quality, sodium concentration increased from 14.03 to 14.06 this value was more than 9 mg L^{-1} which lies under the degree of restriction on use "Severe", indicating that using this groundwater for peach irrigation may cause an increasing sodium toxicity problem. There was also no change in Na^{+}/ Cl^{-} ratio even after using magnetic treatment, and the ratio was 0.8 in both.

The percentage of sodium (Na %) is also commonly utilized for assessing the suitability of water quality for irrigation (Wilcox 1948). In groundwater, the increase of sodium concentration generates undesirable effects as the sodium reacts with the soil in order to decrease the permeability of soil and growth of plants (Vasanthavigar, et al., 2010). Results in Table (3) indicated that the level of (Na%) was decreased after using magnetized water from 58.19 % to 58.13 %, which is within the permissible limits. Magnetic treatment may be to assist reducing 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 (Maheshwari and Grewal 2009). The permeability was decreased by magnetic field treatment from 65.02 % to 64.92 % and according to Doneen (1964) values of PI, groundwater can be classified in to class II (25–75%) classified as good water for irrigation.

The groundwater analysis for both magnetized and unmagnetized showed that Cl > Na > Ca > SO_4 > (HCO_3 + CO_3) > Mg > K is the dominant facies. Groundwater is the main source of agricultural irrigation water in Wadi Al Natrun region. The increase of human activities in Wadi Al Natrun region resulted in overexploitation of groundwater from available aquifers which is accelerated also by land reclamation projects while poor recharge of groundwater. Therefore, sustainable development in this area is governed by availability and quality of groundwater resources. Regardless of the ability of magnetic field treatment to slightly change chemical composition and criteria of magnetized water than in unmagnetized groundwater, however, the suitability categories of magnetized water still located at the same classes of unmagnetized water. However, under the conditions of this study when magnetized water was used in irrigation, soil properties and crop productivity were changed significantly compared to irrigation with unmagnetized water. Magnetic water treatment does not change chemical parameters of water. however, it changes physical parameters and according to some authors, magnetic fields have effect on reduction of surface tension, viscosity, zeta potential, solubility, and diffusion (Cho and Lee, 2005; Chang and Weng, 2006).

3.2 Impacts of magnetic treatment on water and fertilizer use efficiency and peach crop productivity.

Water use efficiency (WUE, kg kg^{-1}) and productivity were assessed mainly by moisture content in root zone, irrigation system application efficiency, while fertilizer use efficiency was assessed (FUE, kg kg^{-1}) by nitrogen use efficiency NUE (kg kg^{-1}), phosphorus use efficiency PUE (kg kg^{-1}) and potassium use efficiency KUE (kg kg^{-1}). Whereas, peach crop productivity was assessed mainly by both water and fertilizer use efficiency as indicators used to evaluate peach crop yield production and profitability. It was hypnotized that irrigation with magnetized water will increase water and fertilizer use efficiencies and consequently crop yield compared to irrigation with unmagnetized groundwater. Results on the effect of magnetic field treatment on these properties after irrigation with magnetized and unmagnetized groundwater are presented in Table (4).

Table 4: Effects of magnetized water on fertilizer and water use efficiency and productivity.

Treatment	$T_{0(control)}$	$T_{1(200)}$	$T_{2(400)}$	$T_{3(600)}$
Moisture content in root zone%	9.45 c*	12.03 a	11.17 b	10.15 d
Application efficiency %	45.93	77.95	74.93	72.87
Water use efficiency WUE (kg m^{-3})	5.97 c	7.49 a	7.30 b	6.41 d
Nitrogen use efficiency NUE (kg kg^{-1})	8.24 c	10.12 a	10.07 a	10.00 a
Phosphorus use efficiency PUE (kg kg^{-1})	8.63 c	10.17 a	10.56 a	10.48 a
Potassium use efficiency KUE (kg kg^{-1})	8.28 c	10.17 a	10.12 a	10.04 a

* Figures followed by the same letters through entire rows are insignificantly different (p>0.05).

