Effect of magnetic strength of the water salinitytreatment devices on salt accumulation in the root zoon and its impact on growth and productivity of olive trees

Abstract: This study was conducted during the two successive seasons 2022and 2023at Wadi El-Natron west Nile Delta (EL-Behera governorate) to evaluate three commercial magnetic devices“Water magnetizers”of different manufacturers (Nefertari Biomagnetic 6000 Gauss, Magnolith 8000 Gauss, Delta Water 14000 Gauss), and to figure out which is more effective to reduce the negative effect of irrigating olive trees with saline water.The study examined the effect on vegetative growth, leaf mineral contents, leaf chlorophyll content, leaf proline content, and relative water content of Manzanillo olive trees.The experiment confirmed that olive trees can be irrigated with water containing 3500 ppm without causing high salt stress.Data also showed a positive effect of magnetically treated water on all vegetative growth characters (growth rate, stem diameter, number of green leaves), an increase in all elements content in experimental plant leaves except sodium and chloride, an increase in leaf chlorophyll content, decreased leaf proline content and increase relative water content. In terms of determining whether commercial devices are more effective than others, the Magnolithhas been demonstrated to achieve the best results when compared to other devices, in most cases the difference between using "Delta Water" or "Nefertari" was not big enough to be significant. "Nefertari"recorded almost the lowest values of the studied vegetative growth characters, leaf chlorophyll, and relative water content.This indicates that the strength of the magnets alone is not the only thing that affects how well the device works; furthermore, it depends also on how the magnetic fields are configured and the manufacturing expertise.

Keywords: Olive**,** magnetically treated irrigation water**,** survival percentage, vegetative growth, leaf mineral contents, leaf chlorophyll content, leaf proline content**.**

INTRODUCTION

Salinity in the soil becomes a problem when the total amount of salts that accumulate in the root zone reaches a level that negatively affects soil structureand plant growth. Salinity can affect plants in three different ways: osmotic stress, specific ion toxicity, and nutritional imbalance.Salty solutions have a higher boiling and lower freezing point than pure water, which means that more energy is needed to produce steam or ice when salts are present. Similarly, a plant must expend more energy to obtain water from the soil if sufficient salts are present to affect the osmotic potential (Leogrande *et al.*, 2012). In 2010, (Ruiz *et al.*)studied the effects of salinity on the growth of young olive trees,plants that were one year oldwere planted in 30L pots, the osmotic potential became more negative when salt concentrations increased, cultivars showed symptoms of toxicity in leaves and shoots which indicates that they accumulate toxic ions in the youngest leaves.High salinity levels induce ionic imbalance given higher Na^+ and Cl^- concentrations in leaves and roots. Because of the accumulation of these ions, the K^+ concentration decreased resulting in a low ratio of K^+/Na^+.

In addition, saline stress has a significant impact on Photosystem II (PSII) by impeding the disintegration of water molecules to obtain the necessary electrons for photochemistry, which diminishes the maximum quantum yield (Parkash & Singh, 2020, Chaudhry *et al.*, 2021).

Some efficient strategies to overcome salinity problems were: 1-leach salts out of the root zone using suitable irrigation management to prevent the accumulation of the salt within the soil profile(Liu *et al.*, 2024, Ayars & Corwin, 2024), 2-Blending saline water with less-saline water(Hanson *et al.*, 1991, Tyagi, 2003), 3-Mulching treatment(Kaswala *et al.*, 2012, Alharbi, 2015), 4-Implementing subsurface irrigation systems(Al-Amoud, 2010, El-sayed & El-Hagarey, 2014), 5-Planting higher salt tolerance cultivars(Walker *et al.*, 2002, Anjum, 2008, Roy *et al.*, 2014), 6- Application of some saline correctors, such as salicylic acid (Borsani *et al.*, 2001), humic substances tend to regulate soil pH and soil salinity and help to retain organic matter in the surface layer, meanwhile the salt content is leaching out from the surface layer accumulating in the layers below(Sandor, 2011), and foliar application by ascorbic acid(Aliniaeifard *et al.*, 2016).

Passing the irrigation water through the permanent magnets or the electromagnets installed in/on a feed pipelinealters several physical characteristicsof the water(Kotb, 2013, Hasaani *et al.*, 2015, Hołysz *et al.*, 2002, Cho *et al.*, 2003). Bogatin *et al.* (1999)concluded that magnetic water treatment enhances root layer conditions by (1) removing excess salts, (2) improving irrigated water permeability, and (3) improving mineral fertilizers dissociation.According to Hilal and Hilal

(2000), magnetic treatment of saline irrigation water can be employed as an effective method of soil desalinization. The application of a magnetic field to water reduced the hydration of salt ions and colloids, improving salt solubility, and accelerating coagulation, and crystallization.Mostafazadeh-Fard *et al.* (2011)used a trickle irrigation method in an experimental field. The results showed that magnetized irrigation water treatments reduced soil sulfate ions by up to 37.3 percent when compared to non-magnetized irrigation water treatments. The reduction of soil sulfate ions decreased the likelihood of calcium sulfate precipitation in the soil and increased the likelihood of salts draining from the soil profile, resulting in better soil conditions for plant growth.Al-Busaidi and Ullman (2014) irrigated grass with a sprinkler irrigation system and discovered that soil samples collected from magnetized sites had lower salt than soil samples taken from non-magnetized locations. They concluded that magnetic treatment of irrigation water aids leaching by increasing salt solubility.Todeshki et al. (2015) and Ahmed and Abdelkader (2016)investigated how salinity in the soil was affected by magnetic irrigation water. They noticed that, at various depths, irrigation with magnetic water resulted in much lower EC values than irrigation with non-magnetic water.

According toHachicha *et al.* (2016), soil salinity (ECe) as well as $Na^+$and Cl^- contents of soils irrigated with electromagnetically treated saline water decreased significantly when compared to soils irrigated with non-treated saline water.Ahmed and Abdelkader (2016)investigated how potato (Solanum tuberosum L.) var. Diamont growth was affected by magnetic irrigation water (water passed througha 1000-gauss magnetron unit). The application of magnetic water raised plant height, leaf area, leaf number, haulm fresh, and dry weights much more than non-magnetic water, according to the results. However, the main stem number was unaffected in either season.Hachicha et al. (2016)observed that electromagnetic treatment had a significant effect on the accumulation of Na^+ in Spuntapotatoes. It decreased the toxicity in all tissues. However, the electromagnetic treatment of saline water increased significantly K+, N, and P adsorption in all tissues of the potato and decreased significantly the adverse effects of saline water.Abdelwahed (2017)found that magnetically treated water had a positive impact on all vegetative growth characteristics (growth rate, stem diameter, and number of green leaves), as well as an increase in all element content in experimental plant leaves(olive, fig, and pomegranate) except sodium and chloride, increase leaf chlorophyll and relative water contents.

Touati *et al.* (2023) carried out a field experiment to examine the impact of magnetized irrigation water on the growth of Arbequina olive trees under drip irrigation with saline water. They discovered that the treatment of irrigation water with electromagnetic energy elevates soil moisture levels and facilitates the absorption of nutrients, including N, P, K+, and Na+, by the leaf tissues of the olive tree. Additionally, the water use efficiency (WUE) in the plot irrigated with treated water was found to be 1.3 times higher than that of the plot irrigated with untreated water. Consequently, there was a 30% improvement in yield when using treated water.

