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EFFECT OF MAGNETIZED SALINE IRRIGATION WATER ON SOIL MECHANICAL PROPERTIES, EMITTERS EFFICIENCY AND YIELD OF EGGPLANT IN SALINE SOILS

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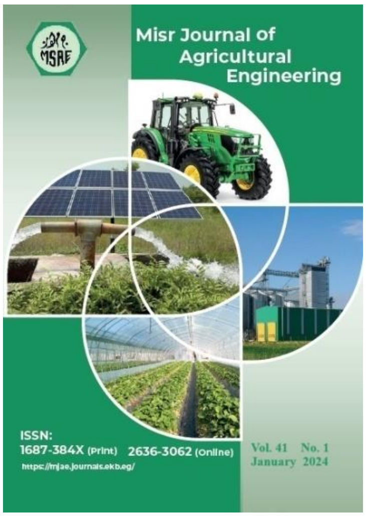

Keywords:

Magnetic Saline Irrigation Water; Soil Properties; Soil Crust; Soil Salt Distribution; Emitters Clogging; Eggplant.

ABSTRACT

Regions close to the coasts generally face difficulties in agriculture, due to salinization of water and soil. This research focuses on evaluating the impacts of magnetic saline water treatment on quality, and yield of eggplant, soil salt distribution, soil mechanical properties, reducing effects of soil crust formation, and emitters efficiency. A standard magnetic device with a strength of 1.45 Tesla was to treat irrigation water salinity of 4.95 dS/m. Field experiment was conducted in soil that had a salinity problem. The effect of magnetized saline water on vegetative parameters, quality and yield of eggplant, soil salt distribution, emitters clogging, and soil mechanical properties and overcome the effect of the soil crust formation were studied. The irrigation water treatments were tap water, saline water, and magnetically treated saline water. The following findings were obtained from a comparison of saline water that was magnetically treated and untreated: the magnetic treatment significantly improved crop growth rate by 51.3%, and increased eggplant productivity by 81.6%. Using magnetic treated saline water, the soil salt content decreased by 35% from the initial value, while, it was increased by 3.7% with untreated saline water. Statistical uniformity coefficients, as an indicator of clogging of emitters in the irrigation system, were 75% for magnetic treated saline water, and 48% for untreated saline water. Measurements of soil mechanical properties, as an indicator of surface crust formation, illustrated that magnetic treated saline water decreased soil penetration resistance by 39.6%, decreased soil cohesion by 8.4%, and decreased internal friction angle by 26.3%.

INTRODUCTION

The northwestern region of the Arab Republic of Egypt is a major location for extensive and diversified economic activities. This area was supposed to meet the demands of the increase in population with limited resources, and therefore the reclamation of these lands was among the important issues on the Egyptian agenda. However, in fact, these areas suffer from restrictions in agricultural activities due to the high salinity of both irrigation water and soil. These difficulties effort on the formation of the surface crust, which leads to soil erosion because of soil seal, as well as reducing the quality of water and the quality of agriculture. Moreover, this layer prevents germination and reduces the permeability of the soil, also it changes the hydrological properties of the soil. This endocrine layer is a significant challenge for these new lands. As a general objective, this study aims to reduce soil crust formation that hinders seedling growth by using magnetically treated saline water for irrigation **(Awadhwal & Thierstein, 1985; Zein Eldin, 1999)**.

Water resources significantly influence sustainable agricultural development in arid and semi-arid regions **(Elnaggar et al., 2018; Morad & Abdel Latif, 2020)**. Soil salinity is influenced by irrigation water, the main water sources are groundwater, and agricultural drainage **(Ezzeldin et al., 2018; Mohamed, 2002)**. If the nature of the soil is calcareous, it causes the soil to make the crust, which it’s a thin layer at the soil surface characterized by a greater density, higher shear strength, and lower hydraulic conductivity than the underlying **(Zein El-Din et al., 2021).** Crust layers hinder the growth of seedlings, especially in the presence of high levels of salinity. Therefore, research tended to treat the cause of the problem by treating the water, precipitating salts, treating the irrigation water magnetically, and other methods **(Youssef et al., 2016).**

Difficulties with salinization and increasing water tables are a result of both man-made and environmental factors. In Egypt, soil salinization issues affect more than 33% of the irrigated territory **(Devkota et al., 2015; Singh, 2021).** Salinity has an important impact on soil structure, and salts in the soil have complicated impacts on the development of aggregate creation and destruction. Additionally, the creation of aggregates is dependent on the salt content of the soil. When soil structure is destroyed, soil pores are destroyed, infiltration by clay dispersion is reduced, and surface crust development is inhibited. **(Liu and She, 2017).**

The processes of aggregate creation and destruction have several intricate effects, such as clay flocculation and swelling as well as soil salt dispersion, which subsequently alter the soil hydraulic properties. Therefore, using methods to reduce soil salinization will stop the destruction of the soil's structure and increase agricultural yield **(Tang et al., 2021)**.

Soil surface crust formation and subsequent erosion resistance are strongly controlled by soil structure and texture **(Bedaiwy, 2008; Zhao et al., 2014)**. For example, **Farres, (1978)** found that soils with huge numbers of minor aggregates had a larger tendency to structural crust formation than those with fewer but bigger aggregates **(Panuska et al., 2008).** The structural crust is shaped from microparticles formed by the breakdown of soil surface aggregates. These particles are reorganized into a denser, more continuous structure by filling and compaction. Soil surface infiltrability gradually declines, potentially resulting in excess water **(Gallardo- et al., 2007).**

Susceptibility to crusting is subject to a combination of soil’s physical, chemical, and biological properties, and procedures, the physical being the greatest influence, mainly soil aggregate stability and texture. Internal soil characteristics such as soil texture, aggregate, clod size, initial moisture level, soil mineralogy, and organic matter affect how susceptible a soil is to crust. Alternatively, environmental variables such as soil salinization, soil compaction, raindrop effect, temperature, and drying speed **(Youssef et al., 2016).**

A tool known as a penetrometer is used to measure soil penetrability. A rod or shaft with a flat end, an enlarged tip, or an enlarged flat plate end makes up a penetrometer. It has been utilized to gauge the strength of the crust. Needles and cones are the two main types of penetrometers that are employed **(Dane et al., 2018; Fernandes et al., 2020)**. To decrease strength, thickness, and bulk density while increasing infiltration rate and hydraulic conductivity, a variety of approaches are utilized as regulating strategies. There are various techniques for each of these systems, which include mechanical, chemical, and physical soil management **(Polláková & Halmo, 2014)**. Magnetic treatment is sorted as a physical controlling technique.

Several types of magnetic field devices have been designed to solve these issues, but their operating mechanisms are the same. Water's structure and physical characteristics, such as density, salt solution capacity, and solid particle deposition ratio, are changed when it passes through a magnetized field to improve soil properties and plant growth **(Liu et al., 2019)**.

The quantity of evaporation, specific heat, and boiling point after magnetization all changed, indicating that the magnetization effect has an impact on how saline water behaves **(Wang et al., 2018)**. By shattering salt crystals, the washing of salts from the soil provider brought on by water magnetism boosts the nutrients' readiness, which in turn stimulates roots to enter the soil and speeds up plant growth **(Suhail & Mahdi, 2013).**

Since **Zhou et al., (2021)** found in the experiments that the strongest effect cumulative soil water content by 33.2% - 56.2% and improving the desalination rate by 29.2% - 50.4%, compared to the control, it is better for the improvement on slightly saline soil than on medium and heavy saline soils. On the other hand, it has been a common irrigation method for farms. It has been discovered that treating water with magnets can improve fruit quality, increase yield, and encourage crop growth **(Zhou et al., 2021)**.

To remove or prevent the formation of hard scale inside industrial and other installations operating at high temperatures, the impact fact to the magnetic field effects was first examined. The following parameters are frequently measured: exposure time to magnetic field, calcium carbonate nucleation and precipitation rates, as well as those of other sparingly soluble salts, coagulation, crystal polymorphism, the zeta potential of precipitated or dispersed particles, electrical conductivity, surface tension, viscosity, pH changes, diffusivity, and others **(Chibowski & Szcześ, 2018)**. Moreover, salinized water re-magnetization levels have no significant impact. The magnetic treatment for saline water was therefore advised to be used just once (single bypass) **(Zeineldin et al., 2023)**.

The research focuses on evaluating the impacts of magnetic saline irrigation water treatment on vegetative parameters, quality and yield of eggplant, soil salt distribution, soil mechanical properties, reducing effects of soil crust formation in saline soil and effect and irrigation emitters efficiency.

MATERIALS AND METHODS

1. The Experimental Area

The experiment took place at the Faculty of Agriculture farm El-Gharbaniyat area (30°51'03.1" N 29°25'09.9" E) within Burj Al-Arab District, Alexandria Governorate. El-Gharbaniyat area has a relatively flat topography with arid characteristics **(Morad & Abdel**

Latif, 2020). The irrigation schedule was planned depends on measurements from the meteorological station, for every hour during the day. The Internet of Things (IoT) system was designed to be a comprehensive, integrated, and independent system. These readings are analyzed throughout the system, and irrigation is planned based on the plant's requirements. Measured data were fine matter or air quality - PM 2.5 (PPM), air temperature (^{o}C), air humidity (%), soil temperature (^{o}C), soil moisture content (%), rainfall (mm), wind speed (m/s), and air pressure (kPa). Data are essential for calculating daily evapotranspiration (ETo), **Fig. (1)** illustrates the weather station.

