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Effects of magnetized saline irrigation water and fertilizers on soil prosperities and wheat productivity

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Abstract

Water magnetization is one of many techniques used to improve properties of irrigation water and therefore, soil fertility and plant growth, are enhanced. A field experiment was carried out during two successive winter seasons of (2019/20- 2020/21) on newly reclaimed sandy soil at Assiut Valley desert, Assiut governorate, Egypt. The study aims to explore the effects of magnetized saline irrigation water and some sources of fertilizers type on growth and yield of wheat (*Triticum aestivum* L.; Gemiza-11variety) and soil properties. The experiment was laid out in a Randomly Complete Block Design (RCBD) with three replicates. The study included four treatments, T_W= control treatment (without fertilization), T_B= Bio-fertilizer (SGM), T_C= Chemical fertilizer and T_O= Organic manure (FYM), with using magnetized and un-magnetized saline irrigation water which applied by drip irrigation system. The results showed a decrease in water salinity values from 4.22 to 3.15 dSm^{-1} at soil treated by T_O treatment with un-magnetized water (UN-MWT). While, using treated magnetized water (MWT) decreased from 4.06 to 2.82. Also, pH values decreased from 8.14 to 8.04 with un-magnetic water but using treated magnetic water decreased from 8.11 to 8.02. In addition to increase grain, straw yields and weight of 1000-grains values to 2.665, 3.744-ton $feddan^{-1}$ (feddan = 4200 m² = 0.420 hectares = 1.037 acres) and 58.67 g, under MWT compared to 2.316, 2.699-ton $feddan^{-1}$ and 53.67 g, respectively under N-MWT. Furthermore, as a result, it's recommended to use magnetic technology with chemical fertilizer has a positive impact on properties of sandy soils and has a good effect in wheat crop productivity and quality.

Keywords: magnetization water, fertilizers, wheat, soil properties, leaching requirement.

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1. Introduction

Salinity concentration increases in irrigation ground water in several regions of Egypt, many farms in newly reclaimed soils are now irrigated with saline water, either from ground wells, emphasizing the importance of physical treatment of saline water by using magnetic devices, magnetized water is regarded as a low-impact technique environmentally (Fanous *et al.,* 2017; Nimmi and Medhu, 2009). The use of saline water for irrigation in water-stressed areas necessitates the transfer of innovative technology as well as sustainable agricultural practices, such as water magnetization, to aid in increasing the productivity of saline water (Abdelhafez *et al.,* 2020; Mohamed, 2013). Magnetization water (magnetically-treated) is passing water through a magnetic field, some physical and chemical properties of water have been reported to change as a result of magnetization including surface tension, refractive index, viscosity, melting temperature, conductivity, salt solubility, and pH (Grewal and Maheshwari, 2011). Magnetization restructures water molecules into very small clusters, each of which is composed of six symmetrically organized molecules. Because of its tiny and uniform hexagonal structure, this tiny and uniform cluster can easily enter the passageways in plant cell membranes (Wang *et al.,* 2013). Drip irrigation can reduce the effects of salinity by maintaining continuously moist soil around plant roots and providing steady leaching of salts to the edge of wetted area (Wang *et al.,* 2011). Drip irrigation increases unit productivity of both water and land, manage fertilizers efficiently, more nutrients efficient distribution, less plant stress, earlier harvests, reduces yield wastes, better crop quality and increased yield homogeneity (Abou Zakhem *et al.,* 2019; Gebremeskel *et al.,* 2018). Drip irrigation increases land suitability by 38% compared to surface irrigation (Dengiz, 2006). Fertilization is the third important factors influencing wheat growth, yield and quality. Because wheat cultivation necessitates a high level of nitrogen as well as chemical, organic and bio-fertilizers for optimum growth, grain production, and seed quality (Abd Elgalil and Abdel-Gawad, 2020). Furthermore, organic manure (FYM) has a high nutritional value, with high concentrations of some nutrients such as N, P and K (Al-Sayed *et al.,* 2019; Yousaf *et al.,* 2022). Bio-fertilizers are distinguished by some specific functional microorganisms with organic substances that are organically and microbial beneficial for soil fertility as they can restructure the soil microbial communities associated to the root-zone of different plants, it can partially replace some chemical fertilizers in addition to organic substrates that are vital for plant growth which has a significant effect on diminished the impact of abiotic stresses like salinity (Al-Sayed *et al.,* 2022; Sayed and Ouis, 2022; Zainuddin *et al.,* 2022). Wheat (*Triticum aestivum L.*) plant the most important cereal in terms of global area production, and it provides more nutrients, calories and proteins to the world's human population dietary requirements (Rekaby *et al.*, 2016). Also, it's high in carbohydrates and contains significant amounts of vitamins B and C as well as several minerals (Eissa *et al.*, 2018). Egypt's population is constantly and rapidly growing, necessitating an increase in food production to meet the rising demand for food. While cultivation of grain crops on newly reclaimed soils may help to alleviate some food shortage (Abdel-Gawad and Morsy, 2020). Wheat plants grown on an area of 1.34 million hectares in Egypt each year, with an annual production of 8.80million tones and an average yield of 6.55 t/ha (FAO, 2020). Wheat plant is one of the most important food grain crops grown worldwide, including in Egypt, due to its adaptability to a variety of agro climatic conditions and soil types (Mohamed *et al.*, 2021). The aim of this study is to investigate the effect of magnetized saline water irrigation and fertilization on soil salinity and wheat productivity and quality.