On the other hand, the most important question for customers is whether or not the magnetic water treatment devices work as advertised or not. The primary topic of this article focuses specifically on three commercial water conditioners from different manufacturersthat are tested scientificallyunder the same conditions. The investigation is done in an olive farm where high-salinity well water is used to irrigate the trees.

MATERIALS AND METHODS

The present study was conducted during the 2022 and 2023 growing seasons at Wadi El-Natron West Nile Delta (EL-Behera governorate), Egypt (longitude 30°29'16"N & latitude 29°53'43"E). The study was carried out on five-year-old trees of "Manzanillo" spaced at 6×6 growing in loamy sand soil and irrigated with underground water having a salinity level of approximately 3500 ppm. The soil was kept free of weeds through the use of herbicides. The trees in the study had a single trunk with branches ranging from 0.6 to 0.7 meters above the ground. The experiment included three magnetic devices for the treatment of irrigation water, one supplied by Nefertari Biomagnetic (Egypt) with a strength of approximately 6000 Gauss, the second supplied by "Magnolith" EWL Umwelttechnik GMBH, a German company, consisting of a series of permanent magnet pairs with north and south poles, and 88 cascaded magnetic fields with alternating strengths of 4500-8000 Gauss. The third device was supplied by Delta Water (Egypt) and had a strength of approximately 14500 Gauss (1.45 Tesla).

The initial and final lengths of the trees in centimeters were measured at the beginning and the end of each experimental season, and the growth rate was calculated according to the following equation:

$$Growth\ rate = \frac{Final\ length - Initial\ length}{Initial\ length} \times 100$$

The diameter of the trunks (thickness) of the trees was measured at a height of 5 cm above ground level. Ten branches were selected and labeled around each treated tree to count the number of green leaves and calculate the average. The fresh and dry weights of the green leaves were also recorded. However, the leaf area was determined by collecting sufficient samples from each plant. The estimates of leaf area were obtained using the following equation:

$$\text{Leaf area} = \frac{\text{X}}{\text{Y}}$$

where (X) is the weight in grams(g) of the area covered by the leaf outline on a millimeter graph paper, and (Y) is the weight of a square centimeter (cm^2)of the same graph paper, according to the method by(Pandey & Singh, 2011).

Leaf samples were thoroughly washed with distilled water and then dried in an oven at 70°C until they reached a constant weight to determine dry matter. Afterward, the dried leaves were finely ground using a stainless steel knife mill and stored in small light bags for the determination of N, P, K, Ca, Mg, Cl, and Na. The samples were then digested using Sulphuric acid and hydrogen peroxide, a method that was first introduced by Evenhuis and de Waard (1980) to prepare them for mineral analysis.Total nitrogen by micro-Kiel Dahl method as outlined by(Jackson, 1973). Phosphorus using a spectrophotometer at 88.2 U.V. according to the method described by(Murphy & Riley, 1962). Potassium and Sodium were estimated using the methods recommended by(Chapman & Pratt, 1961). Calciumand magnesium were determined using an atomic absorption spectrophotometer "Perkin Elmer 3300" (Carter, 1993)

Leaf total chlorophyll content (SPAD Unit) has been estimated in 30 randomly sampled fresh green leaves using a portable chlorophyll meter (Minolta SPAD-502) as recommended by(Peryea & Kammereck, 1997).

Proline was determined spectrophotometrically using the acid ninhydrin method described byBates *et al.* (1973).Acid-ninhydrin was prepared by warming 1.25 g ninhydrin in 30 ml glacial acetic acid and 20 ml 6 M phosphoric acid, with agitation until dissolved. Kept cool (stored at 4°C). Approximately 0.5g of plant material was homogenized in 10 ml of 3% aqueous sulfosalicylic acid and the homogenate was filtered through filter paper. Two ml of filtrate was reacted with 2 ml acid ninhydrin and 2 ml of glacial acetic acid in a test tube for 1 hour at 100°C, and the reaction terminated in an ice bath) The reaction mixture was extracted with 4 ml toluene, and mixed vigorously with a test tube stirrer for 15-20 sec) The chromophore containing toluene was aspirated from the aqueous phase, warmed to room temperature and the absorbance read at 520 nm using toluene for a blank) The proline concentration was determined from a standard curve and calculated on a dried weight basis.

To evaluate the water status, Relative Water Content (RWC) was determined according to(Morgan, 1984). It is a useful indicator of the state of water balance of a plant essentially because it expresses the absolute amount of water, which the plant requires to reach artificial full saturation.

$$\text{RWC} = \frac{fresh\ weight - dry\ weight}{saturated\ weight - dry\ weight} \times 100$$

Fresh leaf material was sampled fromeach replicate and immediately weighed (fresh weight, FW). Sampleswere put in a Petri dish full of distilled water overnight under dark conditions (keep away the sample from physiological activity), so that, the leaves will become fully hydrated and weighed to determine saturated weight(turgid weights, TW).The samples were then dried in an oven at 80 °C for 24 hours and weighed (DW).

By the end of September, the olives had reached their full maturity, and the yieldwas measured in kilograms per tree. Additionally, the characteristics of the fruit were determined, with a total of ten fruits collected from each treatment to calculate the average weight of the fruits in grams and the flesh-to-fruit weight ratio as a percentage.

The experiments were planned using a completely randomized design. Four replications were used in each treatment with one tree per replicate.The data was analyzed using CoStat Version(6.400) CoHort Software. The mean of all treatments was compared by the least significant difference (L.S.D.) at a 5% level of probability according to (Oehlert, 2010).

RESULTS AND DISCUSSION

Chemical properties of the experimental soil

Data presented in Table (1) showed the values of physical and chemical properties of the experimental soil beforethe study, while data in Table (2)showed some chemical properties of the experimental irrigation water.

At the end of the experiment, soil electrical conductivity (ECe), pH, soluble cations (Na^+, Ca^{++}, and Mg^{++}meq/L), soluble anions (Cl^-, $HCO3^-$ and $SO4^{--}$meq/L), and N, P, K, Fe, Mn, Zn, and Cu determinedin the different soil layers and presented in Table (3).

