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Effect of Magnetized Water and Nitrogen Fertilization on Soil Properties and Its Productivity of Eggplant

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A FIELD experiment was carried out on a private farm in Meet Khakan, Shebin ElKom, Menofia Governorate, Egypt, for two successive growing seasons in winter 2021/2022 and 2022/2023. The purpose of this study was to investigate the influence of magnetized water at various N fertilizer application rates on some soil chemical parameters as well as eggplant production (quantity and quality). To attain this goal, non-magnetized well water and magnetic well water were employed for irrigation. Furthermore, N fertilizer (NH_4NO_3) was applied at rates of 25, 50, and 100% of the recommended dose. Except for the BOD value, non-magnetized water had a higher pH, EC (dS m^{-1}), and soluble cation and anion content than magnetized water. At the same soil depth and applied N level, the soil irrigated by magnetized water has low values of pH, EC, and the content of soluble cations (except for K^+) and anions. Irrigation with magnetized water, as well as an increase in added N, resulted in an enhance in plant height (cm), number of leaves per plant, leaf dry matter yield per plant, fruit length and diameters (cm), and fruit yield (kg m^{-2}) compared to plants irrigated with nonmagnetic water, while flowering data (50%) shows a reversible trend. With the same rate of added N, the plant irrigated by magnetized water have a high content of N, P, K, Fe, Mn, Zn and Cu .

Keywords: Water quality; Yeild; Growth parameters; and Available nutrients.

1. Introduction

One method that plant nurseries employ to produce uniform and highly potential seedlings year-round is irrigation **(Ibrahim et al., 2024)**. Population expansion has led to a rise in the demand for water from irrigated agriculture; therefore, it is important to take this into account while analyzing the content **(Jiang et al., 2024)**. According to **(Omara, 2024)**, the solanum melongena L. crop, which grows eggplant, is related to tomato, pepper, and scarlet eggplant in the solanaceae family and needs comparable environmental conditions. The **FAO (2016)** estimated that there were over 1.7 million hectares of eggplant growing worldwide, with an average production of 12.008 tons/feddan (where one feddan is equal to 4200 m2). Using magnetically treated water, which can benefit plants and soil, is one of the emerging technologies as an alternative for conserving water **(Surendran et al., 2016)**. Water molecules can form hydrogen bonds with up to four additional water molecules by nature; however, when water is subjected to magnetic treatment, the water molecules are released, increasing the cohesiveness of the water **(Abdelsalam et al., 2024)**. Water that has been exposed to a magnetic field before usage is known as magnetically treated water (MTW). Although the effectiveness of such treated water is still up for dispute, there are many advantages to adopting it. **Al-Akhras et al. (2024)** conducted research on the magnetization process of water and put forth a theory based on the molecular makeup of the substance. They also suggested that the interaction of the externally applied magnetic field with the electric current generated by protons (or hydrogen ions) improves conductivity along the closed hydrogen-bonded chains of molecules found in water.

Investigating the properties of magnetized water is crucial for clarifying its role and understanding the biological effects of the magnetic field on humans, animals, and plants due to their high water content (70-80%). In order to examine how magnetic fields

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interact with flowing water, **Ibrahim et al. (2024)** measured the absorbance, pH, TDS, EC, viscosity, surface tension, and thermal conductivity of regular tap water both before and after applying magnetic fields with a strength of 6560 G. These fields were created by carefully positioning permanent magnet pieces around the pipe that the water is flowing through. They used accurate and appropriate measuring techniques to examine the physical parameters of the magnetized water. In addition, there was a 12% increase in pH and a 33% and 36% decrease in TDS and EC, respectively. Additionally, there is a 23% and 18% drop in the mechanical parameters viscosity and surface tension, respectively. Even yet, there was a 16% drop in thermal conductivity.mercury, and lead; alkali metals, such as lithium, sodium, potassium, and cesium; metalloids, also known as semi-metals due to their metallic and non-metallic characteristics, such as boron, silicon, arsenic, and antimony; and alkaline earth metals, such as calcium (Ca), magnesium, beryllium, and barium. Metalloids and heavy metals are examples of environmental pollutants (HMs). HMs are also regarded as agricultural soil pollutants since they can negatively impact crop health and yield when they are present in soil at high concentrations **(Qi et al., 2024)**. If plants are unable to absorb or drain heavy metals (HMs), they may remain in the soil for an extended period of time. Cadmium, lead, and other dangerous metals may be present in agricultural soils. Improved soil moisture conditions, increased seed germination and growth, and decreased salinity levels can all be achieved using magnetically treated water **(Surendran et al., 2016 and Abedinpour and Rohani, 2017).**

Nonetheless, numerous research have been conducted in the literature that describe various kinds of magnetic devices, and many of them have produced inconsistent findings **(Abedinpour and Rohani, 2017)**. When considering soil magnetism (SM) mapping and measurement, the soil's reaction to magnetically treated water (MW) can serve as a useful reference for applying magnetic technology to sustainable agriculture. Further research is necessary to determine the most effective usage of SM-based technology for various crops, particularly in light of changing climatic conditions and stressors **(Talat Rashad, 2022)**.

Since the 1950s, due to the population growth, the need of nitrogen (N) fertilizers has increased. These fertilizers are vital to maintaining the human population. Actually, the Haber-Bosch process—which synthesizes ammonia (NH_3) from hydrogen and air to make N-fertilizers—has frequently been praised as the most significant invention of the 20th century and is thought to have improved the lives of three to 3.5 billion people as of 2015. Moreover, our dependence on nitrogen fertilizers has grown along with the world population. Without accounting for the contribution from organic sources, estimates place the world's population at close to 50% reliant on synthetic nitrogen fertilizers, and this tendency does not appear to be abating. **Abd El-Hady et al. (2024)** findings demonstrated that the maximum values of vegetative growth, ion concentrations, yield, and quality were obtained through irrigation with magnetized water. Additionally, plants treated with 75% N + 25% vermicompost produced the greatest grade crisphead plants, while crisphead lettuce fertilized with 50% N + 50% vermicompost showed the maximum vegetative growth, yield, chlorophyll levels, and Mg percentage. Thus, it is advised to fertilize plants with 50% N + 50% vermicompost and irrigate crisphead lettuce with magnetic water. With a good yield, this treatment can assist in a 50% reduction in production costs.

The aim of this study was to assess how magnetized water affected the growth and chemical composition of eggplants as well as the effectiveness of nitrogen fertilizer.