2. Materials and methods

2.1 Experimental site

A field study was conducted during two successive winter seasons of (2019/20 - 2020/21) at a private farm at Assiut valley, Assiut governorate, Egypt, which is located at (27°13'42.1"N and longitude 31°22'3.00.5"E). The climate of the experimental site is arid belt that is characterized by cold winter, long dry and very hot summer with average temperatures ranged between 11.9 and 30.7°C with a mean of 21.3°C in common, very low rainfall (2.9 mm/year) and highly evapotranspiration. The meteorological data of the experimental site are monitored via the Central Lab of Agricultural Climate, Agricultural Research Center (ARC), Ministry of Agriculture and Land Reclamation, Giza, Egypt in Table (1).

Table (1): Weather conditions the experimental site during growth period of wheat plants at two seasons (2019/20-2020/21).

Months	Maximum temperature (°C)	Minimum temperature (°C)	Relative humidity (%)	Wind speed (Km/h)	Sunshine
1st season (2019/20)					
November	28.6	13.7	52.00	14.0	9.4
December	21.5	8.1	57.70	15.4	9.0
January	18.5	5.5	59.60	16.5	8.9
February	21.4	7.4	54.70	17.7	9.7
March	26.2	10.8	44.20	19.3	9.9
April	30.6	14.7	38.00	18.8	10.3
2nd season (2020/21)					
November	25.3	12.7	55.00	14.9	9.4
December	23.6	9.4	53.60	14.3	9.0
January	21.4	7.1	58.90	13.5	8.9
February	21.6	7.3	57.40	15.9	9.7
March	27.1	11.3	43.40	18.6	9.9
April	32.0	15.1	34.40	17.1	11.4

The soil texture is a sandy loam and other soil physical and chemical parameters are shown in Table (2). The experimental field was irrigated with magnetized and un-magnetized saline groundwater, using drip irrigation system; the drip irrigation system consisted of polyvinyl chloride (PVC) pipe serving as a mainline was a 3-inch diameter. At the same time sub-line was a 2-inch plastic tube PVC. The sub-line conveys water to the drip lines installed in each plot. Irrigation was stopped when approximately 2–3 cm water depth was achieved, and all plot parts were wetted properly. The drip lines were polyethylene (PE) tubes with an inside diameter of 16 mm and an equally spaced (50 cm) emitter with a discharge of 4 L h^{-1} at 1.0 bar operating pressure.

Table (2): Some physical and chemical soil properties of the experimental site.

Properties		Value	
		1st season (2019/20)	2nd season (2020/21)
Physical properties			
Particle Size distribution	Sand (%)	73.92	71.88
	Silt (%)	18.00	20.10
	Clay (%)	8.08	8.02
Texture		Sandy loam	Sandy loam
Saturation (%)		33.60	33.00
Field capacity (%)		18.38	18.70
Chemical properties			
$EC_{Ex.}$(1:2.5) (dSm^{-1})		5.70	5.52
$pH_{Susp.}$ (1:2.5)		8.17	8.15
Organic matter (g kg^{-1})		6.8	6.6
$CaCO_3$ (%)		36.87	34.80
Available-N (mg kg^{-1})		39	35
Available-P (mg kg^{-1})		8	7
Available-K (mg kg^{-1})		109	103
Soluble cations (meq L^{-1})			
Ca^{+2}		36	35
Mg^{+2}		22	20
Na^{+}		117	106
K^{+}		0.87	0.61
Soluble anions (meq L^{-1})			
HCO_3^{-}		1.83	1.80
CO_3^{-2}		-----	-----
Cl^{-}		75	69
SO_4^{-2}		94.74	90.81

Each value in this table as mean of three replicates.