Table 1: Physical and chemical properties of the experimental soil before the study

Texture class	Particle size distribution (%)		
	Sand	Silt	Clay
Loamy Sand	85.52	4	10.48

Depth (cm)	Saline ppm	pH	meq/L							
			Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	$CaCO_3$	HCO_3^+	SO_4^{--}
0-30	6336	8.30	178.26	0.20	16.57	10.05	18.86	78.38	2.40	10.42
30-60	6320	8.90	170.45	0.24	15.90	8.39	17.57	76.20	2.12	14.30
60-90	5696	8.90	170.38	0.65	10.88	8.03	16.58	76.38	4.47	13.89

Table 2: Some chemical properties of the experimental irrigation water

pH	EC* (dSm^{-1})	TDS** (ppm)	Cations (meq/L)				Anions (meq/L)			Fe (ppm)
			Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	HCO_3^-	SO_4^{--}	
7.40	5.28	3596	43.90	0.65	4.60	9.20	44.00	6.00	8.35	0.0041

*** EC: Electrical conductivity. **TDS: Total dissolved solids**

Table 3: Chemical properties of the experimental soilat the end of the study

Magnetic treatments		Untreated water			Nefertari			Magnolith			Delta water		
Soil layers*		1st	2nd	3ed	1st	2nd	3ed	1st	2nd	3ed	1st	2nd	3ed
ECe (dSm^{-1})		6.365	5.640	4.855	1.615	1.69	2.215	0.840	1.12	1.265	1.165	1.46	2.43
TDS (ppm)		4073.6	3609.6	3107.2	1033.6	1081.6	1417.6	537.6	716.8	809.6	745.6	934.4	1555.2
pH		8.08	8.12	8.29	8.63	8.64	8.62	8.64	8.72	8.43	8.61	8.62	8.78
Cations & Anions meq/L	Na^+	8.3	8.2	6.25	2.71	2.85	3.13	1.67	2.15	2.26	2.15	2.29	3.79
	Ca^{++}	4.2	2.5	2.8	1.4	1.5	2.1	0.8	1.4	1.2	1	1.9	2.2
	Mg^{++}	0.6	0.7	0.4	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.2
	HCO_3^-	1.4	1.4	1.2	1.8	1.6	1.4	1.5	1.8	1.7	1.6	1.6	2.6
	Cl^-	7.8	6.6	4.8	2.4	1.8	2	1	1.4	1.5	1.4	1.2	2.6
	SO_4^{--}	4.38	3.79	3.82	0.42	1.48	2.72	0.48	1.04	1.54	0.74	2.37	1.48
ppm	N	10.14	14	12	14	16	16	22	24	26	22	14	12
	P	85.2	82.1	27.4	16.1	12.7	14.7	11.6	14.2	11.3	27.5	11.8	15.6
	K	304	288	328	256	256	392	192	232	112	128	344	368
	Fe	1.62	1.53	1.77	1.27	1.97	1.74	1.12	1.14	0.86	1.06	1.61	1.39
	Mn	1.04	0.89	1.31	0.89	1.36	1.12	0.56	0.87	0.79	0.74	0.89	1.06
	Zn	0.26	0.32	0.17	0.31	0.28	0.9	0.37	0.44	0.26	0.34	0.41	0.47
	Cu	0.29	0.33	0.41	0.27	0.32	0.36	0.16	0.34	0.31	0.27	0.28	0.29

* Soil layers: 1st (0-30 cm), 2nd (30-60 cm) and 3ed (60-90 cm)

Table 3 presents data comparing various parameters across different soil layers under different water treatments: untreated water, Nefertari, Magnolith, and Delta water. The data is organized based on the soil layers, denoted as "1st," "2nd," and "3rd.".

The data provided offers valuable insights into the effectiveness of various magnetic water treatments in reducing soil salinity within the root zone of olive trees. Across different soil layers, the Magnolith treatment consistently demonstrated the most substantial reduction in electrical conductivity (ECe), indicating lower salinity levels compared to other treatments. In both the first and second soil layers, Magnolith-treated soils exhibited notably lower ECe values than those treated with Nefertari, Delta water, or untreated water. This consistent trend suggests that the

Magnolith magnetic device is particularly effective at mitigating soil salinity, crucial for promoting optimal conditions for root growth and nutrient uptake in olive trees.

Furthermore, the Magnolith treatment also yielded the lowest total dissolved solids (TDS) concentrations across all soil layers, indicating a comprehensive reduction in dissolved salts. Lower TDS levels are indicative of improved water quality and reduced salinity stress on plant roots. This outcome underscores the efficacy of the Magnolith magnetic device in enhancing soil health and promoting a more favorable environment for olive tree cultivation. The significant reduction in TDS levels associated with Magnolith treatment suggests its potential as a practical solution for addressing salinity issues in agricultural soils, particularly within the root zone of olive trees where optimal soil conditions are critical for sustained growth and productivity.

In addition to reducing salinity, the Magnolith treatment demonstrated favorable effects on nutrient availability and soil pH, which are vital factors influencing plant growth and development. The Magnolith-treated soils exhibited balanced nutrient levels and maintained near-neutral pH levels across different soil layers, contributing to improved nutrient uptake and overall plant health.

Across all soil layers, the pH values in soils treated with magnetic water, particularly with Nefertari and Magnolith treatments, tended to be slightly higher than those in untreated soils. This suggests that magnetic water treatments may have a slight alkalizing effect on the soil pH. However, the differences in pH values between treated and untreated soils were generally small, indicating that magnetic treatment alone may not exert a significant influence on soil acidity or alkalinity. Further studies may be needed to explore the long-term effects of magnetic water treatment on soil pH dynamics and its implications for plant growth and nutrient availability. Some studies have indeed reported slight increases in soil pH following magnetic water treatment (Surendran *et al.*, 2016, Ben Amor *et al.*, 2020) and other studies reported a reduction of the pH in the soil with magnetic treatment (Putti *et al.*, 2023).

Survival percentage

Olive is considered a moderately salt-tolerant plant, it can be irrigated with water containing up to 3500 mg/l of salt, producing new growth. Irrigation water with (ECw of 13.7 dS/m) is the tolerance limit for olive trees(Rugini & Fedeli, 1990). Olive growth is reduced only by 10% when the electrical conductivity of the soil saturation extract (ECe) is 4–6 dS/m. This value can be as high as 6–8 dS/m in soils with high calcium status(Bernstein, 1965).The results obtained during both experimental seasons confirmed thatirrigating olive trees with water containing 3596ppm of salt (EC of 5.28dS/m)did not highly suffer salt stress, as the survival rate was 100% for all treatments.

Vegetative growth

The changes invegetative growth characteristics(growth rate, stem diameter, number of green leaves, and leaf area) at the end of the two experimental seasons of olive plants irrigated with magneticallytreated water and untreatedwater are presented in Table (4).

In the first season, data indicated that magnetic-treatedwater significantly increased the plant'sgrowth rate as compared with plants irrigated withuntreated water (control). The data also showed that the use of Magnolith, however, was significantly higher than the use of other devices. No significant differences were found between using Delta Water or Nefertari and the data obtained in the second season showed the same trend.

Regarding the trunk diameter, data obtained during the first season indicated that magnetically treated water significantly increased the plant's stem diameter as compared with plants irrigated withuntreated water (control). Using Magnolith or Delta Water showed an increase in the stem diameter over Nefertari and the difference was significant. Moreover, the data obtained for the second season was nearly the same as that of the first one.

Table 4: Effect of the magnetic strength of the water salts treatment deviceson vegetative growth characters (growth rate, stem diameter, number of green leaves, and leaf area) of olive plants during the two successive seasons 2022 and 2023.