Monthly mean temperature ranges between 16.18 °C and 27.52 °C in December and August respectively (Farm IOT System Data Logger), with an average annual precipitation of 235 mm in the winter season, and the average humidity of the area is about 70%.

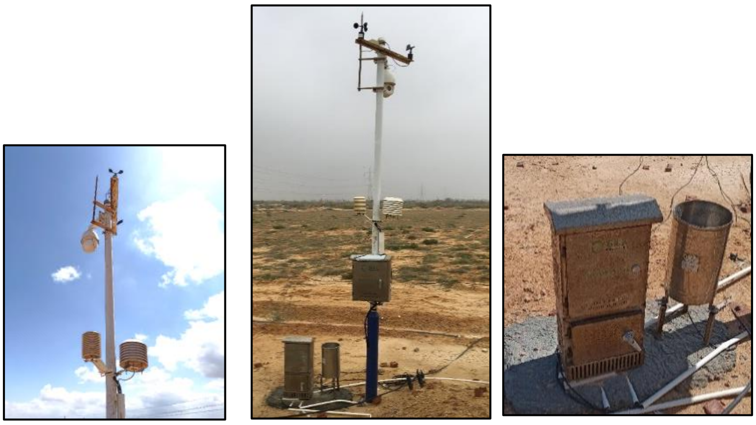

Fig. (1): Farm IoT smart weather station

The following **Table (1)** determines the soil's physical properties. Bulk density (B.D), permanent wilting point (P.W.P), and field capacity (F.C) were determined according to **(Black et al., 2010; Klute, 1986)**. The soil mechanical analysis was carried out using the hydrometer method **(Taylor, 1943)**. Particle size analysis yielded an average value of 70% sand, 22% clay, and 8% silt which classified the soil texture as sandy clay loam soil using the soil-texture triangle **(Menon, 1979)**.

Table (1): Soil physical properties

Depth cm	Particle Size Distribution %			Texture	BD gm/cm^3	P.W.P % m^3 m^{-3}	F.C % m^3 m^{-3}
	Sand	Clay	Silt				
0 – 10	70	22	8	Sandy Clay Loam	1.34	13.52	23.92

Chemical analysis of the soil was conducted as shown in Table (2) pH and electrical conductivity (EC), as well as some soluble cations (Ca^{++}, Mg^{++}, Na^{+}, and K^{+}) and anions (HCO_3^{-}, SO_4^{--}, and Cl^{-}) were determined in the soil extract according to **(Page et al., 1982).**

Table (2): Soil chemical properties

Depth (cm)	pH	EC ds/m	Cations (meq/l)				Anions (meq/l)		
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{--}	Cl^{-}
0 – 10	7.48 ± 0.04	6.78 ± 0.09	14.84 ± 0.53	14.68 ± 0.50	37.22 ± 0.85	1.78 ± 0.04	5.04 ± 0.09	18.12 ± 0.16	20.97 ± 0.39

Values are presented as means ± SD

Water chemical analysis was conducted as shown in **Table (3)** pH and electrical conductivity (EC). Also, some soluble cations (Ca^{++}, Mg^{++}, Na^{+}, and K^{+}) and anions (HCO_3^{-}, SO_4^{--}, and Cl^{-}) were determined in the water according to (Page et al., 1982).

Table (3): Water chemical properties

pH	EC ds/m	Cations (meq/l)				Anions (meq/l)		
		Ca^{++}	Mg^{++}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{--}	Cl^{-}
7.49 ± 0.12	4.95 ± 0.06	17.85 ± 0.52	14.73 ± 0.37	31.45 ± 1.25	0.97 ± 0.09	4.66 ± 0.32	20.42 ± 0.45	25.02 ± 0.15

Values are presented as means ± SD

2. Magnetic Device

The magnetization device is a product of Delta Water Co. for water treatment as shown in the following **Fig. (2).** Its specifications are as follows: constructed from stainless steel material, inner diameter size 2 inches, water flow rate up to 25 m^3/h, connection type thread connection, device length 85 cm, device weight of about 11 kg, working temperature up to 100 °C, working pressure up to 15 bar, and effective for medium salinity water treatment up to 8000 ppm. With a magnetic capacity of 14500 Gauss (1.45 Tesla), Water passes through the magnetic field and becomes magnetized, which causes some physical changes in the composition and shape of water molecules.

Fig. (2): Delta Water Co. magnetic water device

3. Field Experiments

Field experiments were carried out during the summer season of 2023. The seedlings were transplanted on the 15th of April, the experimental plot contained three ridges making 30 meters in length and 6 meters in width at a spacing of 1.0 m between rows making a total area of 540 m^2 per plot **(Rhoades, 1974; Rhoades & Merrill, 1976).** The drip irrigation method was used. The recommended fertilizers of N (285 $kg.ha^{-1}$ N), P (119 $kg.ha^{-1}$ P_2O_5), and K (171 $kg.ha^{-1}$ K_2O) were added according to the recommendations of the Egyptian Ministry of Agriculture and Land Reclamation. The other agricultural practices were performed according to the usual local agricultural management. Meteorological data of experimental location during 2023 are presented in **Table (4).**

Table (4): Meteorological data of experimental location during (2023) as a monthly average

Month	April	May	June	July	August
PM 2.5 (PPM)	23.05 ± 20.47	12.19 ± 10.49	15.62 ± 8.81	17.37 ± 7.99	21.00 ± 14.08
Air Temperature (°C)	19.56 ± 5.25	22.52 ± 6.25	25.13 ± 2.56	26.52 ± 3.09	27.52 ± 3.06
Air Humidity (%)	63.23 ± 9.51	64.98 ± 6.45	66.30 ± 11.29	73.04 ± 11.09	78.28 ± 9.36
Soil Temperature (°C)	18.55 ± 4.32	23.61 ± 7.88	27.74 ± 3.82	28.34 ± 3.09	29.43 ± 3.06
Soil Moisture Content (%)	30.46 ± 4.32	19.76 ± 8.51	21.61 ± 2.76	23.66 ± 0.36	23.66 ± 0.16
Rainfall (mm)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Wind Speed (m/s)	3.15 ± 2.42	2.69 ± 1.90	2.99 ± 1.71	2.99 ± 1.67	3.36 ± 2.48
Air Pressure (kPa)	101.46 ± 0.09	101.43 ± 0.07	101.41 ± 0.15	101.65 ± 0.11	101.53 ± 0.06

Values are presented as means ± SD

The concept of leaching requirement was applied to remove salts from saline soil according to **Karam et al. (2011)**. Plants were grown in lines. On the other hand, the FAO Penman-Monteith equation is used to determine the reference evapotranspiration (ETo). Based on FAO irrigation and drainage paper 56, the decision support tool CROPWAT 8.0 was used **(Allen et al., 1998).** The CROPWAT program includes guidelines for estimating crop evapotranspiration and crop water needs and enables modeling of crop water use under different climatic, agricultural, and soil conditions. Each plot was separated by a buffer zone, and drip irrigation lines with an emitter spacing of 50 cm were placed along the center line. The total volume of water supplied by drip irrigation was 1959.30 $m^3.fed^{-1}$, drip lines were 1.0 m apart, and the flow rate of emitters was 2.1 l/h. The irrigation was applied on the same dates for all the treatments.

The experimental layout was a split-plot design with three replicates with a total of 3 plots. The irrigation treatments included 3 alternative irrigations of tap water ‘T’ as a control treatment, saline water ‘S’, and magnetic field treated saline water ‘M’. Based on the water requirements of eggplant (*Solanum melongena L.*), which are 12 irrigations during the whole growing season. The treatments implied an alternative supply of water as the first treatment was done using tap water (T), then the second treatment was applied saline water (S), and the third treatment was applied with magnetic field treated saline water (M) **(El-Shafik El-Zawily et al., 2019)**, as shown in the **Fig. (3).**