2.2 Experimental design

The experiment was laid out in split plot design with Randomized Complete Block Design (RCBD) with three replicates, included two factors; the main plots were assigned for magnetization and un-magnetization of saline groundwater irrigation. While the sub-main plots ware assigned for different type of fertilizers. The total treatments are consisting of 8 treatments were done as following, T_W = Control treatment (without fertilization), T_B = Bio-fertilizer (SGM) at rate of (10 L. feddan^{-1}) (feddan = 4200 m² = 0.420 hectares = 1.037 acres), T_C = Recommended doses of chemical fertilizers at rate of 120 kg N feddan^{-1} (215 kg urea 46.5 % N), 25 kg P_2O_5 feddan^{-1} (150 kg super phosphate 15.5 % P_2O_5), and 50 kg K_2O_5 feddan^{-1} (100 kg potassium sulphate 48 % K_2O) and T_O = Farmyard manure at rate (20 m^3 feddan^{-1}) was added during the soil preparation before planting. Nitrogen was applied with the irrigation water at five equal doses (initiated 15 days post planting and were administered on a 12-day interval), Bio-fertilizer (SGM) contains of molasse as organic material carrier of microorganisms, and a set of mixed cultures of *Bacillus circulans*, *B. poylmyxa*, *B. megatherium*, *Candida* spp., and *Trichoderma* spp., was added at two doses, the first dose during agriculture and the second dose 15 days after the first dose at a rate of 10 L feddan^{-1}). The area of the experimental plots is 10.5 m^2 (1 m width × 10.5 m long). Each plot had 15 rows of wheat. The rows were 10.5 m long and the distance between rows was 0.50 m. All the agriculture practices were applied at the recommendations of the Ministry Agriculture and Land Reclamation of Egyptian. Wheat grains (*Triticum aestivum c.v.* Gemiza-11variety) were obtained from the ARC, Giza, Egypt, and were sown in the field on 15 and 19 November at both growing seasons (2019/20 - 2020/21), respectively. The grains were sown using the drill method at a seeding rate of 45 kg seeds/feddan. Magnetization water (magnetic field treatment) was applied using magnetic device a 2-inch and its magnetic field flux force of 1.45 tesla (14500 gauss) was called delta water device for magnetic water treatment (size 2-inch, output 25 m^3/hr and weight 11 kg), supplied by Delta Water Company Alexandria, Egypt, was represent in Figure (1).

Figure (1): The magnetizer device from Delta Water Company (Alexandria, Egypt).

Chemical compositions of the tested organic manure (FYM) are presented in Table (3).

Table (3): Some chemical composition of the tested organic manure FYM at two seasons (2019/20-2020/21).

Chemical composition	Values	
	1st season (2019/20)	2nd season (2020/21)
pH (1:10) Susp.	7.73	7.70
E.C (1:10) Ex. (dSm^{-1})	10.60	10.81
Organic matter (%)	39.30	39.34
Organic-C (%)	22.80	22.82
C/N Ratio	11.07:1	10.97:1
Total N (%)	2.06	2.08
Total P (%)	1.35	1.38
Total K (%)	1.81	1.76

FYM = Farm yard manure.

2.3 Saline groundwater irrigation quality evaluation

Before planting wheat, the available saline groundwater irrigation was collected samples for irrigation, and they were analyzed to assess their suitability for wheat plant irrigation and forecasting effect on some soil properties. At each irrigation time, water samples were collected in a clean, dry plastic bottle, filtered and stored at 4.0°C until analysis accordance with Standard Methods for American Public Health Association (APHA, 2012). Chemical analysis of groundwater standards was performed in the field and laboratory samples are shown in Table (4) according to adapted from Ayers and Westcot (1985).

Table (4): Well groundwater sampling and guidelines sustainable use for irrigation with FAO acceptable limits for irrigation water at two seasons (2019/20-2020/21).