Magnetic devices	Growth rate (%)		Trunk diameter (cm)		Number of green leaves		Leaf area (cm^2)	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Untreated	9.82^{c}	9.925 ^{c}	6.60^{c}	8.09^{c}	247^{b}	284.25^{c}	3.54^{b}	4.13^{b}
Nefertari	13.25^{b}	13.975 ^{b}	7.30^{b}	8.92 ^{b}	303.25^{ab}	338b^{bc}	3.95^{a}	4.95^{a}
Magnolith	16.10^{a}	17.05 ^{a}	9.10^{a}	10.62 ^{a}	370.5^{a}	408.25^{a}	4.35^{a}	5.20^{a}

Delta Water	**13.57**[b]	**13.925** [b]	**8.87**[a]	**10.12** [a]	**342.5**[a]	**381.5**[ab]	**4.20**[a]	**5.09**[a]

Means followed by the same letter within a column are not significantly different according to the least significant difference (L.S.D. $_{0.05}$).

According to the number of green leaves,dataobtained from the two experimental seasons indicated that trees irrigated with Magnetic Treated Water (MTW) had more green leaves than those irrigated with Untreated Water (UTW). Furthermore, using Magnolith or Delta Water resulted in a higher number of green leaves compared to using Nefertari, although the differences were not always statistically significant.

Concerning the effect of MTW on the leaf area (cm^2), the data in Table (4) show a significant increase when irrigating plants with magnetically treated water as compared with the control (UTW), whereas the difference between using Nefertari, Magnolith, or Delta Waterwas not big enough to be significant.

Generally, it was clear that the vegetative growth characters (growth rate, stem diameter, number of green leaves) responded in the same manner to the application of magnetically treated water and magnetic strength (different manufacturers), while the leaf area was only affected by the magnetically treated water. The data obtained during the second experimental season showed almost the same trend in the first season for all vegetative growth characters.

The positive effect of magnetically treated water on the vegetative growth characters reported in this study may be due to its role instimulatingnutrient assimilation and absorption, and its role indecreasingthe soil salinity. (Aly *et al.*, 2015, Grewal & Maheshwari, 2011, Mohamed & Ebead, 2013) stated that magnetically treated water is more solvent and has a lower surface tension; therefore, nutrients are absorbed greater in the water. Furthermore, the root growth of various plant species can be enhanced using the MTW technique(Belyavskaya, 2001, Turker *et al.*, 2007).

These findings are in harmony with those obtained byOsman *et al.* (2014)on pear seedlings, who found a significant increase in plant height, leaves number/ plant, freshweight and dry weightas a result of irrigating plants with magnetically treated water. Aly et al. (2015)observed an increase in shoot length, leaf area, shoot number, and shoot thickness of Valencia orange when irrigated with magnetizing water. Ahmed and Abdelkader (2016)reported that magnetized water positively affectspotato growth characteristics(plant height, leaf area, leaf number, haulm fresh and dry weights).

Leaf mineral content

In the first season, the leaf nitrogen content of the olive plants varied significantly depending on the application of MTW. It was almost three times as high as that of the control. The average leaf nitrogen content for the control plants was 0.5% of dry matter, while it reached about 1.5% for those treated with MTW. Regarding the impact of magnetic strength from different devices on leaf nitrogen content, there were slight differences between (Nefertari) and (Delta Water) that were not statistically significant, whereas using (Magnolith) resulted in higher values for nitrogen leaf content(Table 5).In the second experimental season, there was a significant increase in nitrogen content in the leaves of MTW plants compared to those in the control group. The trend observed during this season mirrored that of the first one. When considering different devices' effects, Magnolith led to a notable increase in leaf nitrogen content compared to other devices which showed similar results.

Table 5: Effect of the magnetic strength of the water salts treatment deviceson leaf NPK (as a percentage of dry matter)of olivetrees during the two successive seasons 2022 and 2023.

Magnetic devices	Nitrogen (%)		Phosphorus (%)		Potassium (%)	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Untreated	0.50 c	0.49 c	0.12 c	0.14 c	0.63 c	0.66 c
Nefertari	1.41 b	1.41 b	0.17 b	0.18 b	0.79 b	0.82 b
Magnolith	1.54 a	1.54 a	0.21 a	0.22 a	0.94 a	0.93 a
Delta Water	1.44 b	1.42 b	0.19 ab	0.20 ab	0.84 b	0.80 b

Means followed by the same letter within a column are not significantly different according to the least significant difference (L.S.D. $_{0.05}$).

The mean values of leaf phosphorus content indicated that the using of MTW significantly affected the leaf phosphorus content in the first experimental season, and the data of the second season confirmed the findings of the first one. The differences between using (Nefertari) and (Delta Water)were too slight to be significant as well as between (Delta Water) and (Magnolith).

The leaf potassium content of the different treatments in the two experimental seasons is presented in Table (5). In both seasons, olive trees irrigated with MTW had significantly higher leaf potassium content than those irrigated with untreated water (UTW). The leaf potassium content on a dry weight basis was 0.63 and about0.86 % for the UTW and MTW, respectively. Regarding the magnetic strength (variousdevices), no significant differences were found between (Nefertari and Delta Water) wear as (Magnolith) recorded the height values.

The data presented in Table (6) indicated that in the first season, the application of MTW increased the leaf calciumcontent as compared with the control (UTW). In the treatment of MTW, the leaf calcium content was higher (19.6%) than that with UTW which contained 1.12%, while the MTW contained 1.34%of dry matter. As for the effect of magnetic strength (variousdevices), no significant differences were found. Likewise, in the second season, the application of MTW increased the leaf calcium content as compared with the control (UTW). Moreover, no significant differences were found between different devices.This trend was also observed in the leaf content of magnesium.

Table 6: Effect of the magnetic strength of the water salts treatment devices onleaf Ca, Mg, Na, and Cl (as a percentage of dry matter)of olivetreesin the two successive seasons 2022 and 2023.

Magnetic devices	Ca (%)		Mg (%)		Na (%)		Cl (%)	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Untreated	1.12^{b}	1.11^{b}	0.10^{b}	0.11^{b}	0.32^{a}	0.31^{a}	0.46^{a}	0.43^{a}
Nefertari	1.32^{a}	1.33^{a}	0.13^{a}	0.12^{a}	0.13^{b}	0.12^{b}	0.45^{a}	0.42^{a}
Magnolith	1.39^{a}	1.40^{a}	0.14^{a}	0.13^{a}	0.04^{c}	0.04^{c}	0.43^{a}	0.41^{a}
Delta Water	1.31^{a}	1.32^{a}	0.14^{a}	0.12^{a}	0.04^{c}	0.04^{c}	0.42^{a}	0.43^{a}

Means followed by the same letter within a column are not significantly different according to the least significant difference (L.S.D. $_{0.05}$).

The effect of magnetic treatment of irrigation water on the leaf sodium content of the experimental olive trees is shown in Table (6). The data indicated that the application of MTW decreased the leaf sodium content as compared with the control (UTW). As for the effect of different deviceson the sodium leaf content, no significant differences were found between (Magnolith and Delta Water) wear as (Nefertari) recorded the height values.

The effect of the MTW treatment on the leaf chloride content of the experimental olive trees is shown in Table (6). The data indicated that no significant differences were found between the MTW and UTWin the two experimental seasons.