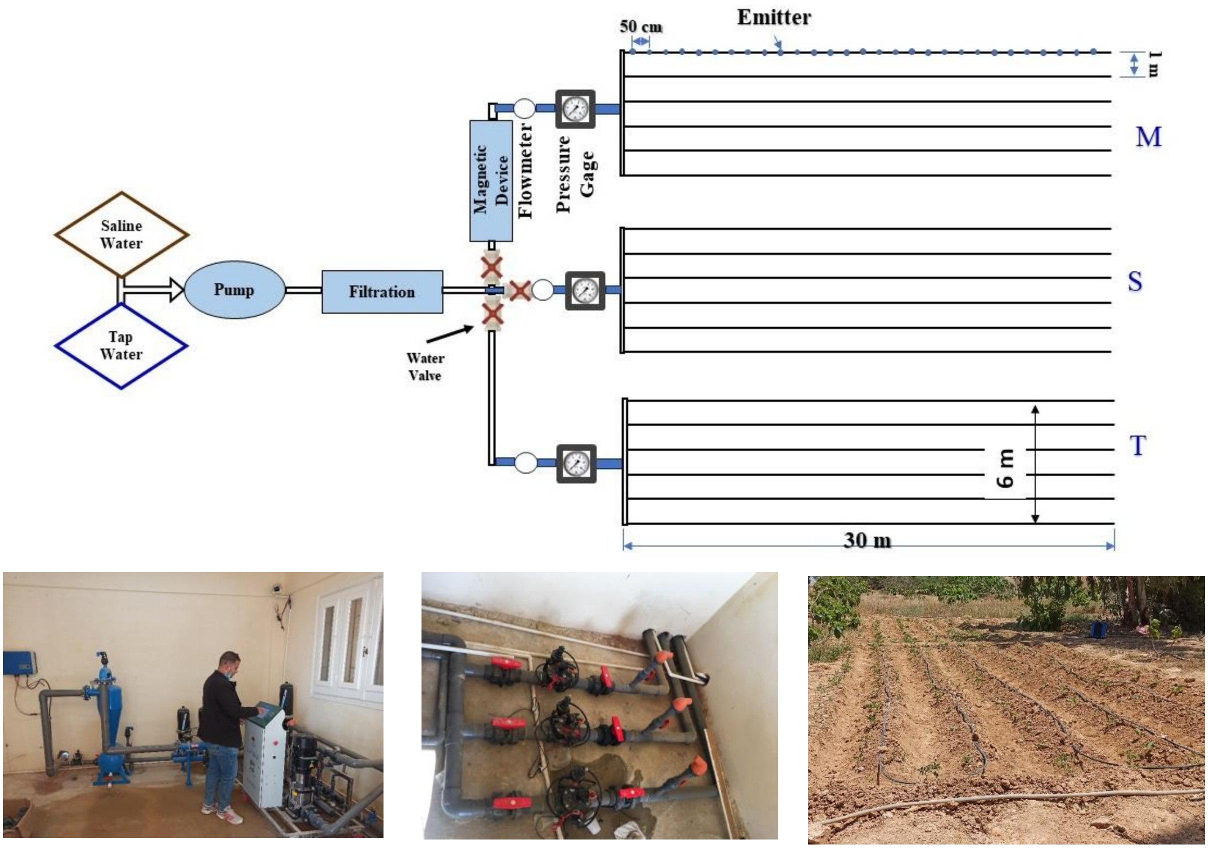

Fig. (3): Experimental Layout

4. Vegetative Parameters and Yield

A representative sample of five plants was randomly taken per plot for measuring plant growth parameters, i.e., branch count (branch per plant), plant height (cm), flowering count (flower per plant), leaf count (leaf per plant), leaf area (cm^2 per plant), and SPAD value (leaf chlorophyll content) at 75 days after transplanting. On the other hand, the growth attribute was computed at two growth stages (45–60 and 60–75 days) after transplanting according to **Stange et al. (2002)**. Two groups of samples were collected at the end of the 7th week and the end of the 9th week of transplanting. Each group contains (T, S, M) samples with 5 replications for each. Crop growth rate (CGR), is defined as the increase in plant dry matter per unit of ground area per unit of time ($g.m^{-2}$ soil per week) and calculated using the following equation:

$$CGR = (W2 - W1)/(T2 - T1)$$

where: W1 and W2 refer to the dry mass of 1 m^2 of ground area of two samples at time T1 and T2 in weeks, respectively.

5. Quality of Yield

The early fruit yield (Mg per fed) was determined from the first two pickings; while the total fruit yield (Mg per fed) was determined from the total weight of fruits collected during all the harvesting periods. Relative yield as a percentage of the control yield was also calculated.

Five fruits per plot were randomly selected to measure the marketable fruit yield (Quality Index) (Mg per fed), which was estimated by subtracting non-marketable yield (diseased and malformed fruits) from the total yield **(El-Zawily et al., 2019)**.

6. Soil Salt Distribution

Soil samples were collected with a 5 cm diameter auger, and soil samples from the eggplant root zone were taken, to determine the soil salt content (SC). A 25 cm collection distance was used for the 0 to 50 cm soil samples. After the leaching solution was allowed to stand for 24 hours, the electrical conductivity (EC) was measured with (CRISON CN35, made in Spain), using the **Rhoades & Van Schilfgaarde, (1976) and Szcześ et al. (2011)** methods. Based on a linear relationship (SC = 4.25*EC; $R_2 = 0.987$; n = 26), the EC value for each soil sample was converted into soil salt content; SC (g salt/kg soil) **(Tan et al., 2017; Yi et al., 2023)**.

Samples were collected in three durations as follows: D1= before transplanting, D2= midseason ‘after 45 days of transplant’, D3= after season ‘90 days after transplant’, with 3 replications for each sample **(Abedinpour & Rohani, 2017)**.

7. Evaluation Clogging in Emitters with Magnetized Saline Water

Clogging in saline water is closely related to the formation of precipitation and its growth inside emitters. A high-grade polyethylene drip pipe is used with turbulent drippers every 50 cm. Additionally, the tube is 16 mm in diameter and 1.1 mm thick, with round emitters that adhere to the inner wall of the hose. The ideal operating pressure is 1 bar with a flow rate of 2.1 ($litter.h^{-1}$).

Dripper flow rates were measured during the season using the volume method. In addition, 15-meter single pipelines in each plot were kept without acid flushing for this experiment.

Dripper flow rates were collected on the first day after transplanting, and continuing for 15 days until the end of the season. The factor that used to determine the emitter performance, is the statistical uniformity coefficient (Uc), using the following equation:

$$U_c = 100(1 - \frac{S_q}{q_{ort}})$$

where Sq is the standard deviation of emitters' discharge rate (litter h^{-1}) and q_{ort} is the mean of emitters discharge rate on a given dripline (litter.h^{-1}). Uc was used to evaluate emitters' flow and work conditions, which reflected the emitter clogging levels. Based on the measured flow rates, these values were calculated according to **Muhammad et al. (2021) and Zhangzhong et al. (2019).** The performances of driplines according to the Uc value classified to three categories; good (Uc > 89%), medium (71% < Uc > 89%), and poor (Uc < 71%) **(Sahin et al., 2012).**

8. Soil Mechanical Properties

8.1. Soil Penetration Resistance

The penetration resistance was measured using a needle penetrometer with a cylindrical flat-tipped 1.59 mm (1/16 inch) needle, as shown in Fig. (4). To fit the conical head into the stem of the flat needle penetrometer, a 0.6 cm diameter cylindrical hole was drilled inside the stem of the instrument. The Italian "Tecnotest" company produced the needle penetrometer ST 207. Its sensitivity is 0.1 kg/cm^2, and its capacity ranges from 0 to 6 kg/cm^2 **(Youssef et al., 2016)**. Also, measurements were taken after one day (D1), two days (D2), and three days (D3) of irrigation to observe the impact on soil penetration resistance.

Fig. 4. Soil needle penetrometer

8.2. Soil Cohesion and Internal Friction Angle

The direct shear box (type D-110 Ay, USA) was used to calculate the soil cohesion and internal friction angle. It is made up of a metal box that is filled with soil. With a height of 5 cm, it has a 25 cm^2 square cross-sectional area. Calculating the typical load applied to the soil sample involved considering the gripper plate's mass of 0.398 kg, as shown in Fig. 5. This was used to gauge the upper half of the shear box's horizontal displacement (shear strain). The dial is 0.001 inches (0.0254 mm) sensitive per division. On top of the ring, weights were gradually added before dial gauge readings were taken. For the following hysteresis dial was calibrated on loading and unloading, as the calibration data were shown in **Fig. (6).**

The gearbox was used to reduce and convert the rotary motion of the manual crank to a shear force on the soil sample. One revolution of the crank corresponds to 0.4 mm displacement. Soil samples were collected after three days of irrigation at the end of the season. Three samples were collected with a bulk density of 1.35 gm/cm^3, and a weight of 101.25 gm for each test to measure soil cohesion and internal friction angle.

9. Statistical Analysis

A split-plot design with three replicates was chosen for the experimental setup. According to **Gomez & Gomez (1984)**, the software program IBM SPSS Statistics version 25 was used to do a one-way analysis of variance on the experiment results, and Duncan's Multiple Range Test **(Duncan, 1965).**

Fig. (5): The Direct Shear box

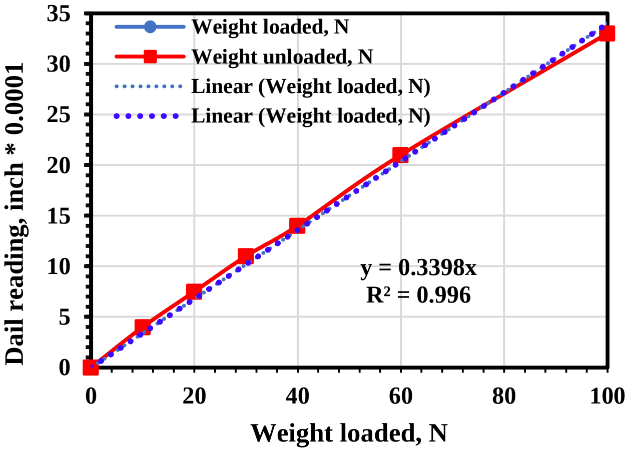

Fig. (6): Calibration curve of the proving ring

The SPSS software was used for the statistical analysis. The control (T), saline (S), and saline water treated with the magnetic field (M) are clearly distinguished from one another in the tables. At a significance level of $P \leq 0.05$, Duncan's formula was used to calculate the variances of the differences between the measurements (T, S, and M). The comparison revealed that, for all means with the same letter, there is no statistically significant difference at $P \leq 0.05$, and vice versa.