Chemical parameters	Ground irrigation water values		Degree of use restriction			Sustainable for irrigation
	1st season (2019/20)	2nd season (2020/21)	None	Moderate	Severe	
pH	7.73	7.75	Normal range 6.5 – 8.4			Suitability
EC_w (dSm^{-1})	3.27	3.19	< 0.7	0.7 – 3.0	> 3.0	Unsuitability
Soluble cations and anions (meq L^{-1})						
(CO_3^{-2}+HCO_3^-)	5.7	5.5	< 1.5	1.5 – 8.5	> 8.5	Suitability
Cl^-	19.0	18.5	< 4	4 – 30	> 30	Unsuitability
Ca^{2+}	5.8	6.2	Normal range 0 – 20			Suitability
Mg^{2+}	3.6	3.4	Normal range 0 – 5			Suitability
Na^+	17.57	17.48	< 3	3 – 40	> 40	Unsuitability
N (ppm)	0.33	0.41	< 1	1 – 10	> 10	Suitability
P (ppm)	0.08	0.05	< 1	1 – 2	> 2	Suitability
K (ppm)	0.06	0.04	< 1	1 – 2	> 2	Suitability
Chemical criteria						
SAR	7.98	7.93	< 10	10 – 18	> 18	Unsuitability
R.S.C (meq/L)	3.70	4.10	< 1.25	1.25 – 2.50	> 2.50	Unsuitability
CAI	0.97	0.88	Normal range 0 – 33.3			Cation-anion exchange
Na^+ (%)	65.20	64.60	< 20	20 - 40	> 40	Unsuitability

SAR= Sodium Adsorption Ratio, RSC= Residual Sodium Carbonate, CAI= Chloro-alkaline indices.

Based on the results in Table (4) showed that, the irrigation well groundwater sample analysis, show this irrigation water limited validity may be use can cause intense troubles for soil and plants. Regarding the effects of magnetic field on irrigation water quality has been reported to change some physical and chemical properties of water such as surface tension, refractive index, viscosity, melting temperature, conductivity, solubility of salts and pH. In addition, torestructures the water molecules into very small clusters It facilitates its passage through plant cell membranes and soil (Grewal and Maheshwari, 2011; Wang *et al.*, 2013).

2.4 Plant sampling

The plants were harvested after six months of cultivation in the two seasons. The grains were separated from the whole plant to calculate economical and biological yields. The plant samples were washed with tap and distilled waters and oven dried at 70°C for 48 hrs, and then ground in a stainless-steel mill and stored for future analyses. The grain samples were then ground and analysis for total nitrogen, phosphorous and potassium. Wheat yield (ton/feddan) was recorded by weighing and calculated per one feddan (4200 m^2). The total N, P, and K concentrations were measured in the digest extract. To measure nutrient concentrations, a mixture of 7:3 ratio of sulfuric to perchloric acids was used to digest the dried ground plant material. The total N, P, and K determined were described by Burt (2004). Nitrogen use efficiency (NUE) was calculates as kg grain yield/kg of applied fertilizer (kg grain/kg fertilizer) calculated according to Anderson *et al.* (1997) as follow:

$$\mathrm{NUE} = \frac{\text{Grain yield of treatment } \left(\frac{\text{kg}}{\text{feddan}}\right) - \text{Grain yield at control (kg/feddan)}}{\text{Fertilizer applied level (kg N/feddan)}}$$

2.5 General analytical procedures on well groundwater

Sodium Adsorption Ratio (SAR) calculated according to Richards (1954) as follow:

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

Residual Sodium Carbonate (RSC) calculated according to Eaton (1950) as follow:

$$\mathrm{RSC} = (\mathrm{HCO_3} + \mathrm{CO_3}) - (\mathrm{Ca} + \mathrm{Mg})$$

Chloro-alkaline Indices (CAI) was calculating formula according to Schoeller (1967) as follow:

$$\mathrm{CAL} = \frac{\mathrm{Cl} - \ ((\mathrm{Na}\ +\ \mathrm{K})}{\mathrm{Cl}}$$

Sodium Percentage (Na %) calculated using the following formula (Negm and Armanuos, 2017):

$$\mathrm{Na} = ((\mathrm{Na} + \mathrm{K}) / (\mathrm{Ca} + \mathrm{Mg} + \mathrm{Na} + \mathrm{K}) * 100$$