Generally, it was noticed that irrigation with magnetically treated water led to an increase in all elements content in olive plant leaves except sodium and chloride. Magnetic water caused an increase in N, P, K, Ca,and Mg in leaves of Manzanillo olive, this increase may be due to that the magnetic water treatment showed higher values for mobile forms of nitrogen and improved the dissolution of fertilizers in the soil irrigated with magnetically treated water and increase in the rate of water absorption. On the other hand, leaf sodium content was reduced while leaf chloride contentwas not significantly affected.Takatshinko (1997)stated that magnetized water removed 50 to 80% of soil Cl^-, compared to the removal of only 30% by normal irrigation water.Bogatin et al. (1999) reported that irrigation with magnetically treated water is most effective for soils with high soda content, CO_2 forms H_2CO_3, which converts insoluble carbonates into soluble bicarbonates. Bicarbonates exchange with Na of the cation exchange complex (CEC). As a result of the exchange reaction, Na is removed from CEC into the soil, which improves the properties of alkaline soils and accelerates their leaching. Acidification of soil moisture accelerates the transfer of phosphoric fertilizers into a more soluble form and becomes additional nutrition for plants.

Gouia *et al.* (1994)worked on salt-sensitive Bean and salt-tolerant Cotton, grown on a nutrient medium containing 0 or 50 mM NaCl. They reported that in bean plants the 50mM NaCl treatment resulted in a marked decrease in the accumulation rate of other major cations (K^+, Ca^{++}, Mg^{++}) in the shoot but not in roots. On the contrary, in cotton plants, the salt treatment did not affect the accumulation rate of other cations in shoots or roots. Saline treatments led to an accumulation of $C1^-$ in 11 parts of the plants. The distributions of Na^+ and $C1^-$ within the plants, however, differed with the plant species. The accumulation rates of N were lowered, especially in bean and cotton shoots, by feeding plants with 50 mM NaCl.Furthermore, NO_3^- uptake and N flows within the plants were negatively altered by salinity. This effect was more pronounced for beans, in which NO_3^- uptake was inhibited by 47%, than for cotton, in which it was inhibited by 33%. In both species, salinity decreased NO_3^- transport rate.

Klobus *et al.* (1988)stated that NO_3^-uptake by roots of barley seedlings was decreased by the addition of salt to the nutrient solution.

The above-mentioned findings are corroborated by the results of many researchers indicating that the nutrient contents of plants were significantly influenced by MTW. Grewal and Maheshwari (2011)found that the MTW treatment significantly increasesthe N, K, Ca, and Mg contents in snow pea seedlings. However, the P contents were not significantly affected.

El-Yazied *et al.* (2012) on tomato plants, reported that the phosphorus percent was increased, meanwhile, the sulfur percent was decreased and sodium percent was not affected in leaves of plants produced from magnetized treatments compared to the control treatment. El Sayed (2014) irrigated the seeds of the broad bean with magnetic water exhibited an increase in potassium, calcium, and phosphorous contents in all parts (roots, stems, leaves, and seeds) of the broad bean plant compared with the control (tap water) plant, whereas, sodium content tended to decreased significantly in all plant parts (roots, stems, leaves and seeds) irrigated with magnetic water than tap water (control) plants.Osman et al. (2014) on pear seedlings. The results showed that irrigation with magnetic water improved significantly the nitrogen and phosphorus percentage of pear seedlings as compared with non-magnetic water. Aly et al. (2015)on Valencia orange,magnetic water caused an increase in nitrogen, phosphorus, potassium, calcium, and magnesium in leaves Valencia orange.Other researchers reported that irrigation of potato plants using magnetic water significantly increased N, P,and K, in both leaves and Tubers(Ahmed & Abdelkader, 2016, Hachicha et al., 2016).

According to Abedinpour and Rohani (2017)findings, the levels of available soil nitrogen and phosphorus were significantly greater following magnetic treatment compared to the non-magnetized control. They attributed this increase to the effect of magnetic treatment on the desorption of nitrogen and phosphorus from soil-adsorbed colloidal complexes, which increased their availability to plants and ultimately led to better plant growth.

Leaf chlorophyll content

Chlorophyll content serves as an indicator of plant health and vigor, playing a crucial role in the growth and productivity of plants. Data presented in Table (7) shows the effect of variable magnetic strengths (as found in commercial devices) on leaf chlorophyll content which is measured as an additional indicator of plant health.

Table 7: Effect of magnetic strength of the water salts treatment devices on leafchlorophyll content, leaf proline content, and relative watercontent of olivetreesin the two successive seasons of 2022 and 2023.

Magnetic devices	Chlorophyll(SPAD Unit)		Total proline (mg/g dry weight)		Relative water	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Untreated	66.5^{b}	68.75^{b}	0.70^{a}	0.61^{a}	74.00^{c}	73.75^{c}
Nefertari	73.25^{a}	73.75^{a}	0.45^{b}	0.44^{b}	79.00^{b}	80.00^{b}
Magnolith	73.75^{a}	75.50^{a}	0.38^{c}	0.37^{c}	82.50^{a}	85.50^{a}
Delta Water	73.50^{a}	74.75^{a}	0.36^{c}	0.40^{bc}	81.75^{a}	84.00^{a}

Means followed by the same letter within a column are not significantly different according to the least significant difference (L.S.D. $_{0.05}$).

The results of the study showed that all magnetic water salt treatment devices had a positive impact on leaf chlorophyll content compared to the control trees(UTW). The devices significantly increased leaf chlorophyll content in both seasons. These findings suggest that magnetic water salt treatment devices can enhance the resilience of olive trees to salinity stress by improving their chlorophyll content.

Since the results obtained indicated that, MTW increases the leaf N and Mg content. Mg is probably best known for its central position in the chlorophyll molecule where it coordinates covalently with four nitrogen atoms from the porphyrin ring (Maathuis, 2009), these findings may explain why MTW increases the leaf chlorophyll contents.The improvement of photosynthetic pigments was recorded in sunflowers(Oldacay & Erdem, 2002), and soybeans(Atak & Rzakoulieva, 2003) when seeds or explants were exposed to a magnetic field for a short time.

Similar results were observed on date palms(Dhawi & Al-Khayri, 2009)reported that the photosynthetic pigments (chlorophyll a and chlorophyll b pigments) were significantly increased under a static magnetic field. Similarly, chickpea plants when irrigated with magnetic water(Nasher, 2008)recorded significant increases in pigment fractions. (Al-Khazan *et al.*, 2011)have reported that the magnetically treated water has an enhancing effect on the photosynthetic pigments content of Jojoba compared to the control. On Pepper (Rawabdeh *et al.*, 2014) indicated that irrigation with magnetic water inducesa positive effect on chlorophyll content.

Leaf proline content

The effect of the MTW treatment on the leaf proline content of the experimental olive trees is shown in Table (7). The data of the first season showed that the proline content of the leaves decreased significantly when olive treeswere irrigated with MTW as compared with the control (UTW). The averages were 0.65 and 0.40 for the UTW and MTW, respectively. The decrease obtained was about 62.5 % as the control. As for the effect of various devices,no significant differences were found between (Magnolith and Delta Water) wear as (Nefertari) recorded the height values. In the second season, the same trend of results was obtained and the results followed the same trend as reported byOsman et al. (2014)on pear seedlings,they concluded that the proline increased by irrigated with non-magnetic water compared with magnetic one.

On the other hand, the findings obtained here did not agree with those reported by (El Sayed, 2014) who found that magnetic water irrigation exhibited a marked significant increase in total proline contents at all plant parts (leaves, stems, roots) of broad bean compared with control plants.