2. Materials and Methods

Study area location

In Meet Khaqan, Shebin El Kom, Menofia Governorate, Egypt, a private farm hosted a field experiment. Situated at 30°56′76″ N latitude and 31°03′08″ E longitude The climate of the research region is semi-arid, with chilly winters and scorching, dry summers.

Soil sampling

Soil samples were collected at three depths of 0-30, 30-60, and 60-90 cm from three distinct locations within the study area prior to transplanting. These samples were individually air-dried, ground, well-mixed, and sieved through a 2 mm sieve. The fine soil of each soil depth was then thoroughly mixed and subjected to an analysis process that followed the guidelines provided by **Cottenie et al. (1982)**, **Sparks et al. (2020)**, and **Klute (1986)** to determine its physical and chemical properties as well as its available nutrient content.Table 1 contains the data that were discovered.

Sources of irrigation water

There were two kind of irrigation water used in this investigation. The first was non-magnetic well water from a study area water well, and the second was the first after it was magnetized using a Delta Water Company "Tesla" magnetic device and exposed to a 16 mT magnetic field.

Table 1. Some physical and chemical properties of the experiment soil.

Soil properties	**Soil depth (cm)**			
	0-30	**30-60**	**60-90**	**Mean**
	a- Physical properties			
Particles size distribution (%)				
Sand	18.50%	18%	18%	18.17
Silt	30%	30%	30%	30
Clay	51.50%	52%	52%	51.83
Texture	Clay	Clay	Clay	
	b- Chemical properties			
pH (1:2.5) soil: water susp.	7.21	7.25	7.32	
EC (1:5) soil : water extract (dS m^{-1})	1.67	1.63	1.61	1.64
Soluble ions (mmol$_c$.l^{-1})				
Na^+	4.7	4.61	4.59	4.63
K^+	0.23	0.22	0.2	0.22
Ca^{++}	6.5	6.4	6.35	6.42
Mg^{++}	5.3	5.1	4.95	5.12
Cl^-	7.5	7.45	7.36	7.44
HCO_3^-	4.26	4.1	3.98	4.11
SO_4^{2-}	4.97	4.78	4.75	4.83
OM (%)	1.6	1.81	1.88	1.76
CEC (cmolkg^{-1})	27.33	27.32	27.32	27.32
	c- Available macronutrients (mg.kg^{-1})			
N (NO_3-N)	٩.5	9	9.2	8.8
P	3.53	3.42	2.95	3.3
K	298.65	295.64	294.56	296.28
Ca	15.3	14.5	14.3	14.7
Mg	8.43	7.52	6.95	7.63
S	5.26	5.22	5.23	5.24
	d- Available micronutrients(mg.kg^{-1})			
Fe	3.92	3.52	3.46	3.63
Zn	1.59	1.56	1.54	1.56
Mn	5.23	4.32	4.21	4.58
Cu	0.23	0.35	0.39	0.32

Samples of the two irrigation water types that were employed were taken before to transplanting in the two growth seasons and at two intervals of the growing period (40 and 80 days), and their chemical composition was examined using the techniques outlined by **Cottenie et al. (1982)**. Table (2) contains the average data for each type of irrigation water.

Table 2. Chemical analysis of the used water resources,(non-magnetized water and magnetized).

Properties	Magnetic water	Non- magnetic water
pH	7.38	7.76
EC	1.54	1.74
BOD (mg/l)	22.23	5.25
CO_3^{2-} (meq/l)	3.64	4.52
HCO_3^- (mmol$_c$/l)	5.6	6.62
Cl^- (mmol$_c$ /l)	4.2	4.41
SO_4^{2-} (mmol$_c$ /l)	1.99	2.2
Ca^{2+} (mmol$_c$ /l)	7.85	8.22
Mg^{2+} (mmol$_c$ /l)	5.11	6.5
Na^+ (mmol$_c$ /l)	2.1	2.6
K^+ (mmol$_c$ /l)	0.41	0.43
SAR	0.824	0.958

Experiment design

In order to assess the impact of magnetized water on eggplant (Solanum melongena L.) reaction to N fertilization, this experiment was carried out during the two subsequent growing winter seasons of 2021/2022 and 2022/2023. The 378 m^2 study area was split up into 18 experimental units, each measuring 21 m^2 or "3x7m. Control treatment was 21 m^2 and conducted to the experiment to compare the difference, as well as " Prior to the seedlings being transplanted, farmyard manure (FYM) as shown in Table (3) was administered at a rate of 5 ton fed^{-1} (25 kg plot^{-1}) as an organic fertilizer, and ordinary superphosphate (15.5% P_2O_5) at a rate of 100 kg fed^{-1} (feddan = 4200 m^2) "500 g plot^{-1}" was applied to all plots. The experimental soil's 15-cm surface layer was combined with both the P and FYM applications after soil preparation. Each plot was then split into four lines, each measuring 70 cm in width. The experimental units were split into two main groups, each consisting of nine units, to represent the two types of irrigation water that were used: magnetized and non-magnetic. After then, the watering process was completed. On October 20, 2021 and 2022, eggplant seedlings were transplanted, with a space of 15 cm between each pair of seedlings. The irrigation cycle was repeated every fifteen days. After 20 days of seedling transplantation, the plots of each main group were divided into three subgroups (3 plots per subgroup) representing the experimental levels of N fertilization, where it was used in ammonium nitrate (NH_4NO_3-33% N) form at application rates of 25, 50, and 100% of the recommended dose "RD" (150 kg fed^{-1}) as recommended by the Egyptian Agriculture Ministry. All eggplant farming processes followed the Agriculture Ministry's instructions. Furthermore, after 20 days of transplantation, all plants were fertilized with potassium sulphate (K_2SO_4) (48% K_2O) at a rate of 100 Kg Fed^{-1} (500 g plot^{-1}). N fertilizer additions at three rates were carried out in two equal doses after 20 and 42 days of transplantation. Both K and N fertilizers were applied to the soil. This means that the experimental treatments (6 treatments) were distributed among the experimental units in a split totally randomized block design with three replications (Fig 1). At 70 age days, certain vegetative growth parameters of eggplant were measured.