RESULTS AND DISCUSSION

1. Vegetative Parameters and Yield

The following **Tables (5) and (6)** showed the impact of water treatments on the vegetative parameters and growth attributes of eggplant (*Solanum melongena L.*) after 75 days of transplanting at a constant growth rate. Firstly, the branches count range (branch per plant) for control water ‘T’ values were (3 - 8), and for saline water ‘S’ values were (2 - 5). Secondly, for plant height (cm. plant^{-1}), the highest value was (58.40 ^{a} ± 3.32) for control water ‘T’, and the lowest value was (31.33 ^{b} ± 3.05) for saline water ‘S’. Thirdly, the flowering count range (flower per plant) for control water ‘T’ values were (8 - 16), and for saline water ‘S’ values were (1 - 5). Fourthly, the leaf count range (leaf per plant) for control water ‘T’ value was (24 - 41), and for saline water ‘S’ value was (7 - 15). Fifthly, for leaf area (cm^{2} per plant), the highest values were (531.75 ^{a} ± 59.36) for control water ‘T’, and the lowest value was (180.67 ^{c} ± 16.82) for saline water ‘S’. Sixthly, for SPAD value (leaf chlorophyll content), the highest value was (47.85 ^{a} ± 0.60) for control water ‘T’, and the lowest value was (42.87 ^{b} ± 0.59) for saline water ‘S’, as shown in Table (5), and **Fig. (7).**

On the other hand, for the magnetic treatment ‘M’, the results of vegetative parameters were very close to the control treatment tap water ‘T’, as follows: branches count range (3-7), plant height (cm) (57.00 ^{a} ± 2.21), flowering count range (flower per plant) (6 - 18), leaf count range (leaf per plant) (20 - 37), leaf area (cm^{2}. plant^{-1}) (392.02 ^{b} ± 13.02), and SPAD value (leaf chlorophyll content) (46.60 ^{a} ± 0.52), as shown in **Table (5), and Fig. (7).** The research results of **Surendran et al. (2016)**, who demonstrated that water used for irrigation types treated with magnets improved the development of crops, were in perfect agreement with the results of this investigation.

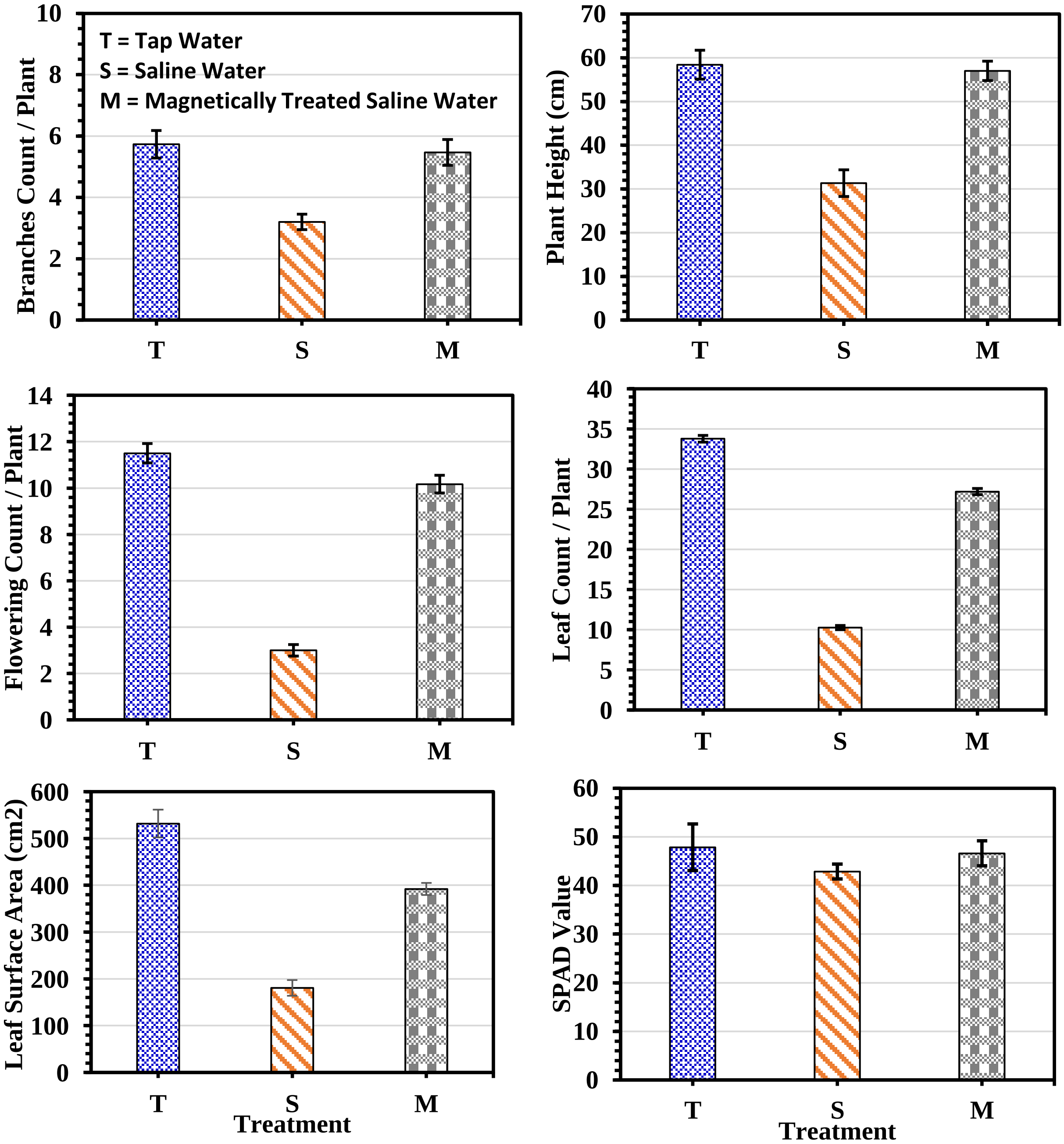

Fig. (7): Vegetative parameters for eggplant (*Solanum melongena L.*) (Values are presented as means ± SD)

Moreover, for the growth attributes of eggplant (*Solanum melongena L.*), **Table (6) and Fig. (8)** showed the impact of magnetic treatment (M), saline water (S), and control water (T) on the crop growth rate (CGR) (gm.m^{-2}.soil per week). The results showed that the highest CGR value was (3.34 ^{a} ± 0.28) for control water 'T', and the lowest value was (2.71 ^{b} ± 0.15) for saline water 'S'. Alternatively, for the magnetic treatment 'M', the result of CGR was very close to the control treatment tap water 'T',

Table (5): Vegetative parameters for eggplant (*Solanum melongena L.*)

Treatment	**Branches Count Range** (branch.plant^{-1})	**Plant Height** (cm.plant^{-1})	**Flowering Count Range** (flower.plant^{-1})	**Leaf Count Range** (leaf.plant^{-1})	**Leaf Area** (cm^{2}.plant^{-1})	**SPAD** (leaf chlorophyll content)
T (Control)	(3 - 8) ^{a} ± 0.45	58.40 ^{a} ± 3.32	(8 - 16) ^{a} ± 0.42	(24 - 41) ^{a} ± 0.42	531.75 ^{a} ± 59.36	47.85 ^{a} ± 0.60
S (Without Treatment)	(2 - 5) ^{b} ± 0.25	31.33 ^{b} ± 3.05	(1 - 5) ^{b} ± 0.25	(7 - 15) ^{c} ± 0.24	180.67 ^{c} ± 16.82	42.87 ^{b} ± 0.59
M (With Treatment)	(3 - 7) ^{a} ± 0.42	57.00 ^{a} ± 2.21	(6 - 18) ^{a} ± 0.38	(20 - 37) ^{b} ± 0.37	392.02 ^{b} ± 13.0.	46.60 ^{a} ± 0.52

Values are presented as means ± SD, except count values presented as (min-max) ± SD

Means per factor followed by the same letter/s are not significantly different at P ≤ 0.05

Table (6): Growth attributes for eggplant (*Solanum melongena L.*)