Proline has been known to be involved in the response to several environmental stresses, particularly salt and drought stress. Osmotic stresses are caused by excessive accumulation of salt in the soil, either directly, because of salinization, or indirectly, because of water loss. The decrease in soil water potential led to an alteration of the plant water status which may cause stomatal closure, photosynthesis reduction, and thus growth inhibition. Proline is a low molecular weightosmoprotectantthat helps to preserve structural integrity and cellular osmotic potential within different compartments of the cell(Wang *et al.*, 2011). In the present study, there was a positive correlation between proline accumulation and salt stress. However, the accumulation of proline was decreased when plants were irrigated with MWT.

Relative water content (RWC)

The effect of the MTW treatment on the relative watercontent of the experimental olive trees is shown in Table (7).The values of relative watercontent in the first season increased in the plants irrigated with MTW than in those of the control (UTW),the mean values were74 and 81 for the

UTW and MTW, respectively. The data also showed that the use of Magnolith, however, was significantly higher than the use of Nefertari. No significant differences were found between using Magnolith and Delta Water. Moreover, data obtained in the second season showed the same manner. The mean values were 73.75and 83.16 for the UTW and MTW, respectively.

RWC is the appropriate measure of plant water status in terms of the physiological consequence of cellular water deficit (Basant *et al.*, 2007). Perhaps the reason for this increase is the ability of these plants to absorb water, as a result of an increase in the root length of these plants (Al-Khazan et al., 2011). The relative decrease of RWC in normal water plants might be due to greater resistance to water flow at the soil rate interface as a result of salt (mainly sodium accumulation).Similarly, the result of Al-Khazan et al. (2011)on jojoba, and Maheshwari and Grewal (2009)on celery and snow pea. Meanwhile, Hozayn and Qados (2010) stated that irrigating chickpeas with magnetically treated water did not affect the relative water content as compared with the control.

Table 8: Effect of the magnetic strength of the water salts treatment devices on total yield/tree and fruit characteristicsof olivetreesin the two successive seasons of 2022 and 2023.

Magnetic devices	Total yield/tree (kg)		Fruit weight (gm)		Flesh/fruit weight (%)	
	Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
Untreated	14.10^{c}	9.22^{d}	4.19^{c}	4.16^{c}	81.48^{b}	81.07^{b}
Nefertari	16.50^{b}	13.75^{c}	4.72^{b}	4.72^{b}	81.06^{b}	82.62^{a}
Magnolith	18.87^{a}	16.32^{a}	5.25^{a}	5.22^{a}	84.39^{a}	83.13^{a}
Delta Water	17.37^{ab}	15.12^{b}	4.75^{b}	4.89^{ab}	82.99^{ab}	83.23^{a}

Means followed by the same letter within a column are not significantly different according to the least significant difference (L.S.D. $_{0.05}$).

The data presented in Table 8shows that the magnetic strength of water salt treatment devices has a significant effect on the total yield per tree. The untreated trees had the lowest total yield in both season 1 and season 2, indicating that the use of magnetic devices can have a positive impact on olive productivity. Among the treated trees, Magnolith had the highest total yield per tree in both seasons, followed closely by Delta Waterand then by Nefertari. This suggests that the strength of the magnetic device plays a crucial role in determining the effectiveness of water salt treatment in increasing the total yield. Moreover, there was a similar effect on both fruit weight and the ratio of flesh to fruit weight.

These results are consistent with findings from other research indicating that the effect of magnetic water treatment on crop yield and fruit quality is positive(Putti *et al.*, 2024, Shao *et al.*, 2024, Xuesong *et al.*, 2023)

Overall, the results demonstrate that there is a clear correlation between the magnetic strength of water salt treatment devices and total yield per tree. Trees treated with stronger magnetic devices such as Magnolith showed significantly higher yields compared to those treated with weaker devices or left untreated. This highlights the importance of using high-quality and effective magnetic devices in agricultural practices to maximize crop production and ensure sustainable farming practices. Further research into optimizing magnetic treatments for different types of crops and environmental conditions could potentially lead to even greater improvements in agricultural productivity.

Conclusion:

Water salinity is a major issue faced by farmers, and the use of magnetic devices for treating this problem has been gaining traction. However, it's essential to understand that magnetic forces alone do not determine the quality and effectiveness of these devices. The manufacturing method and arrangement of magnetic forces play a crucial role in giving the device its effective effect.

While Delta Water devices are considered the strongest, with a measurement of 14000 Gauss, the Magnolith device is the one that stands out with a strength of 8000 Gauss. While Nefertari has a strength of 6000 Gauss, studies have shown that the Magnolith device consistently outperforms the other two.

It's essential to subject magnetic devices to academic evaluation before they are approved in the market to protect farmers from ineffective products that lead to unsuccessful agriculture. In some research and experiments, the use of magnetic devices for treating salinity in irrigation water did not have significant effects, leading to a negative impression.

Although the effect of magnetic treatment of irrigation water with these devices did not exceed the improvement rate of 20%, they are still considered an effective means of treatment and improvement. However, it's crucial to note that they are not a permanent solution to the salinity problem.

In conclusion, the Magnolith device has proven to be the most effective of the three devices. Farmers must consider all factors that determine a device's effectiveness before investing in them. While magnetic treatment devices may not solve the salinity problem entirely, they are a means of treatment and improvement that can lead to successful agriculture.

References:

Abdelwahed, S. M., 2017: Impact of Irrigation with Saline Water Treated by Magnetic Technique on Some Species of Young Fruit Trees. *PhD of Science Thesis, Department of Pomology, Faculty of Agriculture. Alexandria University.*

Abedinpour, M. and E. Rohani, 2017: Effects of magnetized water application on soil and maize growth indices under different amounts of salt in the water. *Journal of Water Reuse and Desalination,***7,** 319-325.

Ahmed, M. E. M. and N. I. Abdelkader, 2016: The Influence of Magnetic Water and Water Regimes on Soil Salinity, Growth, Yield and Tubers Quality of Potato Plants. *Middle East Journal of Agriculture Research,* **05,** 132-143.

Al-Amoud, A., Subsurface drip irrigation for date palm trees to conserve water. in Proceedings of the IV International Date Palm Conference 882, 2010, p. 103-114.

Al-Busaidi, A. and J. Ullman, 2014: Applying Magnetic Technologies To Improve Water Productivity of Soil Irrigated By Saline Groundwater. *International Journal of Environment & Water,***3,** 1-6.

Al-Khazan, M., B. M. Abdullatif and N. Al-Assaf, 2011: Effects of magnetically treated water on water status, chlorophyll pigments and some elements content of Jojoba (Simmondsia chinensis L.) at different growth stages. *African Journal of Environmental Science and Technology,***5,** 722-731.

Alharbi, A., 2015: Effect of mulch on soil properties under organic farming conditions in center of Saudi Arabia. *Journal of American Science,***11**.

Aliniaeifard, S., J. Hajilou, S. Tabatabaei and M. Sifi-Kalhor, 2016: Effects of Ascorbic Acid and Reduced Glutathione on the Alleviation of Salinity Stress in Olive Plants. *International Journal of Fruit Science***,** 1-15.