Results of this study showed that when irrigated with magnetized water, soil moisture content in root zone was significantly increased from 9.45 for control treatment (irrigated with unmagnetized water) to 12.03 % in the first 200 m irrigation distance from the magnetic field device. Moisture content in root zone was significantly increased as the irrigation distances increased from 0 to 200 m distance and was significantly decreased as the irrigation distances increased from 200 to 400 m and 600 m distances (Table, 4). This indicates that the effect of magnetizing irrigation water decreases with increasing the irrigation distance from the magnetic device at the head of the field. As water and fertilizers use efficiency is based on the amount of NPK fertilizers and water required to produce the yield. Thus, the efficiency of water productivity and N use efficiency for peach (Table, 4) were increased from 5.97 and 8.24 before magnetic treatment to 7.49 and 10.12%, respectively. Fanous et al., (2017) stated that a plant's metabolism contains of 90-95% water, therefore irrigation with magnetized water increases water uptake and enhances plant metabolism and crop productivity.

higher distribution uniformity causing increased water and fertilizers use efficiencies and consequently peach crop yields and quality parameters. The results showed that the dripper discharge average is influenced by type of irrigation water (magnetized and unmagnetized) and drip irrigation distances (200, 400 and 600m) from the magnetic treatment device.

3.2.1. Effects of magnetized water on uniformity of soil moisture distribution.

Results of this study showed that wetted soil volume more than or equal 100% from field capacity in root zone ($WSV_{\geq 100\%FC}$) (moisture content in root zone) was significantly increased in plots irrigated with magnetized water compared to control treatment. ($WSV_{\geq 100\%FC}$) in root zone decreased insignificantly as the irrigation distances increased from the magnetic device. All the restrained soil moisture contents for the magnetized and control treatments were evaluated using Surfer Software (Golden Software, Inc., Golden, CO). Moisture content in soils is the key element to evaluate efficiency of surface drip irrigation systems where the moisture content depends on emitters discharge amount and clogging rates.

Effects of magnetic water on wetted soil volume more than or equal 100% from field capacity in root zone ($WSV_{\geq 100\%FC}$) was determined by calculating the wetted soil volume surrounded by contour line 10.6 which approximately representing the field capacity. The wetted soil volume surrounded by contour line 10.6 turned to uniform volume. Figures (1, 2, 3 and 4) showed the relation between magnetized water and unmagnetized water and average the taller design drip irrigation on wetted soil volume "$WSV_{\geq 100\%FC}$ " in root zone and also illustrate the effect of magnetized water on moisture content in root zone " MCRZ" under magnetized water.

$WSV_{\geq 100\%FC}$ at magnetized water under (control unmagnetized) was too small at control. the average of maximum width for contour line 10.6 from the emitter to 25 cm length was 4.2 cm and maximum depth was 21.32 cm, this mean the area of $WSV_{\geq 100\%FC}$ was 89.54 cm^2 and average of maximum width for contour line 10.6 cm from the emitter across lateral was 41.45 cm hence, $WSV_{\geq 100\%FC}$ was 3711.43 cm^3

$WSV_{\geq 100\%FC}$ at magnetized water under (200 m) was the average of maximum width for contour line 10.6 from the emitter to 25 cm length was 5.20 cm and maximum depth was 55.34 cm, this mean the area of $WSV_{\geq 100\%FC}$ was 287.77 cm^2 and average of maximum width for contour line 10.6 cm from the emitter across lateral was 21.78 cm hence, $WSV_{\geq 100\%FC}$ was 6267.63 cm^3.

$WSV_{\geq 100\%FC}$ at magnetized water under (400 m) was the average of maximum width for contour line 10.6 from the emitter to 25 cm length was 4.9 cm and maximum depth was 38.64 cm, this mean the area of $WSV_{\geq 100\%FC}$ was 189.34 cm^2 and average of maximum width for contour line 10.6 cm from the emitter across lateral was 31.98 cm hence, $WSV_{\geq 100\%FC}$ was 6054.96 cm^3.