Treatment	T_1 = 7 weeks			T_2 = 9 weeks			Crop growth rate (CGR) (gm.m^{-2} soil.week^{-1})
	Leaf Area (LA_1) (cm^{2}.plant^{-1})	**Fresh Weight (FW_1)** (gm.plant^{-1})	**Dry Weight (DW_1)** (gm.plant^{-1})	**Leaf Area (LA_2)** (cm^{2}.plant^{-1})	**Fresh Weight (FW_2)** (gm.plant^{-1})	**Dry Weight (DW_2)** (gm.plant^{-1})	
T (Control)	347.89 ^{a} ± 30.19	54.80 ^{a} ± 3.43	7.96 ^{a} ± 0.11	531.75 ^{a} ± 51.41	66.49 ^{a} ± 1.78	11.30 ^{a} ± 0.30	3.34 ^{a} ± 0.28
S (Without Treatment)	118.50 ^{c} ± 10.55	22.62 ^{c} ± 2.08	3.20 ^{c} ± 0.20	180.67 ^{c} ± 14.32	26.59 ^{c} ± 1.75	4.52 ^{c} ± 0.31	1.32 ^{c} ± 0.09
M (With Treatment)	248.64 ^{b} ± 20.06	37.62 ^{b} ± 2.36	5.64 ^{b} ± 0.37	392.02 ^{b} ± 11.28	44.18 ^{b} ± 4.71	8.35 ^{b} ± 0.46	2.71 ^{b} ± 0.15

Values are presented as means ± SD

Means per factor followed by the same letter/s are not significantly different at P ≤ 0.05

2. Quality of Yield

The effect of water treatments on the yield for eggplant (Solanum melongena L.) after the first two pickings (gm.fruit^{-1}), and the quality of yield were illustrated in **Table (7), and Fig. (9).** The results indicated the following yield parameters as yield after the first two pickings (gm.fruit^{-1}), total fruit yield (Mg.fed^{-1}), marketable fruit yield (quality index) (Mg.fed^{-1}), and relative yield (as % of control). Firstly, for the yield after the first two pickings (gm.fruit^{-1}), the highest value was (260 ^{a} ± 14.25) for control water 'T', and the lowest value was (110 ^{b} ± 6.96) for saline water 'S'. Secondly, for total fruit yield (Mg.fed^{-1}), the highest value was (14.15 ^{a} ± 0.36, 100%) for control water 'T', and the lowest value was (3.47 ^{b} ± 0.17, 24.51%) for saline water 'S'. Thirdly, for marketable fruit yield (Quality Index) (Mg.fed^{-1}), the highest value was (13.88 ^{a} ± 0.31, 100%) for control water 'T', and the lowest value was (3.39 ^{b} ± 0.13, 24.51%) for saline water 'S'. On the other hand, for the magnetic treatment 'M', the results of yield after the first two pickings (gm fruit^{-1}), total fruit yield (Mg.fed^{-1}), marketable fruit yield (Quality Index) (Mg.fed^{-1}), and relative yield (as % of control) were very close to the control treatment tap water 'T', as shown in, as shown in **Table (7), and Fig. (9).** The results of this analysis were completely consistent with those of **El-Zawily et al., (2019)**, which showed that saline irrigation water treated with magnets increased crop yield.

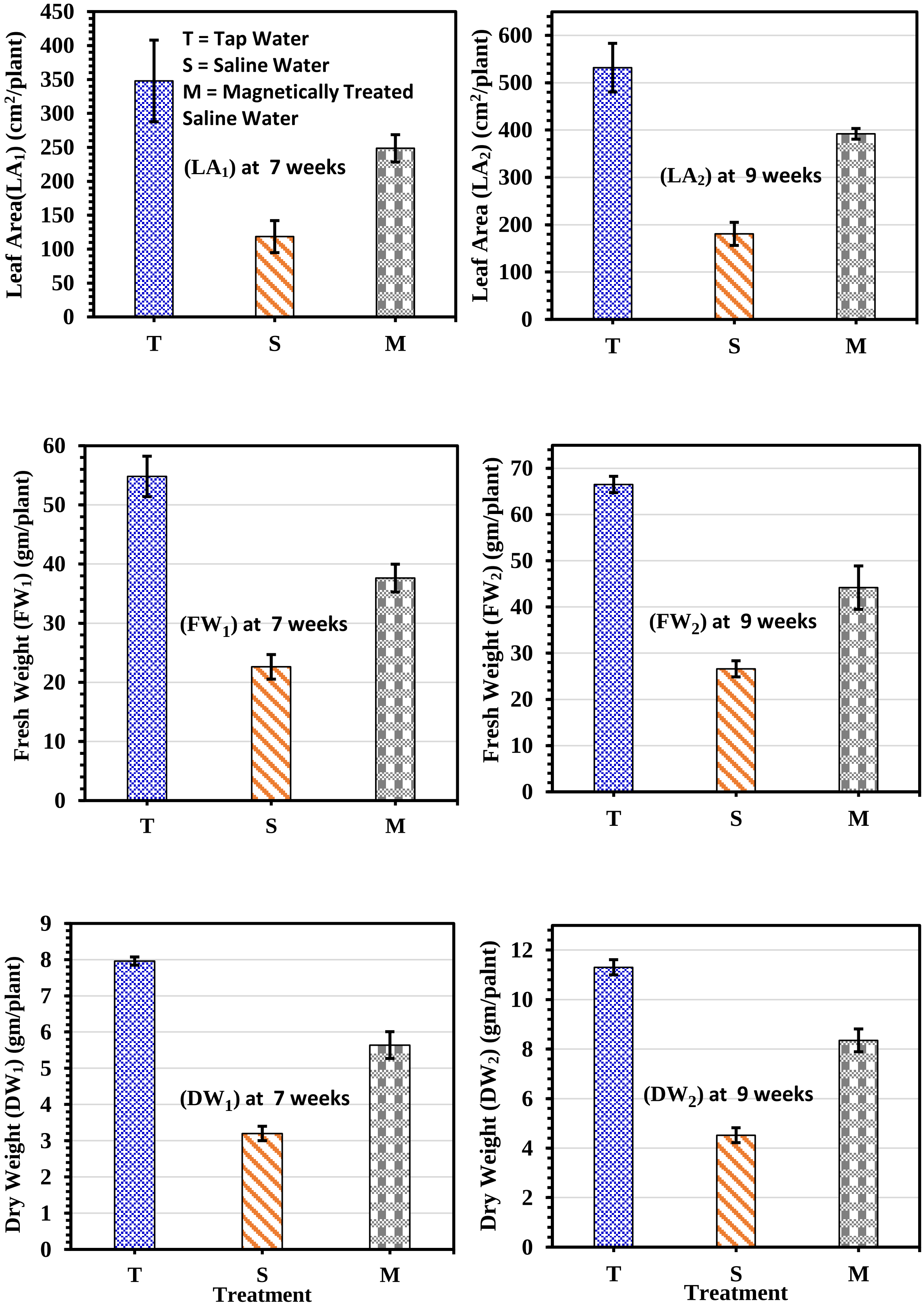

Fig. (8): Growth attributes for eggplant (*Solanum melongena L.*) (Values are presented as means ± SD)

Table (7): Yield and quality for eggplant (*Solanum melongena L.*)

Treatment	Yield after the first two pickings (gm.fruit^{-1})	Total fruit yield (Mg fed^{-1})	Marketable fruit yield (Quality Index) (Mg fed^{-1})	Relative yield (as % of control)
T (Control)	$260^{a} \pm 14.25$	$14.15^{a} \pm 0.36$	$13.88^{a} \pm 0.31$	100.00
S (Without Treatment)	$110^{b} \pm 6.96$	$3.47^{b} \pm 0.17$	$3.39^{b} \pm 0.13$	24.51
M (With Treatment)	$250^{a} \pm 19.78$	$11.54^{a} \pm 0.68$	$11.21^{a} \pm 0.56$	81.59

Values are presented as means ± SD

Means per factor followed by the same letter/s are not significantly different at $P \leq 0.05$

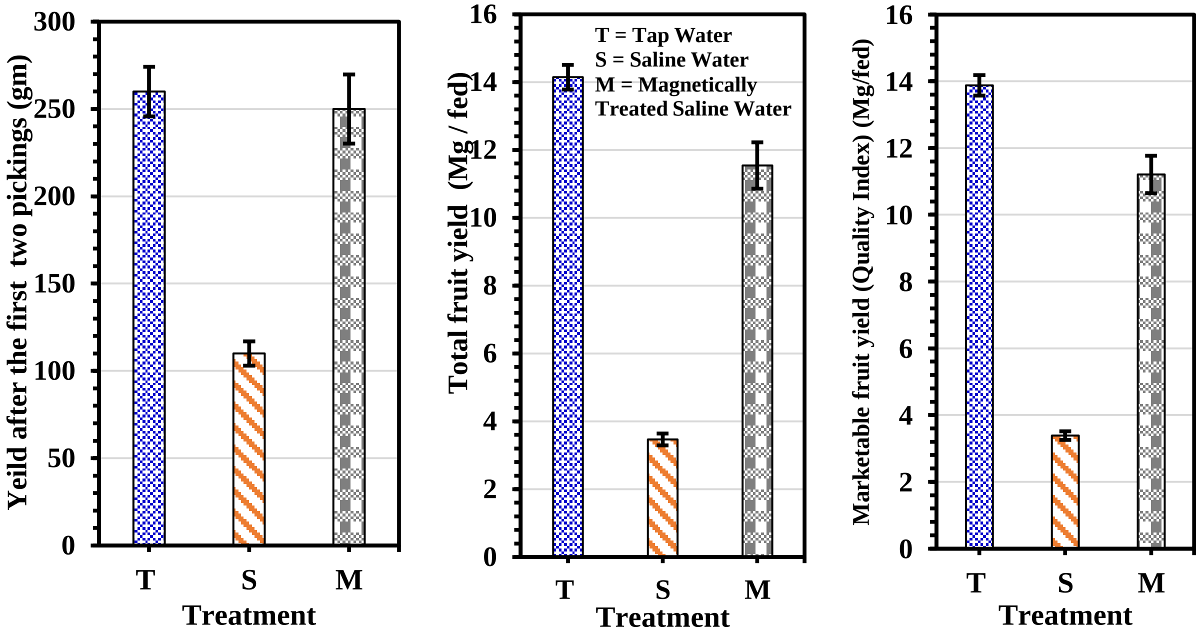

Fig. (9): Yield and quality of yield for eggplant (Values are presented as means ± SD)