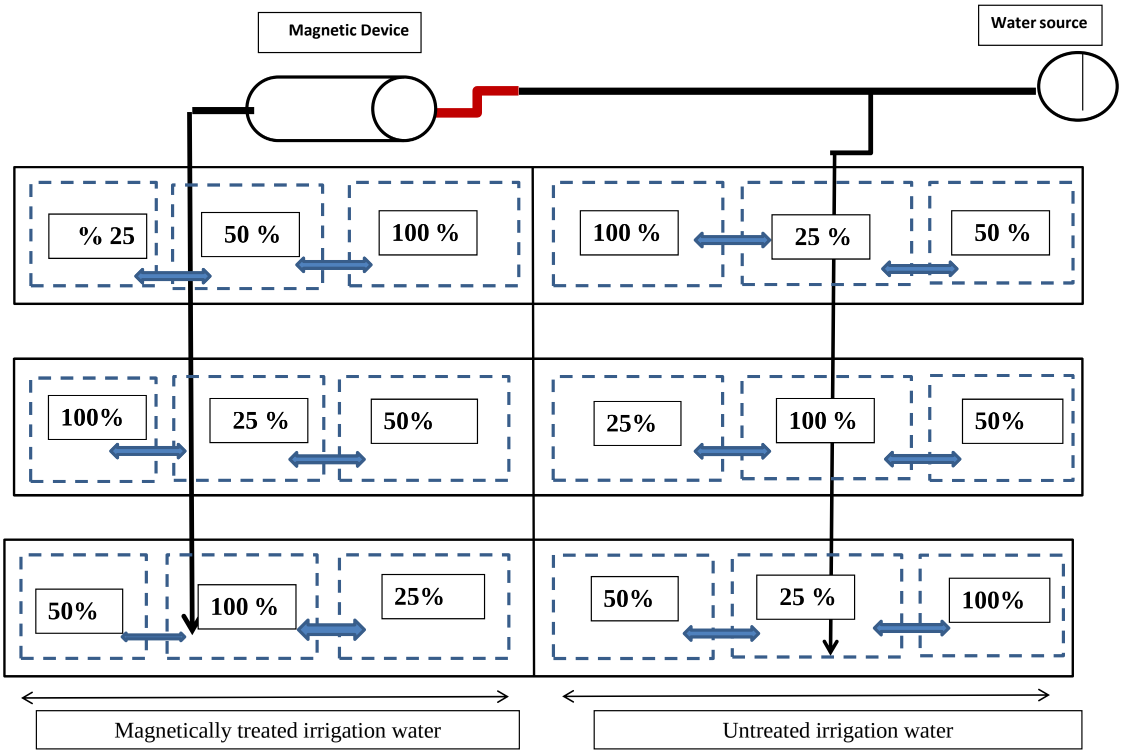

Fig. 1. Flowchart of the experiment design.

Table 3. Chemical analysis of Farmyard manure "FYM".

Components	FYM
OM, %	34.5
OC, %	20
Total N, %	1.9
Total P, %	0.45
Total K, %	0.39
pH (1:5)	8

Soil analysis

Following plant harvesting, soil samples from each replication were collected at depths of 0-30, 30-60, and 60-90 cm. Each soil sample was air-dried, pulverized, sieved, and evaluated for certain chemical qualities, as previously described by **Cottenie et al. (1982) and Sparks et al. (2020).**

Plant measurements

The height (cm), number of leaves, days to 50% flowering, dry matter percentage of leaves, fruit length (cm), number of fruits/m^2, number of fruits per plant, weight and yield of fruits as kg/m2 and mg fed^{-1} of the eggplant plant were all measured. A known weight of fruit sample was collected from each replicate, weighed, air-dried, oven-dried at 70°C for 48 hours, pulverized, and evaluated for N, P, and K content. Each oven-dried plant sample (fruits) weighed 0.2 g and was digested on a sandy plate with 5 ml of concentrated H_2SO_4 and 2-4 drops of concentrated $HClO_4$. Distilled water was used to dilute the clear digest to a height of 50 cm. The digest contents of N, P, and K were then ascertained using the methodology outlined by **Sparks et al. (2020)**. The Agronomic Efficiency Index (AE) was calculated using the equation AE = $Y_f - Y_0$ /N where AE represents the Agronomic Efficiency Index, Y_f represents yeild in fertilized plots, Y_0 represents yeild in control plots, and N represents the amount of nitrogen fertilizer applied in Kg fed^{-1} **(Illera-Vives et al., 2017)**.

Statistical Analyses

The gathered data were statistically analyzed using three-way completely randomized designs with three replicates, as per the computer application Costat statistical software. Mean values were compared and Duncan. **(Costat 6.311; Copyright (C) 1998–2005)**.

Result

Influence on soil's chemical properties

With the exception of the BOD (biological oxygen demand) value, magnetized water pH, and EC, the data presented in Table (2) clearly demonstrate the differences between the chemical compositions of the two types of irrigation water that were used. Soluble anions (CO_3, HCO_3^-, Cl^-, and SO_4^{-2}) and soluble cations (Na^+, K^+, Ca^{++}, and Mg^{++}) were found to be lower in the magnetized water than in the non-magnetized water.

Irrigation water, N fertilization impact's on soil chemical properties

The data shown in Table (4) illustrates how the kind of irrigation water and amount of N fertilizer affect some soil chemical parameters following the harvesting of eggplants. These findings show that, when compared to soil irrigated with non-magnetized water, soil salinity, measured as EC dSm^{-1}, was lower in the soil irrigated with magnetized water. These results were observed at all N fertilizer addition levels and were especially evident in the top layer (0–30 cm) of soil. When utilizing magnetized water, the percentage (%) EC drop (mean values of each level of N) was higher than when irrigating the soil with non-magnetized water. Table (4) displays the soil's soluble cation and anion concentration when $meq.l^{-1}$ of magnetized irrigation water is used. With the exception of the K^+ content, which was a result of the soil being irrigated with magnetized water, there were evident differences in their contents. The soluble soil cations (Ca^{2+}, Mg^{2+}, and Na^+) and soluble anions (Cl^-, HCO_3^-, and SO_4^{2-}) were also clearly reduced by the irrigation process using magnetized water. This pattern was observed for all soil depths and N fertilization intensities.

Table 4. Effect of non and magnetized irrigation water on some chemical properties of experimental soil under different levels of N fertilization.