Soil leaching requirement (L.R%) calculated using the following formula (Ayers and Westcot, 1985):

$$L.R. = EC_W / (5*EC_e - EC_W) *100$$

2.6 Soil characteristics

Before planting in each season, soil samples were collected from each plot at a 0 –30 cm depth by using a spiral auger. Soil samples were air-dried and sieved through 2 mm mesh sieve prior to analyses. Soil pH was determined in soil to a water solution 1:2.5 with a digital pH meter. EC was measured from the extract using a method with an EC meter. Particle size distribution was determined using the pipette method (Jackson, 1973). Soil organic matter (SOM) content was determined using the Walkley-Black method (wet oxidation) (Walkley and Black 1934). Calcium carbonate ($CaCO_3$): were determined according to method described by Nelson (1982). Calcium and magnesium (Ca+Mg), Sodium and Potassium (Na+K): were determined according to method described by Page *et al.* (1982). The available N was determined following the Kjeldahl method (Jackson, 1973). The available P was estimated by spectrophotometer at a 640 nm wavelength from $NaHCO_3$ at pH8.5 (Olsen *et al.*, 1954). Available K extracts, using a flame photometer according to Jackson, (1973).

2.7 Economic evaluation

The net return and profit cost ratio (BCR) of the field experiment for wheat plant are present in Table (5). Total cost and benefit of wheat crop production calculated according to Elahi *et al.* (2015) by following:

- Gross income = Grain yield × Price + Straw yield × Price.
- Net return = Gross income – Total production costs.
- Benefit cost ratio (BCR) = Gross income ÷ Total production costs.
- Revenue = Grain yield × Price.
- Net revenue = Revenue – Total cost cultivation.
- P/C ratio = Net revenue ÷ Revenue.

Table (5): Parameter used to calculate the economic evolution for the different fertilization and magnetic technology treatments on wheat yield production at two seasons (2019/20-2020/21).

Parameters	Actual values 1st season (2019/20)	Actual values 2nd season (2020/21)	Parameters	Actual values 1st season (2019/20)	Actual values 2nd season (2020/21)
Price of FYM (6 ton/feddan)	1600 L.E. /ton	1700 L.E. /ton	Price of yield of seed	5.70 L.E. /kg	5.80 L.E. /kg
Price of Bio fertilizer (10 L/feddan)	450 L.E. /feddan	500 L.E. /feddan	Price of straw of yield	1.96 L.E. /kg	2.00 L.E. /kg
Price of (urea 46.5 %) (200 Kg/feddan)	1000 L.E. /feddan	1800 L.E. /feddan	Labor wages and soil prepare (feddan)	3700 L.E. /feddan	4000 L.E. /feddan
Price of wheat seeds (45 Kg/feddan)	390 L.E. /feddan	420 L.E. /feddan	Magnetic technology (L.E./feddan)	500 L.E. /feddan	550 L.E. /feddan

Sources: Central Agency for Public Mobilization and Statistics (CAPMAS).

2.8 Data analysis

Data statistical analyses were performed using Co-Stat software (Steel and Torrie, 1984). Least Significant Differences tests (LSD) at 5% level of probability were used to test the significant differences between the treatments.

3. Results and Discussion

3.1 Effect of magnetized saline irrigation water accompany with some sources of fertilization on some soil chemical properties

3.1.1 Soil salinity (EC)

Data in Figure (2) indicated that initial electrical conductivity (EC) in the soil (experimental sites) prior to initiation of the experiment were 5.70 and 5.52 dSm^{-1} in the first and the second soil used at both seasons respectively. After irrigated by normal water these figures were decreased to 4.22 and 4.18 for the mentioned soil respectively, after harvest the wheat plants reached to 26 and 24% percent for the two seasons respectively. This decrease in the EC values may be to removal of excess salt during irrigation and leaching. Also, the results pointed out that, irrigated the soils with magnetized water decreased the soil salinity significantly compared to the control (T_W) treatments irrigated with normal water. Whereas MWT decreased the EC values by 3.8 and 7.9% of the soils used at the two seasons respectively over the control (UN-MWT), on the other found ,there an increase in salt removed by magnetized water of about 29% in the first season and 30% in the second season respectively, compared with the initial state of the soils EC values, from the above results it be stated that, the soil salinization could continue with a greater accumulation in the following irrigations with normal water compared to magnetized water. This decrease in EC values maybe due the irrigation water magnetically main observed effects in soil are the removal of excess soluble salts, Na, and Cl contents, also a significant decrease in soil salinity EC in soils irrigated with electromagnetically treated saline water compared to non-treated saline water (Hachicha *et al.*, 2018). Also, the soil EC values had markedly influenced at the end the first and second seasons due to application of T_B, T_O and T_C fertilizers to the treatments irrigated with (N-MWT) and (MWT) (Figure 2). There for, values of the soil EC decreased by 17, 23 and 10% due to application of T_B, T_O and T_C fertilizers respectively over the control treatments (T_W) irrigated with N-MWT. The widespread use of aforementioned sources of fertilizers with water magnetization decreased the soil EC values by 21, 26 and 7 % in the first season. Whereas, in the second season were 24, 27 and 3% for T_B, T_O and T_C fertilizers, respectively compared with the control treatments (T_W) without fertilizers. From the above-mentioned results, it is well notice that the EC values in the soil treated with farmyard manure (T_O) be recorded the best reduction for the EC values compared with both T_B and T_C. Consequently, soil salinity affected by the treatments can be arranged in the descending order: T_O > T_B > T_C, may be due to the removal of excess soluble salts, in comparison to the other FYM the presence of organic substances associated with salts that move from the surface layer to the bottom in the soil profile. While T_C recorded the lowest decrease in the values of soil EC due to increase in EC values may be due chemical fertilizer increased available-N, P and K also many other nutrients. Ali (2020) obtained that the utilization of chemical fertilizer increased the electrical conductivity EC values by 20 % compared to control treatment. These results are consistent with both (Al-Sayed, 2020 and Dar *et al.*, 2021). From the aforementioned results, the widespread use of moderate saline water and use of irrigated soil after it is magnetized combined with organic fertilizers had the best treatments in this respect.