3. Soil Salt Distribution

Samples were collected in three ranges of soil depth 0 cm (T_0, S_0, M_0), 25 cm (T_1, S_1, M_1), and 50 cm (T_2, S_2, M_2). Moreover, samples were collected in three durations as follows: D1= before season 'before transplanting', D2= midseason 'after 45 days of transplant', D3= after season '90 days after transplant'. The results were illustrated in **Table (8) and Fig. (10).**

The data were divided into three groups (D1, D2, and D3) based on the durations, which showed the soil salt content (g.kg^{-1}). Firstly, before season results, the highest value was ($28.69^{e} \pm 0.05$) for magnetically treated water at a depth of 0 cm 'M_0', and the lowest value was ($25.54^{a} \pm 0.21$) for saline water at a depth of 50 cm 'S_2'. Secondly, in midseason results, the highest value was ($28.41^{g} \pm 0.29$) for saline water at a depth of 0 cm 'S_0', and the lowest value was ($21.17^{a} \pm 0.05$) for tap water at a depth of 25 cm'T_1'. Lastly, in after-season results, the highest value was ($29.24^{d} \pm 0.14$) for saline water at a depth of 0 cm 'S_0', and the lowest value was ($15.00^{a} \pm 0.14$) for tap water 'T' at a depth of 50 cm 'T_2' as shown in **Table (8) and Fig. (10).**

On the other hand, for the soil salt content (g.kg^{-1}), data showed that the effect of saline water treatment with magnetic (M) decreased the soil salt content, as the following values (18.62 ^{b} ± 0.11, 19.89 ^{c} ± 0.20, 19.93 ^{c} ± 0.12) compared to the saline water 'without treatment' (29.24 ^{d} ± 0.14, 27.75 ^{d} ± 0.10, 27.54 ^{e} ± 0.24) as shown in **Table (8) and Fig. (10).** These results completely agreed with the result obtained by **Yi et al. (2023)** which demonstrated that the soil salt content with control and magnetic-treated saline water lower than the saline water only.

Table (8): Soil salt content (g.kg^{-1}), for treatments in three depths during the season

Soil Profile (Depth)	Treatment	D1= before transplanting	D2= midseason 'after 45 days of transplant'	D3= late season '90 days after transplant'
0 - 20 cm	T_0	28.28 ^{d} ± 0.21	23.08 ^{c} ± 0.34	15.22 ^{a} ± 0.22
	S_0	28.18 ^{d} ± 0.18	28.41 ^{g} ± 0.29	29.24 ^{d} ± 0.14
	M_0	28.69 ^{e} ± 0.05	23.63 ^{d} ± 0.30	18.62 ^{b} ± 0.11
20 - 40 cm	T_1	26.39 ^{b} ± 0.36	21.17 ^{a} ± 0.05	15.17 ^{a} ± 0.12
	S_1	25.93 ^{a} ± 0.05	25.97 ^{f} ± 0.30	27.75 ^{d} ± 0.10
	M_1	26.86 ^{c} ± 0.21	24.61 ^{e} ± 0.34	19.89 ^{c} ± 0.20
40 - 60 cm	T_2	26.94 ^{c} ± 0.18	22.14 ^{b} ± 0.29	15.00 ^{a} ± 0.14
	S_2	25.54 ^{a} ± 0.21	26.27 ^{f} ± 0.34	27.54 ^{e} ± 0.24
	M_2	25.71 ^{a} ± 0.18	24.40 ^{e} ± 0.27	19.93 ^{c} ± 0.12

Values are presented as means ± SD

Means per factor followed by the same letter/s are not significantly different at $P \leq 0.05$

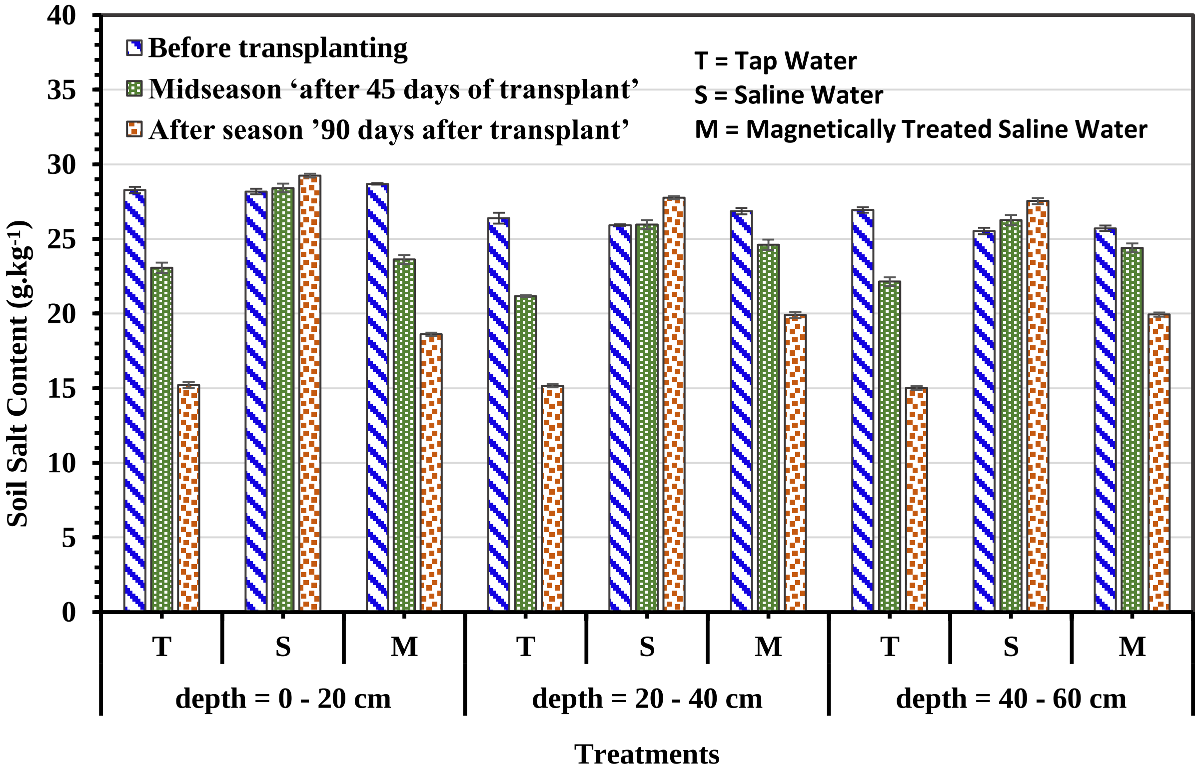

Fig. (10): Soil water-salt distribution for treatments in three depths during the season (Values are presented as means ± SD)

4. Evaluation Clogging in Emitters with Magnetized Saline Water

Evaluation of clogging in emitters with magnetized saline water is illustrated in **Table (9) and Fig. (11)** as statistical uniformity coefficient (Uc) (%).

Statistical uniformity coefficient (U_c) (%) values for 'tap water' (T) were (99.63 ^{a} ± 4.98) at 0 days (same day of transplanting), and (78.20 ^{a} ± 5.32) after 90 days of transplanting. On the other hand, for saline water (S) treatment, U_c was (99.55 ^{a} ± 5.97) at 0 days, and reached (48.03 ^{c} ± 7.68) after 90 days of transplanting. Additionally, for magnetic water treatments (M), U_c was (99.54 ^{a} ± 3.48) at 0 days and reached (74.95 ^{b} ± 7.12) after 90 days of transplanting, that is very close to the control treatment tap water 'T', as shown in **Table (9) and Fig. (11).** The results of this analysis were completely consistent with those of **Muhammad et al., (2021) and Sahin et al. (2012)**, who showed that magnetic water (M) treatment reduced clogging in emitters.