Type of water	Rate of N fertilizer (%)	Soil Depth (cm)	pH	EC dSm^{-1}	Soluble Cations ($mmol_c$ /l) Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}
	Control		7.15c	1.70 a	4.8 d	0.24a	6.6 c	5.36 c	7.8 c	4.3 b	4.9 c
Non magnetized water	**25%**	**0-30**	7.21 c	1.67 a	4.7 c	0.23c	6.5 c	5.3 c	7.5 b	4.26b	4.97 c
		30-60	7.25 bc	1.63 c	4.61 c	0.22c	6.4 c	5.1 c	7.45b	4.1b	4.78 c
		60-90	7.32 c	1.61 b	4.59 c	0.2c	6.35 c	4.95 c	7.36 b	3.98b	4.75 c
	50%	**0-30**	7.32 c	1.56 c	3.5 b	0.23c	6.45 c	5.45 b	7.6ab	4.35bc	3.68bc
		30-60	7.42 b	1.52 c	3.42b	0.22b	6.42bc	5.15 b	7.3 ab	4.12ab	3.79bc
		60-90	7.45 b	1.49 b	3.35b	0.2bc	6.33 c	4.98 c	7.35ab	3.96ab	3.55b
	100%	**0-30**	7.5 b	1.51 c	3.2 a	0.25c	6.2 b	5.42 b	7.62 a	4.15a	3.3b
		30-60	7.55 b	1.51 b	3.18 a	0.22c	6.3 b	5.39 b	7.56 a	3.99a	3.54b
		60-90	7.56 b	1.50 a	3.11a	0.23bc	6.32 b	5.35 b	7.55a	3.5a	3.96c
magnetized water	**25%**	**0-30**	7.53 b	1.52 c	3.2 c	0.23b	6.5 c	5.3 c	6.7 c	4.26 c	4.27 c
		30-60	7.56 b	1.48 c	3.11c	0.22 c	6.4 c	5.1 b	6.65 c	4.1c	4.08c
		60-90	7.64 b	1.46 b	3.09c	0.2 b	6.35 c	4.95 b	6.56 c	3.98c	4.05c
	50%	**0-30**	7.55 b	1.50 b	3.12 bc	0.2 c	6.4 b	5.23 b	6.5 b	3.9b	4.55 c
		30-60	7.58 b	1.49 a	3.08 b	0.19ab	6.32 b	5.35 b	6.3 bc	3.5b	5.14 b
		60-90	7.68 a	1.46 a	3.05 b	0.18b	6.28ab	5.12 c	6.2 b	3.2b	5.23b
	100%	**0-30**	7.55 ab	1.46 a	3.12 bc	0.18ab	6.33 a	4.95 bc	6.35b	3.54b	4.69ab
		30-60	7.62 a	1.42 b	2.88 b	0.17a	6.25 a	4.88 a	6.29b	3.33b	4.56a
		60-90	7.65 a	1.41 b	2.85 b	0.15a	6.21 a	4.85a	6.25b	3.23ab	4.58a
	F		**	*	****	*	ns	***	*	*	ns

Values followed by different letters in the same column are significantly different according to DMRT ($P \leq 0.05$).

Influence on eggplant growth parameters

A few vegetative development metrics of eggplants are displayed in Figure (2) along with the type of irrigation water and N fertilizer utilized. Magnetized water caused the appearance of offsets (suckers) in eggplant plants. These offsets produced a crop yield similar to the parent plant, but the fruit size was slightly smaller. This was very noticeable on all plants unlike with non-magnetized water. The results indicate that when N fertilizer was applied at the same rate, the plants irrigated with magnetized water had greater plant height (measured in centimeters), more leaves per plant, and longer and more symmetrical fruits than the plants irrigated with non-magnetized water. Furthermore, compared to plants that were irrigated with non-magnetized water, the plants that received magnetized water had a shorter timeframe on which to begin flowering. For instance, the eggplants fertilized by 100% NRD had plant height, number of leaves, days to 50% flowering, fruit length, and fruit diameter of 65.5 cm, 24, 72 days, 28.8 cm, and 6.3 cm in the non-magnetized plant and 72.7 cm, 29, 57 days, 30 and 9.88 cm in the magnetized plant, respectively.

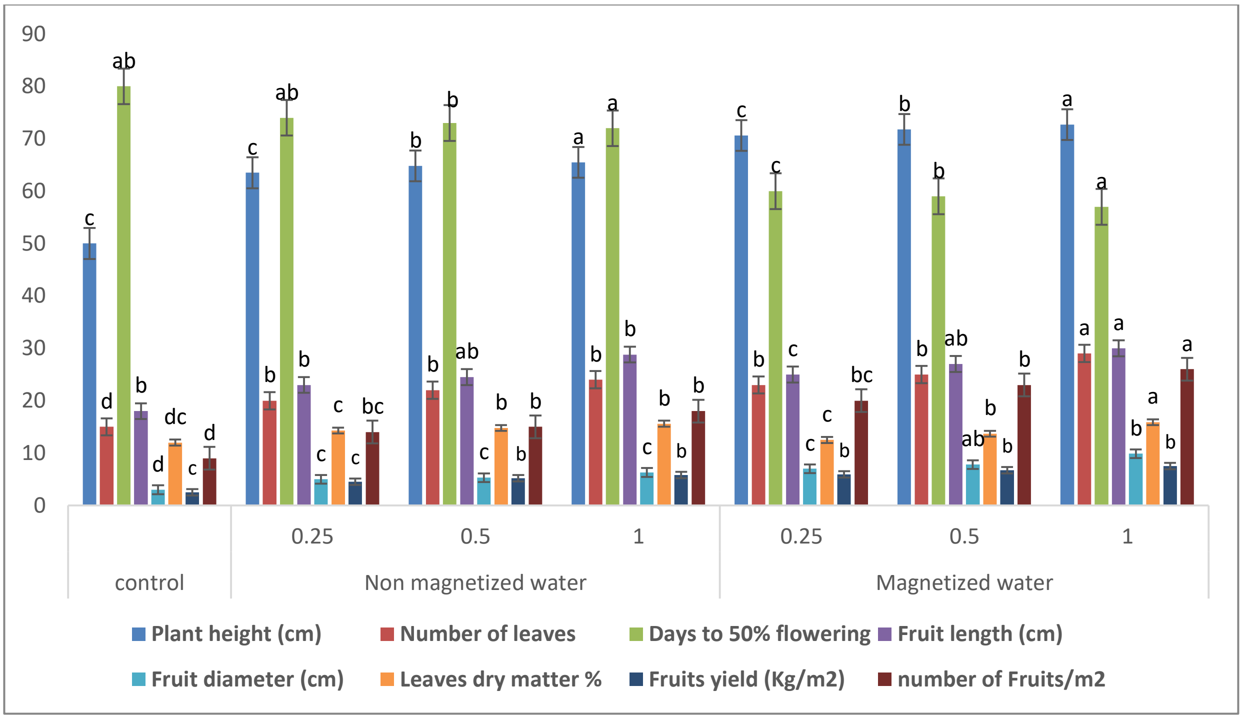

Fig. 2. Effect of non and magnetized water on some growth parameters under different levels of N fertilization.