$WSV_{\geq 100\%FC}$ at magnetized water under (600 m) was the average of maximum width for contour line 10.6 from the emitter to 25 cm length was 4.46 cm and maximum depth was 35.30 cm, this mean the area of $WSV_{\geq 100\%FC}$ was 157.44 cm^2 and average of maximum width for contour line 10.6 cm from the emitter across lateral was 37.30 cm hence, $WSV_{\geq 100\%FC}$ was 5872.44 cm^3

Results showed that, for irrigation with unmagnetized water treatments (control), wetted front area and wetted soil volume up to the final irrigation were 89.54 cm^2 and 3711.43 cm^3 reflecting low water application efficiency of 45.93%, while wetted front area and wetted soil volume were 287.77 cm^2 and 6267.63 cm^3 reflecting high water application efficiency of 77.95%, for irrigation with magnetized water at drip irrigation distance of 200m from the magnetic device. Also, wetted front area and wetted soil volume were 189.34 cm^2 and 6054.96 cm^3 reflecting high water application efficiency of 74.93%, for irrigation with magnetized water at drip irrigation distance of 400m, respectively. Soil wetted front area and wetted soil volume were 157.44 cm^2 and 5872.44 cm^3 reflecting low water application efficiency of 72.87%, for irrigation with magnetized water at drip irrigation distance of 600m, respectively. The differences influenced by the magnetic field treatment rely on numerous parameters, including magnetic field strength, path of magnetic field, time of magnetic contact, solution discharge, irrigation distances and pH (Khoshravesh et al., 2018). Irrigation with magnetized water showed high significant influence on soil wetted front area and wetted soil volume reflecting high distribution uniformity and water application efficiency compared to control (irrigation with unmagnetized water).

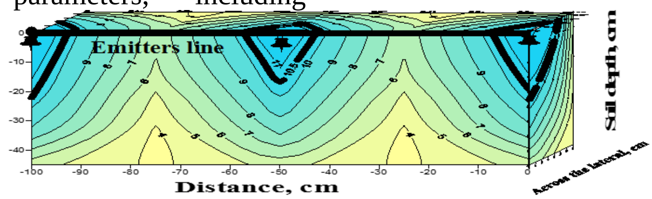

Figure (1). Three dimensional soil moisture distribution and wetted soil volume with (un magnetic water controal .

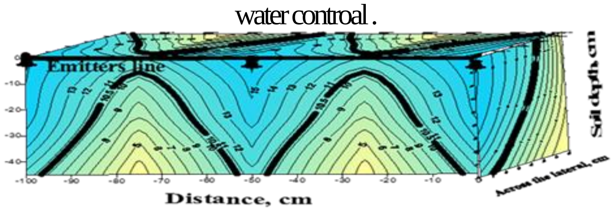

Figure (2).Three dimensional soil moisture distribution and wetted soil volume with (magnetic water and 200 m).

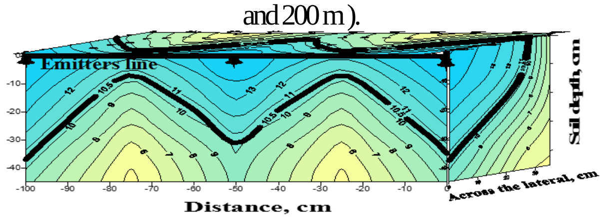

Figure (3). Three dimensional soil moisture distribution and wetted soil volume with (magnetic water and 400 m).