Table (9): Evaluation clogging in emitters with magnetized saline water using statistical uniformity coefficient (Uc) (%) value

Treatment	0 Day	15 Days	30 Days	45 Days	60 Days	75 Days	90 Days
T (Control)	99.63 ^{a} ± 4.98	98.90 ^{a} ± 6.92	98.28 ^{a} ± 5.41	93.91 ^{a} ± 5.07	89.49 ^{a} ± 7.16	84.02 ^{a} ± 4.28	78.20 ^{a} ± 5.32
S (Without Treatment)	99.55 ^{a} ± 5.97	98.96 ^{b} ± 9.90	97.78 ^{b} ± 9.29	76.40 ^{b} ± 6.80	53.05 ^{ab} ± 8.75	50.46 ^{c} ± 6.06	48.03 ^{c} ± 7.68
M (With Treatment)	99.54 ^{a} ± 3.48	98.52 ^{a} ± 5.52	93.61 ^{a} ± 7.30	88.85 ^{a} ± 4.80	78.75 ^{b} ± 4.41	76.72 ^{b} ± 3.84	74.95 ^{b} ± 7.12

Values are presented as means ± SD

Means per factor followed by the same letter/s are not significantly different at $P \leq 0.05$

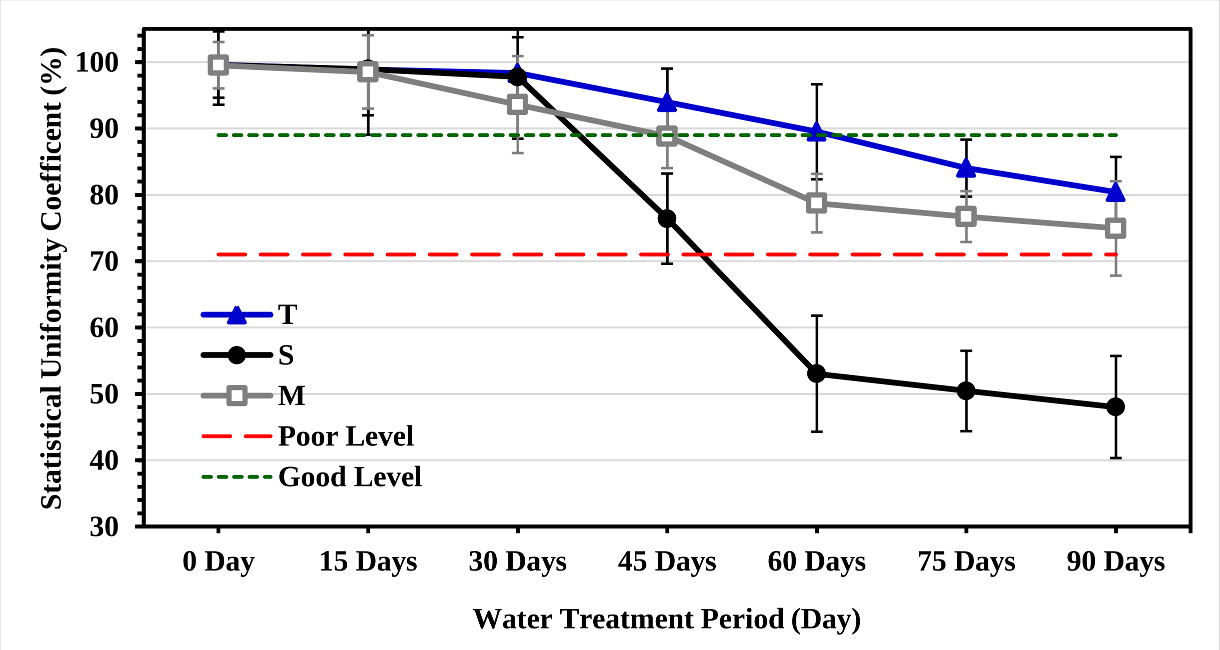

Fig. (11): Evaluation clogging in emitters with magnetized saline water using statistical uniformity coefficient (Uc) (Values are presented as means ± SD. Uc values are good when Uc > 89%), and poor when (Uc < 71%))

5. Soil Mechanical Properties

5.1. Soil Penetration Resistance

Measurements of soil penetration resistance (kg/cm^2) were performed after one day (D1), two days (D2), and three days of irrigation (D3) to determine the influence of water treatments on soil penetration resistance. The results are shown in **Table (10) and Fig. (12).** Initially, for one day after irrigation, the maximum value was (0.74 ^{a} ± 0.10) for saline water 'S', and the minimum value was (0.46 ^{a} ± 0.06) for tap water 'T'. Then, for two days after irrigation, the maximum value was (1.03 ^{b} ± 0.08) for the saline water 'S', and the minimum value was (0.75 ^{a} ± 0.08) for tap water 'T'. Lastly, for a three-days after irrigation, the maximum value was (2.40 ^{b} ± 0.16) for the saline water 'S', and the minimum value was (1.43 ^{a} ± 0.06) for tap water 'T', as illustrated in **Table (10) and Fig. (12)**.

On the other hand, for the magnetic treatment 'M', the results of soil penetration resistance (kg/cm^2), were very close to the control treatment tap water 'T', as shown in **Table (10)** and **Fig. (12)**. The results of this analysis were completely consistent with those of **Abed, (2012)**, which demonstrated that the formation of the surface crust was decreased by the application of magnetic irrigation water.

Table (10): Soil penetration resistance (kg/cm^2) as affected by different treatments and intervals of irrigation

Treatment	Intervals after irrigation (days)		
	D1 (One day after irrigation)	D2 (Two days after irrigation)	D3 (Three days after irrigation)
T (Control)	0.46 ^{a} ± 0.06	0.75 ^{a} ± 0.08	1.43 ^{a} ± 0.06
S (Without Treatment)	0.74 ^{a} ± 0.10	1.03 ^{b} ± 0.08	2.40 ^{b} ± 0.16
M (With Treatment)	0.48 ^{a} ± 0.05	0.77 ^{a} ± 0.08	1.45 ^{a} ± 0.09

Values are presented as means ± SD
Means per factor followed by the same letter/s are not significantly different at $P \leq 0.05$

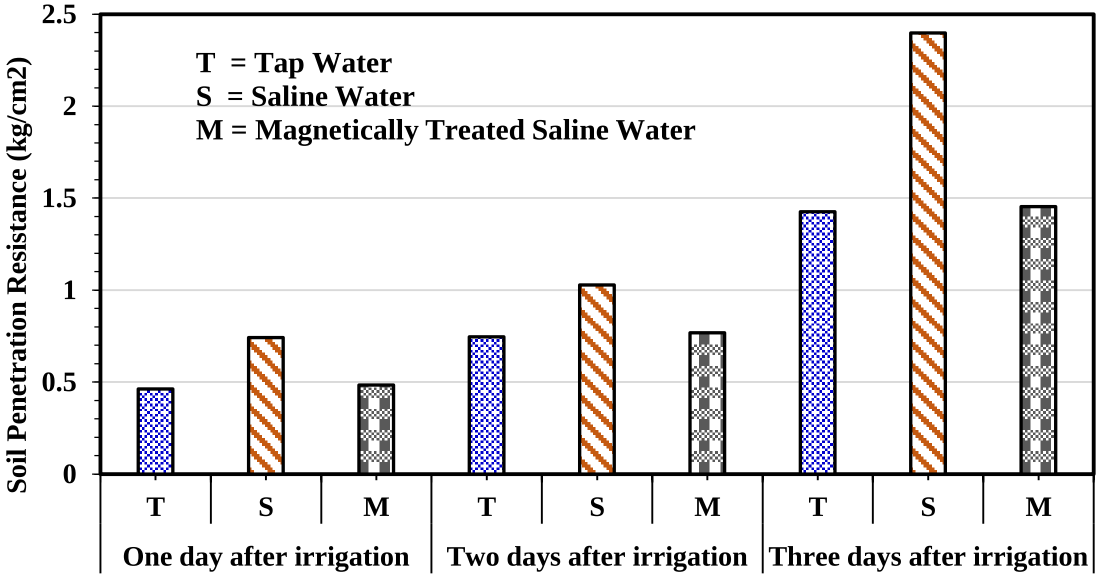

Fig. (12): Soil penetration resistance (kg/cm^2) as affected by different treatments and intervals of irrigation

5.2. Soil Cohesion and Internal Friction Angle

Measurements of soil cohesion (kPa) and soil internal friction angle (degree) were performed after three days of irrigation at the end of the season (after 90 days of transplanting). The results are shown in **Table (11) and Fig. (13).** Firstly, for soil cohesion (kPa) parameters, the maximum value was (9.450 ^{b} ± 0.30) for saline water ‘S’, and the minimum value was (8.452 ^{a} ± 0.23) for tap water ‘T’. In contrast, for soil internal friction angle (degree), the maximum value was (7.925 ^{c} ± 0.60) for saline water ‘S’, and the minimum value was (5.654 ^{a} ± 0.21) for tap water ‘T’, as shown in **Table (11) and Fig. (13).** The results of this analysis were completely consistent with those of **Zhang et al., (2019)**, which demonstrated that the soil cohesion (kPa), and soil internal friction angle (degree) decreased due to the application of magnetic irrigation water.