Conversely, when N was added up to 100% NRD, the projected growth characteristics increased dramatically with the same type of irrigation water. For instance, plant height, leaf count, and blooming date in plants that were watered with magnetized water were 70.6 cm, 23 and 60 days at 25% NRD, and increased to 72.7 cm, 29 and 57 days with the addition of N up to 100% NRD, respectively. Fruit length and fruit diameter also rose, reaching 25 and 7 cm in plants irrigated with magnetized water at 25% NRD and 30 and 9.88 cm in plants fed with 100 NRD, respectively.

Figure (2) also demonstrates how the rate of N fertilizer application and the types of irrigation water utilized impact the fruits production of eggplant, which is expressed as kg/m^2. When comparing the results of employing magnetized water for irrigation with non-magnetized water, the plants that received the highest values of fruit yield were those that had the same application rate of additional nitrogen. For instance, fruit yields at control was 2.5 kg/m^2 but at 100% NRD for plants irrigated with non-magnetized water were 5.8 kg/m^2 and 7.5 kg/m^2, respectively. Fruit yield increased significantly when the rate of additional N fertilizer was increased from 25% to 100% NRD, but only slightly increased when the applied N fertilizer was increased from 50% to 100% NRD. Based on the information shown in figure (2), it can be inferred that the application of magnetized water during irrigation enhanced the effectiveness of the applied N fertilizer, leading to a rise in fruit output.

The data in Figure (3) displays the agronomical efficiency (AE), which is expressed as kg/m^2 yield to kg of N fertilizer applied to soil , on the fruit production of eggplant that was watered with two different types of irrigation water at the same rate of added N fertilizer application. Compared to plants irrigated with non-magnetized water, eggplant grown with magnetized water had a higher AE value. For instance, in plants that were watered with non-magnetic and magnetized water, the AE of N fertilizer at NMW25, NMW50, NMW100, MW25, MW50 and MW100 were 250, 158.8, 94.3, 425, 247.1 and 142.9 respectively.

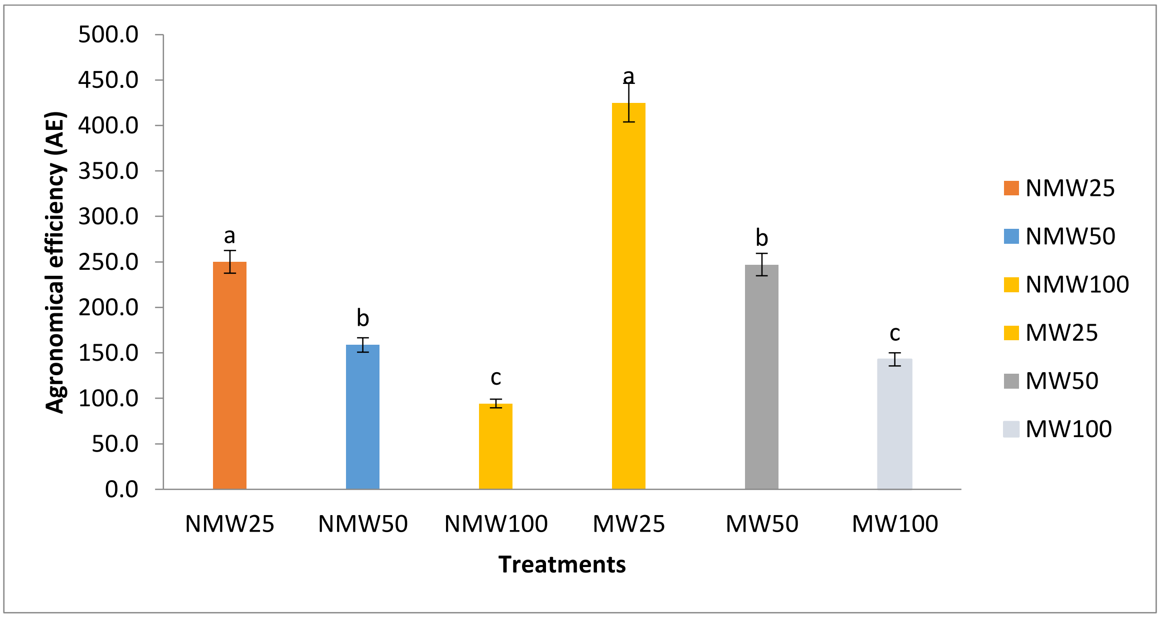

Fig. 3. Agronomical efficiency of N fertilizer on plant affected by using magnetized water in Irrigation. (NMW= Non magnetic water , MW= Magnetic water).

Influence on eggplant content of some macro and micronutrients

In a similar vein, Tables 5 and 6's findings demonstrate that, as compared to plants irrigated with non-magnetized water, eggplants irrigated with magnetized water had higher concentrations of N, P, K, Fe, Mn, Zn, and Cu.

Table 5. Effect of non and magnetic water and N fertilizer on the fruits of eggplant plants content of some macronutrients (%).

Type of Water	Rate of N fertilizer (%)	Macro nutrients content in fruits of eggplants (%)		
		N	P	K
control		1.12c	0.10c	0.055c
Non magnetized water	25%	1.252c	0.111 c	0.058 c
	50%	1.321 ab	0.152 b	0.062 ab
	100%	1.52 a	0.165 a	0.22 a
Magnetized water	25%	1.454 c	0.152 c	0.073 c
	50%	1.58 ab	0.22 ab	0.22 b
	100%	2.15 a	0.45 a	0.56 a

Values followed by different letters in the same column are significantly different according to DMRT (P≤0.05).

Table 6. Effect of non and magnetic irrigation water on the fruits of eggplants plants content of some micronutrients (mg kg^{-1}).

Type of Water	Rate of N fertilizer (%)	Micro nutrients content in fruits of eggplants (mg kg^{-1})			
		Fe	Cu	Mn	Zn
control		248.5c	43.12c	70.2c	9.5c
Non magnetized water	25%	250.35 c	43.76 c	71.7 c	10.65 c
	50%	250.5 c	43.5 c	71.65 c	10.72 c
	100%	249.8 c	43.6 c	71.82 c	11.2 b
Magnetized water	25%	295.85 b	50.5 b	76.8 b	16.4 a
	50%	296.5 ab	51.2 ab	77.6 ab	17.8 a
	100%	297.8 a	52.5 a	78.9 a	18.23 a

Additionally, adding more N fertilizer caused the content of N, P, K, Fe, Mn, Zn, and Cu in eggplant to significantly increase. These increases, which occurred with both non-magnetic and magnetized water, could be the result of improved environmental conditions in the root zone.