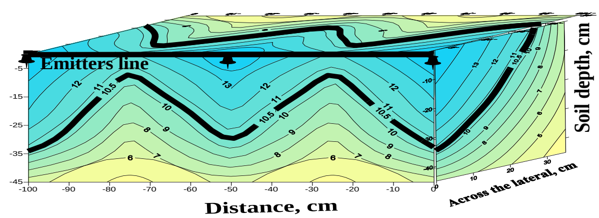

Figure (4). Three dimensional soil moisture distribution and wetted soil volume with (magnetic water and 600 m)

Finally, soil moisture content, uniformity of water distribution and emitters discharge variations in drip irrigation increased with irrigation by magnetic water compared to unmagnetized water. Therefore, the use of magnetized water for drip irrigation is recommended to achieve higher moisture distribution uniformity and emitters discharge and consequently increase in the crop yields and productivity. Khoshravesh et al., (2018) stated that dripper discharge and distribution uniformity were higher for drip irrigation with magnetic water compared to non-magnetic water. The magnetic water showed a significant effect ($P \leq 0.01$) on distribution uniformity of drippers. Limited or comprehensive dripper clogging causes lower water application uniformity and therefore declines crop production and irrigation efficiency (Khoshravesh et al., 2018). These results indicated that distribution uniformity of soil moisture, moisture content in root zone % and accordingly peach crop yield per unit of water or NPK fertilizers required are significantly influenced by type of irrigation water (magnetized and unmagnetized) and drip irrigation distances (200, 400 and 600m) from the magnetic treatment device. This data signpost increased available water in a such coarse textured sandy soil and high solubility of nitrogen, phosphate and potassium under the influence of the magnetic treatment, showing clear influence of the magnetic treatment on the increase in water availability and nutritional solubility and accordingly peach crop yield.

3.3 Impacts of irrigation with magnetized water on the investigated sandy soil properties.

Results on the effects of magnetized water on the investigated sandy soil properties are presented in Table (5). Sandy soil properties assessed mainly by changes in soil pH, soluble salt content (EC_e), main soluble cations and anions, and sodium adsorption ratio (SAR) and some soil physical properties such as field capacity.

In general, main high significant impacts observed of magnetic field treatment on the investigated sandy soil are the removal of excess soluble salts away from the root zone, increasing soil pH values, and the dissolving of soluble cations and anions such as chloride, carbonates, sodium and sulfates. It is known that sodium and chloride are some of the most undesirable ions in soil as they have very strong negative impacts on plant growth and yield. The results shown in Table (5) showed that irrigation with the magnetically treated water has a positive effect on reducing sodium and chloride in the root zone of the investigated sandy soil. Results also showed that, levels of mean soil soluble cation and anions measured in the soil irrigated with magnetized saline water were highly less than the soil irrigated with unmagnetized saline water in the root zone area. In addition, a significant decrease in soil salinity in terms of electrical conductivity (EC) and sodium adsorption ratio (SAR) in soils irrigated with magnetically treated saline water was observed. These significant changes are probably happened due to the changes in the arrangement of water molecules and polarization caused by the magnetic field treatment (Amer et al., 2014). Also, the magnetic field treatment might change hydrogen bonds between water molecules and rebuilt them in hexagonal structure consequently increased the leachability of the soluble salts. This may indicate the higher efficiency of magnetized water in leaching soluble salts from the soil profile compared to unmagnetized water. Several researchers confirmed that the magnetized water increased solubility and leachability of salts from the soil profile (Amer et al., 2014; Hilal et al., 2013).

Table (5): Impacts of magnetized water on the investigated sandy soil properties.

		Soil irrigated with Magnetized Water			**Soil irrigated with Unmagnetized Water**		
Irrigation distance (m)		0 – 100	100 – 200	200 - 300	0 - 100	100 - 200	200 - 300
Field Capacity %		12.66a	12.56a*	12.43a	10.52b	10.45b	10.32b
Wilting Point %		3.22a	3.36a	3.44a	3.56a	3.68a	3.59a
Available Water		9.44a	9.20a	8.99a	6.96b	6.77b	6.73b
Bulk Density g/cm^3		1.49	1.51	1.45	1.59	1.55	1.58
Soil Chemical Properties:							
pH (1:2.5)		7.79	7.75	7.06	7.97	7.88	7.11
EC (1:5) (dS m^{-1})		1.01a	1.08a	1.91a	2.65b	2.63b	2.59b
$CaCO_3$ g kg^{-1}		5.44a	5.55a	4.97b	9.52c	9.61c	8.46c
Soluble Anions (mmol$_c$ L^{-1})	(HCO_3^-+ CO_3^{2-})	0.98	0.95	1.12	1.66	1.45	1.04
	CL^-	5.88a	6.63a	12.22b	18.28c	18.07c	18.46c
	SO_4^{2-}	2.55	2.37	3.22	5.01	5.41	5.55
Soluble Cations (mmol$_c$ L^{-1})	Ca^{2+}	2.43	3.55	5.52	11.52	11.35	11.57
	K^+	0.24	0.16	0.82	0.19	0.11	0.09
	Mg^{2+}	2.32	2.02	1.94	3.33	3.41	3.55
	Na^+	4.82a	4.88a	7.51b	10.46c	10.44c	10.43c
Sodium adsorption ratio (SAR)		3.13a	2.92a	3.89b	3.85b	3.84b	3.79b