Aly, M. A., M. E. Thanaa, O. S. M. and A. A. A. Mazek, 2015: Effect of Magnetic Irrigation Water and Some Anti-Salinity Substances on the Growth and Production of Valencia Orange. *Middle East Journal of Agriculture Research* **4,** 88-98.

Anjum, M. A., 2008: Effect of NaCl concentrations in irrigation water on growth and polyamine metabolism in two citrus rootstocks with different levels of salinity tolerance. *Acta Physiologiae Plantarum,***30,** 43-52.

Atak, Ç. and A. Rzakoulieva, 2003: Stimulation of regeneration by magnetic field in soybean (Glycine max L. Merrill) tissue cultures. *Journal of Cell & Molecular Biology,***2**.

Ayars, J. E. and D. L. Corwin, 2024: Salinity management. *Microirrigation for Crop Production.* Elsevier.

Basant, M., S. Bunce and G. Harshan, 2007: Irrigation and water saving potential of magnetic treated water in vegetable crops. *Research Direction Office of Research Services, Sydney, Australia***,** 12-22.
Bates, L., R. Waldren and I. Teare, 1973: Rapid determination of free proline for water-stress studies. *Plant and soil,***39,** 205-207.
Belyavskaya, N., 2001: Ultrastructure and calcium balance in meristem cells of pea roots exposed to extremely low magnetic fields. *Advances in Space Research,***28,** 645-650.
Ben Amor, H., A. Elaoud, H. Ben Hassen, N. Ben Salah, A. Masmoudi and K. Elmoueddeb, 2020: Characteristic study of some parameters of soil irrigated by magnetized waters. *Arabian Journal of Geosciences,***13,** 1007.
Bernstein, L., 1965: *Salt tolerance of fruit crops*.Agriculture Research Service, US Department of Agriculture.
Bogatin, J., N. P. Bondarenko, E. Z. Gak, E. E. Rokhinson and I. P. Ananyev, 1999: Magnetic treatment of irrigation water: experimental results and application conditions. *Environmental science & technology,***33,** 1280-1285.
Borsani, O., V. Valpuesta and M. A. Botella, 2001: Evidence for a role of salicylic acid in the oxidative damage generated by NaCl and osmotic stress in Arabidopsis seedlings. *Plant physiology,***126,** 1024-1030.
Carter, M. R., 1993: *Soil sampling and methods of analysis*.CRC Press.
Chapman, H. and P. Pratt, 1961: Methods of Analysis for Soils, Plants and Waters. Priced Publication 4034. Division of Agriculture Sciences. *University of California, Berkeley*.
Chaudhry, U. K., Z. N. Ö. Gökçe and A. F. Gökçe, 2021: Drought and salt stress effects on biochemical changes and gene expression of photosystem II and catalase genes in selected onion cultivars. *Biologia,***76,** 3107-3121.
Cho, Y. I., S. Lee, W. Kim and S. Suh, 2003: Physical water treatment for the mitigation of mineral fouling in cooling-tower water applications.
Dhawi, F. and J. M. Al-Khayri, 2009: Magnetic fields induce changes in photosynthetic pigments content in date palm (Phoenix dactylifera L.) seedlings. *The Open Agriculture Journal,***3**.
El-sayed, O. M. and M. E. El-Hagarey, 2014: Evaluation of Ultra-low Drip Irrigation and Relationship between Moisture and Salts in Soil and Peach (pruns perssica) Yield. *Journal of American Science,***10**.
El-Yazied, A. A., A. El-Gizawy, S. Khalf, A. El-Satar and O. Shalaby, 2012: Effect of magnetic field treatments for seeds and irrigation water as well as N, P and K levels on productivity of tomato plants. *Journal of Applied Sciences Research,***8,** 2088-2099.
El Sayed, H. E. S. A., 2014: Impact of magnetic water irrigation for improve the growth, chemical composition and yield production of broad bean (Vicia faba L.) plant. *American Journal of Experimental Agriculture,***4,** 476.
Evenhuis, B. and P. de Waard, 1980: Principles and practices in plant analysis. *FAO Soils Bulletins (FAO)*.
Gouia, H., M. H. Ghorbal and B. Touraine, 1994: Effects of NaCl on flows of N and mineral ions and on NO3-reduction rate within whole plants of salt-sensitive bean and salt-tolerant cotton. *Plant Physiology,***105,** 1409-1418.
Grewal, H. S. and B. L. Maheshwari, 2011: Magnetic treatment of irrigation water and snow pea and chickpea seeds enhances early growth and nutrient contents of seedlings. *Bioelectromagnetics,***32,** 58-65.

Hachicha, M., B. Kahlaoui, N. Khamassi, E. Misle and O. Jouzdan, 2016: Effect of electromagnetic treatment of saline water on soil and crops. *Journal of the Saudi Society of Agricultural Sciences*.

Hanson, B., W. Bowers, S. Grattan, D. Grimes and K. Tanji, 1991: Trace elements limit potential for blending San Joaquin drainwater with canal water. *California Agriculture*,**45,** 17-19.

Hasaani, A. S., Z. L. Hadi and K. A. Rasheed, 2015: Experimental Study of the Interaction of Magnetic Fields with Flowing Water. *International Journal of Basic and Applied Science,***03,** 1-8.

Hilal, M. and M. Hilal, 2000: Application of magnetic technologies in desert agriculture. II-Effect of magnetic treatments of irrigation water on salt distribution in olive and citrus fields and induced changes of ionic balance in soil and plant. *Egyptian Journal of Soil Science,***40,** 423-435.

Hołysz, L., M. Chibowski and E. Chibowski, 2002: Time-dependent changes of zeta potential and other parameters of in situ calcium carbonate due to magnetic field treatment. *Colloids and Surfaces A: Physicochemical and Engineering Aspects,***208,** 231-240.

Hozayn, M. and A. M. S. A. Qados, 2010: Irrigation with magnetized water enhances growth, chemical constituent and yield of chickpea (Cicer arietinum L.). *Agriculture and Biology Journal of North America,***1,** 671-676.

Jackson, M., 1973: Soil Chemical Analysis. *Prentic Hall (India) Pvt. Ltd. New Delhi*.

Kaswala, A., R. Patil, K. Patel, A. Patel, A. Sabalpara and R. Patel, 2012: Effect of salinity, phasic salinity stress and mulching on yield of brinjal as well as soil properties. *Journal of Environmental Research And Development Vol,***6**.

Klobus, G., M. R. Ward and R. C. Huffaker, 1988: Characteristics of injury and recovery of net NO3− transport of barley seedlings from treatments of NaCl. *Plant physiology,***87,** 878-882.

Kotb, A., 2013: Magnetized Water and Memory Meter. *Energy and Power Engineering,***5,** 422.

Leogrande, R., O. Lopedota, F. Montemurro, C. Vitti and D. Ventrella, 2012: Effects of irrigation regime and salinity on soil characteristics and yield of tomato. *Italian Journal of Agronomy,***7,** 8.

Liu, Y., Y. Hu, C. Wei, W. Zeng, J. Huang and C. Ao, 2024: Synergistic regulation of irrigation and drainage based on crop salt tolerance and leaching threshold. *Agricultural Water Management,***292,** 108679.