3. Discussion

The aim of magnetic water treatment is to change the chemical and physical characteristics of water by subjecting it to a magnetic field. These results indicate that changes in the chemical composition of water were caused by a 16 mT magnetic field. Previous research has linked the influence of magnetic fields on the chemical composition of irrigation water to their impact on the physico-chemical characteristics and molecular structure of water, which ultimately impact water quality **(Al-Akhras et al., 2024)**.

According to **Putti et al. (2024),** the altered water molecules are the source of the physical and chemical modulations that occur when they are subjected to magnetic treatment. Previous research conducted by **(Abu-Saied et al., 2023)** demonstrated a similar influence of magnetic field on irrigation water parameters. According **to (Putti et al., 2024),** A large stem diameter (SD) and the nutrients N, K, Cu, and B were associated with a high explanation of the data when tomatoes were irrigated with UW at high salinities (4.0, 5.5, and 7.5 dSm^{-1}). When it comes to storing soluble materials for later use by plants, the stem diameter is crucial. Both direct and indirect impacts, namely the toxic effects of the salts taken by plants—primarily Na$^+$ and Cl$^-$ in the cells and the decrease in total water potential brought on by an increase in salt content, can impede the growth of stem diameter **(Abd-Elrahman and Shalaby, 2018)**. The outcomes of MW irrigation were dependent upon the electrical conductivity range of the solution, whereas the water that has been magnetically treated plays a significant part in reducing saline stress. Plants smaller than 1.5 dSm^{-1} had a strong correlation with plant height (PH), fruits per plant (FPP), Fe content, and leaf fresh weight (LFW) when considering both UW and MW. Since the pressure potential of the cell tends to match that of the soil, diminished growth is typically the first sign that plants under saline stress display. This is because the decreased water potential of the soil solution prevents cell expansion. Based on these findings, studies have been published in the literature on the use of magnetic water treatment as a technique and the height decrease of plants exposed to salt water.

Commercial productivity, a vital criterion for farmers, was significantly affected by salinity levels and irrigation water type. When tomatoes were irrigated with MW and given doses of 5.5 and 7.0

dSm−1, they showed increases of 20% and 15%, respectively, in relation to UW; no difference was seen with the other doses. This indicates the significance of this technology for management in agricultural areas with high salinity in the water and soil. The findings show that in a salinized environment, magnetic water tends to reduce osmotic and ionic effects, enhancing the plant's root-shoot ratio and having a favorable influence on fruit output in the end. The results of using magnetically treated water for irrigation, and found that it enhances the land's moisture condition by allowing the soil to hold onto more water **(Putti et al., 2024 and Kamel et al., 2023)**.

Applying magnetically treated irrigation water to the soil raised the amount of soluble salts that leached. According to one theory, water's surface tension decreases in magnetic fields because hydrogen bonds are broken, allowing for quick melting **(Abu-Saied et al., 2023)**.These results are consistent with **(Dobránszki, 2023)**, who reported that, Because magnetization alters the hydrogen bonds in an aqueous solution, treating saline water with MF is likely to alter the water's qualityAs predicted, magnetization leads to alterations in hydrogen bonding, which in turn increases ion mobility and salt solubility. It also improves colloids and electrolytic material sedimentation. The water that was magnetized had a decrease in salinity **(Dobránszki, 2023)**. Magnetic treatment may modify hydrogen bonding and promote ion mobility, resulting in decreased EC, and TDS. The following is a description of the EC decline: Fine colloidal molecules and electrolytic compounds found in magnetically treated water react to the magnetic treatment by becoming more sedimentable, which lowers the electrical conductivity (EC) **(Abu-Saied et al., 2023)**. The soil salinity reduced after one month and eight magnetic treatment sessions, from 4.88–6.15 dsm-1 to 2.734.15 dsm-1 and 1.452.83 dsm-1, respectively**(Fanous et al., 2017)**

Additionally, the pH value of the soil irrigated with magnetized water was lower than that of the soil irrigated with non-magnetized water, as well as in comparison with the pH of the soil before to planting, at the same soil depth, particularly in the top layer, and with the same amount of added N. These declines are explained by the soil's poor buffering capacity when irrigated with non-magnetized water. This results corroborates those of other researchers who found that water treated with magnetism had a direct or indirect impact on soil. Many of the features of soil, such as pH, phosphorus concentration, and extractable potassium, are changed when it is irrigated with magnetized water **(Abedinpour and Rohani, 2017; sary, 2021; Ahmad and Soubh, 2024)**. Furthermore, the data indicate that soil EC (dsm^{-1}) and the concentration of soluble cations (Na^{+}, Ca^{2+}, and Mg^{2+}) and onions (Cl^{-}, CO_3^{2-}, HCO_3^{-}, and SO_4^{2-}) were lower in the soil irrigated by magnetized water compared with those found in the soil irrigated by non-magnetized water, regardless of the effect of N fertilizers. This was caused by changes in the surface tension and water molecule structure **(Abu-Saied et al., 2023 and Kamel et al., 2023).**

Plant growth has been researched in relation to magnetic water; by enhancing plant health overall and water absorption as well as nutrient uptake, magnetic water treatment can improve plant development. While some studies discover no appreciable differences when compared to untreated water, others claim favorable impacts including higher germination rates, faster plant growth, or increased yield. The capacity of the plants to absorb more magnetically-treated water than ordinary water accounts for the increase in weight and fruit length of the eggplants irrigated with magnetic water in this study.

The plant tissues receive more energy from their improved ability to absorb water, and as a result, they often develop more quickly than those that receive regular irrigation. Additionally, **Abu-Saied et al. (2023)** the effects of magnetic therapy on the development and production of cucumber plants when applied to fresh and salt irrigation water. With the exception of average fruit weight, no discernible differences in characteristics were found to be caused by variations in soil fertility. With the exception of the number of days until the first female flower, harvesting period, and average fruit weight, notable changes in characteristics were noted at various saline water concentrations and magnetic treatment **(Fanous et al., 2017)**.