* Figures followed by the same letters through entire rows are insignificantly different at <5% probability level.

4. CONCLUSIONS

Assessment of groundwater quality for irrigation is very important for newly reclaimed desert lands that contingent mainly on the groundwater as a principal source. The available studies and application of the magnetic technology for irrigation water treatment in the Egyptian agriculture is very limited. Based on the experiments conducted in this study and on the results obtained herein, no significant changes in properties of magnetized groundwater from unmagnetized water were observed by magnetic field treatment, nevertheless water use efficiency and productivity, NPK fertilizers use efficiency and peach crop production were increased significantly when irrigated with magnetized water. Future studies and applications are needed in this field to understand impacts of magnetic field orientation and magnitude on groundwater quality to maximize the benefits of the abundant saline groundwater in Egypt. In addition, field studies are needed to determine the magnetically treated saline water impacts on different crops with different types of soils under different areas of arid conditions.

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الري بالمياه الممغنطة يعزز كفاءة استخدام المياه والأسمدة وإنتاج الخوخ في ظل الظروف القاحلة.

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يمكن أن يكون الري بالمياه الممغنطة تقنية مفيدة في مجال الزراعة في ظل الظروف القاحلة. أجريت تجربة حقلية لدراسة تأثير المعالجة المغناطيسية على جودة المياه الجوفية للري، وبالتالي تأثير المياه الممغنطة على خصائص التربة الرملية المروية وإنتاج محصول الخوخ تحت الظروف الصحراوية. أشارت نتائج هذه الدراسة إلى عدم وجود تغيرات معنوية في معايير ملاءمة المياه للري سواء للمياه الممغنطة أو غير الممغنطة بعد المرور بالمجال المغناطيسي.

ومع ذلك، أدى الري بالمياه الممغنطة إلى زيادة كبيرة في كفاءة استخدام المياه والأسمدة والإنتاجية وبالتالي زيادة غلة محصول الخوخ عن الري بالمياه غير الممغنطة. أظهرت نتائج هذه الدراسة أنه عند الري بالمياه الممغنطة، زاد محتوى رطوبة التربة في منطقة الجذر بشكل كبير من 9.45٪ لمعاملة الكنترول إلى 12.03٪ في أول 200 متر مسافة الري من جهاز المجال المغناطيسي. أيضا انخفض المحتوى الرطوبي في منطقة الجذور بشكل كبير عندما زادت مسافات الري من 200 إلى 400 و600 متر. مما يشير إلى أن تأثير المجال المغناطيسي على مياه الري يقل مع زيادة مسافة الري من الجهاز المغناطيسي على رأس الحقل. على النقيض من ذلك، انخفضت انسداد المنقطات بشكل كبير من 12.5٪ لمعاملة الكنترول إلى 8.21٪ في أول مسافة للري 200 متر من جهاز المجال المغناطيسي. يمكن الاستنتاج أن استخدام التكنولوجيا المغناطيسية لمعالجة المياه الجوفية في المناطق القاحلة يزيد من إمكانية استخدام المياه المالحة للري بشكل آمن على المدى الطويل.

الكلمات المفتاحية: تكنولوجيا المياه المغناطيسية، المياه الممغنطة، معايير الملاءمة.