Maathuis, F. J. M., 2009: Physiological functions of mineral macronutrients. *Current Opinion in Plant Biology,***12,** 250-258.

Maheshwari, B. L. and H. S. Grewal, 2009: Magnetic treatment of irrigation water: Its effects on vegetable crop yield and water productivity. *AGWAT Agricultural Water Management,***96,** 1229-1236.

Mohamed, A. I. and B. M. Ebead, 2013: Effect of magnetic treated irrigation water on salt removal from a sandy soil and on the availability of certain nutrients. *International Journal of Engineering,***2,** 36-44.

Morgan, J. M., 1984: Osmoregulation and water stress in higher plants. *Annual review of plant physiology,***35,** 299-319.

Mostafazadeh-Fard, B., M. Khoshravesh, S.-F. Mousavi and A.-R. Kiani, Effects of Magnetized Water on Soil Sulphate Ions in Trickle Irrigation. in Proceedings of the Proceedings of

International Conference on Environmental Engineering and Applications (ICEEA 2011), 2011.
Murphy, J. and J. P. Riley, 1962: A modified single solution method for the determination of phosphate in natural waters. *Analytica chimica acta*,**27,** 31-36.
Nasher, S. H., 2008: The effect of magnetic water on growth of chick-pea seeds. *Eng. & Tech*,**26,** 4.
Oehlert, G. W., 2010: A first course in design and analysis of experiments. *Macmillan*,**University of Minnesota,** 659 pp.
Oldacay, S. and G. Erdem, 2002: Evaluation of chlorophyll contents and peroxides activities in I (Helianthus annuus L.) genotypes exposed to radiation and magnetic field. *Pak. J. of Appl. Sci*,**2,** 934-937.
Osman, E. A. M., K. M. A. El-Latif, S. M. Hussien and A. E. A. Sherif, 2014: Assessing the effect of irrigation with different levels of saline magnetic water on growth parameters and mineral contents of pear seedlings. *Global Journal of Scientific Researches*,**2(5),** 128-136.
Pandey, S. and H. Singh, 2011: A simple, cost-effective method for leaf area estimation. *Journal of Botany*,**2011**.
Parkash, V. and S. Singh, 2020: A Review on Potential Plant-Based Water Stress Indicators for Vegetable Crops. *Sustainability*,**12,** 3945.
Peryea, F. J. and R. Kammereck, 1997: Use of Minolta SPAD- 502 chlorophyll meter to quantify the effectiveness of mid- summer trunk injection of iron on chlorotic pear trees. *Journal of Plant Nutrition*,**20,** 1457-1463.
Putti, F. F., B. Arruda, E. F. Vicente, P. P. N. Chaves, B. B. Nogueira, W. A. L. Zanetti, E. O. Ono and A. R. dos Reis, 2024: Magnetic technology to reduce the effects of saline stress on tomato plants. *Environmental Technology & Innovation*,**34,** 103544.
Putti, F. F., E. F. Vicente, P. P. N. Chaves, L. P. B. Mantoan, C. P. Cremasco, B. Arruda, J. C. Forti, J. F. S. Junior, M. Campos, A. R. d. Reis and L. R. A. G. Filho, 2023: Effect of Magnetic Water Treatment on the Growth, Nutritional Status, and Yield of Lettuce Plants with Irrigation Rate. *Horticulturae*,**9,** 504.
Rawabdeh, H., S. Shiyab and R. Shibli, 2014: The Effect of Irrigation by Magnetically Water on Chlorophyll and Macroelements uptake of Pepper (Capsicum annuum L.). *Jordan Journal of Agricultural Sciences*,**10**.
Roy, R., M. Robbani, M. Ali, S. Bhowal and A. Erfan, 2014: Variations in salinity tolerance of selected mango rootstocks. *Bangladesh Agronomy Journal*,**17,** 89-94.
Rugini, E. and E. Fedeli, 1990: Olive (Olea europaea L.) as an oilseed crop. *Legumes and Oilseed Crops I.* Springer.
Ruiz, M., G. Olivieri and F. Vita Serman, Effects of Saline Stress in Two Cultivars of Olea europea L:'Arbequina'and'Barnea'. in Proceedings of the XXVIII International Horticultural Congress on Science and Horticulture for People (IHC2010): Olive Trends Symposium-From the 924, 2010, p. 117-124.
Sandor, F., 2011: The Effect of Humic Substances on Pomegranate Nursery Production in Nangarhar, Afghanistan. *Journal of Environmental Science and Engineering*,**5**.
Shao, F., H. Yan, S. Lin, Q. Wang, W. Tao, J. Wu and L. Su, 2024: Magnetically treated water drip irrigation combined with carboxymethyl cellulose (CMC) application: A regulating strategy for enhancing the jujube yield and quality in southern Xinjiang of China. *Scientia Horticulturae*,**326,** 112723.

Surendran, U., O. Sandeep and E. Joseph, 2016: The impacts of magnetic treatment of irrigation water on plant, water and soil characteristics. *Agricultural water management,* **178,** 21-29.

Takatshinko, Y., Hydromagnetic systems and their role in creating micro climate. in Proceedings of the International symposium on sustainable management of salt affected soils, Cairo, Egypt, 1997, p. 22-28.

Todeshki, A. R. S., H. R. Vanani, M. Shayannejad and K. O. A. Askari, 2015: Effects of Magnetized Municipal Effluent on Some Chemical Properties of Soil in Furrow Irrigation. *International Journal of Agriculture and Crop Sciences,* **8,** 482.

Touati, R., L. Laajili-Ghezal, I. Nsiri, H. Ben Hassine, A. Eleuch, A. Bannour and Z. Farhat, 2023: Effects of electromagnetic irrigation water treatment on soil properties and arbequina olive trees in Tunisia (Sminja, Zaghouan). *Communications in Soil Science and Plant Analysis,* **54,** 1492-1509.

Turker, M., C. Temirci, P. Battal and M. E. Erez, 2007: The effects of an artificial and static magnetic field on plant growth, chlorophyll and phytohormone levels in maize and sunflower plants. *Phyton,* **46,** 271-284.

Tyagi, N., 2003: Managing saline and alkaline water for higher productivity. *JW, Kijne, R., Barker, D., Molden (eds.). Water productivity in agriculture: limits and opportunities for improvement. CAB International***,** 69-87.

Walker, R. R., D. H. Blackmore, P. R. Clingeleffer and R. L. Correll, 2002: Rootstock effects on salt tolerance of irrigated field- grown grapevines (Vitis vinifera L. cv. Sultana).: 1. Yield and vigour inter- relationships. *Australian Journal of Grape and Wine Research,* **8,** 3-14.

Wang, K., Y. Liu, K. Dong, J. Dong, J. Kang, Q. Yang, H. Zhou and Y. Sun, 2011: The effect of NaCl on proline metabolism in Saussurea amara seedlings. *African Journal of Biotechnology,* **10,** 2886-2893.

Xuesong, W., M. Weiyi, W. Quanjiu, D. Xiaoxian and S. Yan, 2023: Effects of Aerated and Magnetized Irrigation Water on Growth, Yield and Fruit Quality of Gala Apple in Xinjiang. *Journal of Irrigation & Drainage,* **42**.