Magnetized water irrigation has been linked to higher plant growth, according to **Ferrari Putti et al. (2023)** findings. Additionally, he discovered that irrigation with magnetic water improved photosynthesis and had a good impact on plants' defensive mechanisms. Consequently, applying magnetically treated water improves the quality and yield of plants by stimulating plant development. Consequently, applying magnetically treated water improves the quality and yield of plants by stimulating plant development. This trend was mostly caused by an increase in the amount of readily available vital nutrients in the soil as well as an improvement in the chemical characteristics of the soil when utilizing magnetized water for irrigation.

Putti et al. (2023)states that from a plant nutrition standpoint, irrigation of horticultural crops with magnetically treated water appeared to, in some cases, alter the soil pH, electrical conductivity, available phosphorus (P) and potassium (K) that are extractable by the crop when compared to irrigation without magnetically treated water. In comparison to irrigation with conventional water, the application of MW in this study resulted in improved yield and product quality by increasing the availability of macro- (N, P, Ca, and Mg) and micronutrients (Cu and Mn) in the soil due to the higher concentration in the lettuce shoot.Additionally, it showed that when the solution's electrical conductivity was varied, the N and C contents increased. In order to mitigate the negative effects of water stress, the magnetic field increases photosynthetic efficiency, decreases water stress, and decreases the formation of free radicals and antioxidant enzyme activity in treated water.

Among those studies **(Helmy et al., 2023 and Abd El-Hady et al., 2024)**, the idea of magnetized water and its impact on plant nutrient availability is an exciting field of study. This is a thorough examination of the potential effects of magnetized water on macro- and micronutrient availability.Water that has been subjected to a magnetic field and had its chemical and physical characteristics changed is called magnetized water. Magnetized water may improve nutrient availability through the following mechanisms: Better Solubility and Mobility: Water that has been magnetized can lessen surface tension, which facilitates water's ability to permeate the soil and carry dissolved nutrients. This may improve the soil's ability to transfer nutrients like calcium (Ca), magnesium (Mg), phosphorus (P), and nitrogen (N), which may increase the nutrients' availability to plants. A more conducive environment for soil microorganisms may be produced by the magnetized water's changed characteristics, leading to increased soil microbial activity. These bacteria break down organic materials and increase the availability of nutrients for plants, which is a critical part of the nutrition cycle. Increased Root Absorption, The permeability of roots and their capacity to take up nutrients can both be impacted by magnetized water. This may result in a more effective absorption of macro- and micronutrients. Nitrogen (N), By increasing soil moisture and microbial activity, which are necessary for nitrogen fixation and mineralization processes, magnetized water can increase the availability of nitrogen. Plants may exhibit faster growth and higher tissue nitrogen content. Phosphorus (P), Due to its poor solubility, phosphorus's availability may be restricted. Phosphorus compounds can become more soluble in magnetized water, increasing their availability for plant absorption. Better root development and general plant growth could come from this.

Calcium (Ca), The cation exchange capacity and pH of the soil might affect the availability of calcium. The structure and flow of water in the soil can be enhanced by magnetized water, which may increase the amount of calcium available to plant roots—a mineral that is essential for the stability and growth of cell walls. Magnesium (Mg), Soil characteristics influence the availability of magnesium, just like they do calcium. The production of chlorophyll and photosynthesis can benefit from increased magnesium availability, which can be achieved by improved water infiltration and distribution using magnetized water **(Dobránszki, 2023)**. Micronutrient effects, Because copper tends to attach closely to soil particles, its availability in soil is sometimes restricted. Copper is essential for a number of enzymatic processes in plants, and magnetized water can accelerate its desorption from soil particles. The pH and redox state of the soil have a significant impact on manganese availability. By raising soil moisture and aeration, magnetized water can affect these parameters and increase manganese availability, which is necessary for photosynthesis and nitrogen metabolism **(Talat Rashad, 2022; Helmy et al., 2023b; Putti et al., 2023)**. Magnetized water has been found to have favorable impacts on plant growth and nutrient availability in numerous studies. Enhanced Yield and Quality, Studies show that the enhanced nutrient uptake caused by magnetized water might result in increased crop yields and superior quality food. Enhanced Nutrient Concentrations, Research has shown that plants irrigated with magnetized water had higher concentrations of calcium, magnesium, phosphorus, and nitrogen. Improving Soil Health, It has been noted that improved soil structure and increased microbial activity increase total soil fertility **(Surendran et al., 2016; Talat Rashad, 2022; Abu-Saied et al., 2023; Helmy et al., 2023b; Kamel et al., 2023; Putti et al., 2023; Abd El-Hady et al., 2024; Omara, 2024)**.

Regardless of the type of irrigation water used, the study's findings highlight the significance of adjusting nitrogen fertilizer application rates to achieve high agronomical efficiency. Nutrient dynamics can be influenced by both magnetized and ordinary water, however overuse of fertilizer can have negative effects on the environment and diminish efficiency. It is imperative to implement optimal management strategies, such as targeted fertilization and irrigation, in order to boost the effectiveness of nitrogen utilization and encourage sustainable farming methods **(Lin et al., 2024)**.

4. Conclusion

Our results validate the idea that applying magnetically treated water is necessary to improve soil properties like pH, soluble ion concentration, and electrical conductivity (EC). Furthermore, it has been demonstrated that adding water that has been magnetically treated to soil encourages plant growth and development, which raises plant yield. This finding could have a big impact on farming methods since it can be used to enhance soil quality and increase plant yield with inexpensive magnetic energy.

List of abbreviations:

NMW: Non magnetic water
MW: The magnetically treated water
SM: Soil magnetism measurement
IFA:International Fertilizer Association
EC: Electirical Conductivity

Declarations

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References

Abd-Elrahman, S., and Shalaby, O. (2018). Response of wheat plants to irrigation with magnetized water under Egyptian soil conditions. Egypt. J. Soil Sci. Vol. 57, No.4, pp. 477 - 488 (2017). doi: 10.21608/ejss.2017.1605.1122

Abd El-Hady, M., Shehata, M., and abdelhameed, ahmed (2024). Effect of mineral and organic fertilization rates under magnetized water irrigation on growth, yield, and quality of crisphead lettuce. Egypt. J. Soil Sci. Vol. 64, No. 1, pp: 275-286 (2024). doi: 10.21608/ejss.2023.240320.1670