Table (11): Soil Cohesion and Internal Friction Angle after 3 days of irrigation at the end of the season (after 90 days of transplanting)

Treatment	**Normal stress** (kPa)	**Shear Strain** (inch*0.0001)	**Shear Load** (N)	**Shear Stress** (kPa)	**Soil Cohesion** (kPa)	**Internal Friction Angle** (degree)
T (Control)	4	7.45	21.92	8.77	8.452 ^{a} ± 0.23	5.654 ^{a} ± 0.21
	16	8.59	25.28	10.11		
	39	10.45	30.75	12.30		
S (Without Treatment)	4	8.52	25.07	10.03	9.450 ^{b} ± 0.30	7.925 ^{c} ± 0.60
	16	9.84	28.96	11.58		
	39	12.68	37.32	14.93		
M (With Treatment)	4	7.69	22.63	9.05	8.654 ^{a} ± 0.14	5.844 ^{b} ± 0.52
	16	8.72	25.66	10.26		
	39	10.76	31.67	12.67		

Soil cohesion and internal friction angle values are presented as means ± SD

Means per factor followed by the same letter/s are not significantly different at $P \leq 0.05$

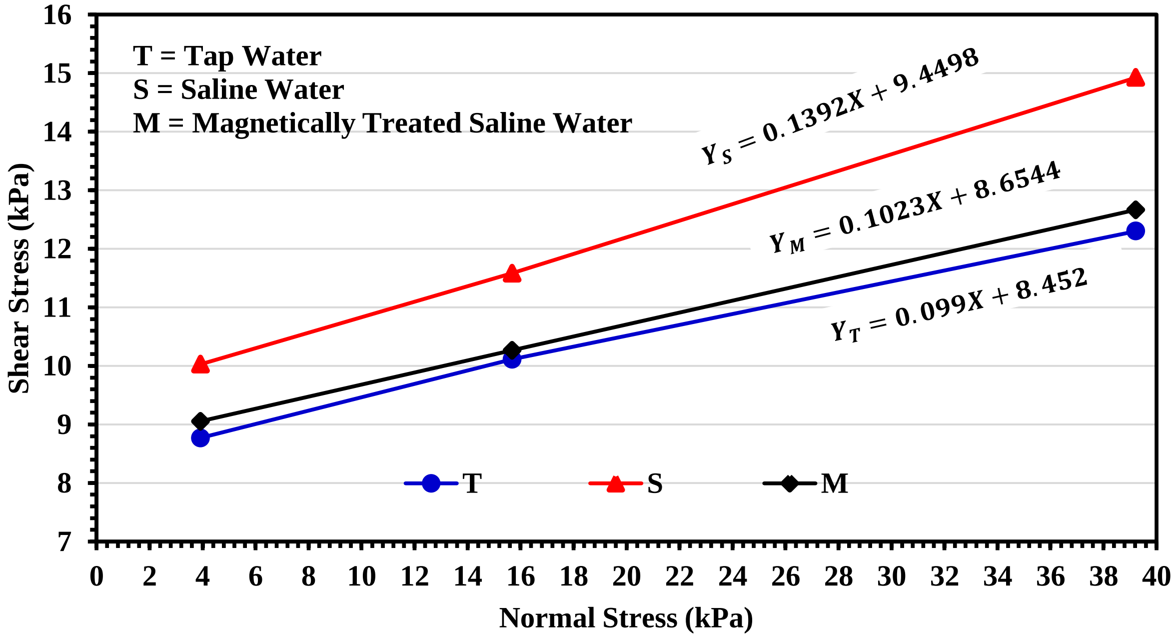

Fig. (13): Soil Cohesion and Internal Friction Angle after 3 days of irrigation at the end of the season (after 90 days of transplanting)

SUMMARY AND CONCLUSION

Magnetic treatment for saline water showed an optimal treatment compared with saline water only to control soil salinity, reduce the effect of salinity, increase the quality and growth of the crop, control the soil surface crust formation, and achieve sustainable development. However, magnetic treatment has no effect on salinity, but it does work to break down the saline particles, making it easier for the plant to absorb the water. So, it can be said that the magnetic treatment works to change the properties of the water.

Crop productivity using magnetic saline water treatment is considered a successful outcome in that the quality produced is close to that of using tap water for irrigation. The findings of this study show that the eggplant plant was able to mitigate the negative effects of saline water by treating this water magnetically. Moreover, treating saline water magnetically reduces dripper clogging, which is a common problem with salt water in drip irrigation networks. The findings of the magnetic saline water treatment also showed a decrease in soil penetration resistance, soil cohesion, and internal friction angle, which is a reflection of the decrease in soil surface crust formation.

Finally, it can be concluded that the salinity issues affecting the soil and water throughout the experiment were successfully resolved by utilizing magnetic treatment in the process of treating saline water, based on the various measurements and findings of the water and soil. The outcomes are acceptable when compared to using simple saline water.

RECOMMENDATIONS

From the scope of the previous results, we recommend the need to apply the following:

- Applying magnetically treatment on saline water, to obtain the highest yield and crop quality compared to saline water without treatment.
- Treating saline water as a magnet with an excellent effect to overcome the clogging of emitters in the irrigation network, as well as an economical solution to overcome the problems of salinity in both water and soil.
- Magnetic treatment reduced the soil surface crust formation and improved the mechanical properties of the soil (penetration resistance, soil cohesion, and the soil internal friction angle).
- This research is an important solution to overcome the salinity problem of irrigation water.
- It recommends the liability of a field experiment on a larger scale, with the same previous treatments, to study the economics of agriculture.
- It recommends doing more research in this direction, to achieve sustainable development in modern agriculture.

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تاثير مغنطة مياه الري المالحة علي خصائص التربة الميكانيكية وكفاءة النقاطات وإنتاجية الباذنجان في التربة الملحية

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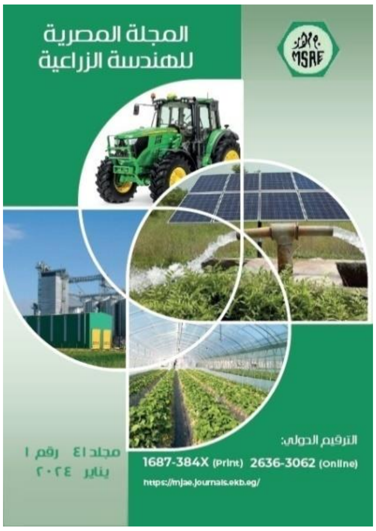

الكلمات المفتاحية:
مغنطة المياه المالحة؛ خواص التربة؛ القشرة السطحية للتربة؛ توزيع الأملاح؛ انسداد النقاطات؛ الباذنجان.

الملخص العربى

تواجه المناطق الساحلية صعوبات في الزراعة، ويرجع ذلك الى تملح المياه والتربة. وتساهم الأملاح في تكون طبقة صماء تعيق الانبات، وتعمل على تغيير الخصائص الميكانيكية للتربة. ويوجد العديد من الطرق لحل هذه المشكلة ولكنها تعد مكلفة مقارنة بطريقة معالجة المياه مغناطيسياً والتي تعد اقتصادية. يهدف هذا البحث إلي تقييم تأثير المعالجة المغناطيسية لمياه الري المالحة في التربة الملحية على خصائص التربة وتوزيع الاملاح وكفاءة النقاطات وإنتاجية الباذنجان. لذلك استخدم جهاز مغنطة قياسي بشدة 1.45 Tesla طبقاً لقيم ملوحة ماء الري والتي تقدر 4.95 dS/m. تم اجراء تجربة حقلية فعلية لتربة تعاني من هذه المشاكل وتم قياس المؤشرات النباتية لنبات الباذنجان، وتتبع الأملاح في التربة، وتقيم انسداد المنقطات، وقياسات على الخواص الميكانيكية للتربة لمعرفة تأثير المعاملة على تكون القشرة السطحية للتربة. وكانت المعاملات المستخدمة في التجربة هي المستوي القياسي "ماء الصنبور، وماء مالح، وماء مالح معالج مغناطيسياً. وكانت النتائج للماء المالح المعالج مغناطيسياً كقيم نسبية مقارنة بالماء المالح قبل المعالجة كما يلي: حسنت المعالجة المغناطيسية الخصائص النباتية بشكل ملحوظ، حيث زاد معدل النمو بمقدار ٥١,٣%. انتاجية الباذنجان عند استخدام المياه المعالجة مغناطيسيا أعلى بنسبة ٨١,٦%. كمية الأملاح بالتربة عند استخدام الماء المالح المعالج انخفض بمعدل ٣٥% عن القيمة الابتدائية، مقارنة بزيادة قيم الأملاح بمقدار ٣,٧% للماء المالح فقط. معامل الانتظامية الاحصائي كمؤشر لانسداد النقاطات في شبكة الري كان للماء المالح المعالج ٧٥%، وللماء المالح فقط ٤٨%. قياسات الخواص الميكانيكية للتربة كمؤشر لتكون القشرة السطحية، للماء المالح المعالج قلت قيم مقاومة اختراق التربة بمقدار ٣٩,٦%. أما قيم تماسك التربة قلت بمقدار ٨,٤%، وكذلك بالنسبة لقيم زاوية الاحتكاك الداخلي للتربة قلت بمقدار ٢٦,٣%.