Abdelsalam, H., Mostafa, H., El-Ansary, M., Awad, M., and Sultan, W. (2024). Evaluation of saline and magnetized water on emitter hydraulic performance and clogging in drip irrigation. Sci. Rep. 14, 2–9. doi: 10.1038/s41598-024-57543-8

Abedinpour, M., and Rohani, E. (2017). Effects of magnetized water application on soil and maize growth indices under different amounts of salt in the water. J. Water Reuse Desalin. 7, 319–325. doi: 10.2166/wrd.2016.216

Abu-Saied, M. A., El Desouky, E. A., Abou Kamer, M. E., Hafez, M., and Rashad, M. (2023). Influence of magnetic field on the physicochemical properties of water molecule under growing of cucumber plant in an arid region. J. King Saud Univ. - Sci. 35, 102890. doi: 10.1016/j.jksus.2023.102890

Ahmad, A. A., and Soubh, A. M. (2024). The Effect of Magnetic Treatment on some Physico-Chemical Properties of Landfill Leachate (Wadi Al-Hada). Pollution 10, 383–391. doi: 10.22059/POLL.2023.364132.2035

Al-Akhras, M. A. H., Al-Quraan, N. A., Abu-Aloush, Z. A., Mousa, M. S., AlZoubi, T., Makhadmeh, G. N., et al. (2024). Impact of magnetized water on seed germination and seedling growth of wheat and barley. Results Eng. 22, 101991. doi: 10.1016/j.rineng.2024.101991

Dobránszki, J. (2023). From mystery to reality: Magnetized water to tackle the challenges of climate change and for cleaner agricultural production. J. Clean. Prod. 425. doi: 10.1016/j.jclepro.2023.139077

Fanous, N., Mohamed, A., and Shaban, K. (2017). Effect of Magnetic Treatment of Irrigation Ground water on Soil salinity, Nutrients, Water Productivity and Yield Fruit Trees at Sandy Soil. Egypt. J. Soil Sci. Vol. 57 No. 1, pp.113-123 (2017) doi: 10.21608/ejss.2017.1528

Ferrari Putti, F., Cremasco, C. P., Neto, A. B., Barbosa, A. C. K., Júnior, J. F. da S., Reis, A. R. dos, et al. (2023). Fuzzy Modeling Development for Lettuce Plants Irrigated with Magnetically Treated Water. Plants 12. doi: 10.3390/plants12223811

Helmy, A. M., Niel, E. M., Shaban, K. A., and Ramadan, M. F. (2023a). Magnetic Treatment of Irrigation Water and Seeds and Its Effect on the Productivity and Quality of Wheat (Triticum aestivium L.) Grown in Saline Soil. Commun. Soil Sci. Plant Anal. 54, 1583–1600. doi: 10.1080/00103624.2023.2177305

Helmy, H. S., Abd Elhay, Y. B., and Salem, A. (2023b). Effect of Magnetic Water on The Growth of the Nile Tilapia and Lettuce Plant in the Aquaponic System. Egypt. J. Aquat. Biol. Fish. 27, 213–228. doi: 10.21608/ejabf.2023.309143

Ibrahim, N., Ismail, shadia, and Abd El-Latif, K. M. (2024). The Impact of Irrigation Levels with Normal and Magnetic Water, Bio Fertilization on Garlic Growth, Yield and Storage. J. of Plant Production, Mansoura Univ., Vol. 15 (3):91 – 100, 2024 doi: 10.21608/jpp.2024.266857.1306

Jiang, Z., Wang, Q., Ning, S., Hu, X., and Song, Z. (2024). Enhancing cotton (Gossypium hirsutum L.) productivity and quality with magnetized ionized water and Bacillus subtilis intervention under film-mulched drip irrigation in saline soil in Xinjiang. F. Crop. Res. 311, 109377. doi: 10.1016/J.FCR.2024.109377

Kamel, Y., Hegab, S., Youssef, M., and Abd El-Gawad, A. (2023). Effects of magnetized saline irrigation water and fertilizers on soil prosperities and wheat productivity. Arch. Agric. Sci. J. Volume 6, Issue 1, 2023, Pages 113–141. doi: 10.21608/aasj.2023.17742 2.1135

Lin, S., Wang, Q., Wei, K., Sun, Y., Shao, F., Lei, Q., et al. (2024). Enhancing pakchoi (*Brassica chinensis* L.) agriculture with magnetized-ionized brackish water and organic fertilizers: A sustainable approach to soil quality and crop yield optimization. J. Clean. Prod. 450, 141935. doi: 10.1016/J.JCLEPRO.2024.141935

Omara, A. I. (2024). EFFECT OF MAGNETIZED SALINE IRRIGATION WATER ON SOIL. 41, 39–62. doi: 10.21608/mjae.2023.234521.1117

Putti, F. F., Arruda, B., Vicente, E. F., Chaves, P. P. N., Nogueira, B. B., Zanetti, W. A. L., et al. (2024). Magnetic technology to reduce the effects of saline stress on tomato plants. Environ. Technol. Innov. 34. doi: 10.1016/j.eti.2024.103544

Putti, F. F., Vicente, E. F., Chaves, P. P. N., Mantoan, L. P. B., Cremasco, C. P., Arruda, B., et al. (2023). Effect of Magnetic Water Treatment on the Growth, Nutritional Status, and Yield of Lettuce Plants with Irrigation Rate. Horticulturae 9, 1–17. doi: 10.3390/horticulturae9040504

Qi, S., Lei, Z., Huo, Q., Zhao, J., Huang, T., Meng, N., ... & He, C. (2024). Ultrathin High-Entropy Fe-Based Spinel Oxide Nanosheets with Metalloid Band Structures for Efficient Nitrate Reduction towards Ammonia. *Advanced Materials*, 2403958.

Sary, D (2021). The response of saline irrigation water to magnetization and its effect on soil properties and cowpea productivity in newly reclaimed lands in North Sinai. Egypt. J. Soil. Sci. Vol. 61, No. 1, pp. 79-93 (2021). doi: 10.21608/ejss.2021.52186.1415

Surendran, U., Sandeep, O., and Joseph, E. J. (2016). The impacts of magnetic treatment of irrigation water on plant, water and soil characteristics. Agric. Water Manag. 178, 21–29. doi: 10.1016/J.AGWAT.2016.08.016

Talat Rashad, R. (2022). Soil Magnetism and Magnetically Treated Water and Possible Role for Sustainable Agriculture: A review. Egypt. J. Soil Sci. Vol. 64, No. 1, pp: 275-286 (2024). doi: 10.21608/ejss.2022.135265.1500