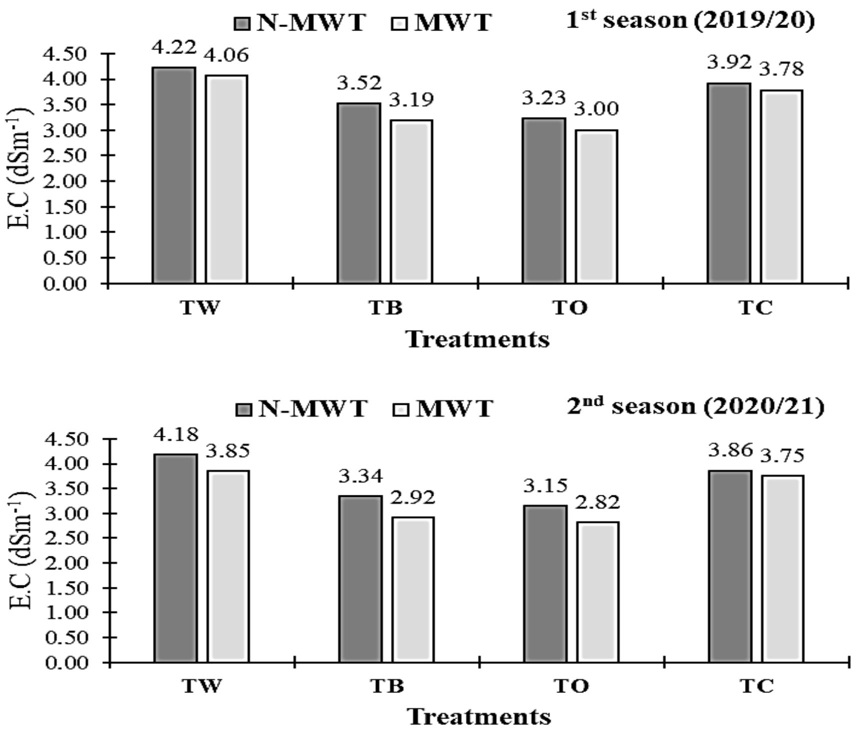

Figure (2): Synergistic effects of irrigation water magnetization and fertilization on soil salinity EC at surface layer after wheat harvest in two seasons (2019/20-2020/21).

3.1.2 Soil reaction pH

Data in Figure (3) showed that, the results of post-harvest for soil pH varied significantly with the application of some fertilizers (T_B, T_O and T_C) with un-magnetically treated irrigation water observed soil pH treated by T_O treatment at both seasons showed decreasing by 0.62 and 0.86%, respectively compared to T_W treatment under without magnetically treated. In generally, the applications of FYM decreased the soil pH may be could the organic acids were released during the microbial decomposition of FYM, lowering soil pH. Agbede *et al.* (2020) who found the application of FYM decreased the soil pH, the increased availability of organic matter and exchangeable basic cations in the FYM may be responsible for the decrease in soil pH. These results are similar to those of (Al-Sayed *et al.*, 2019; Yousef *et al.*, 2022).

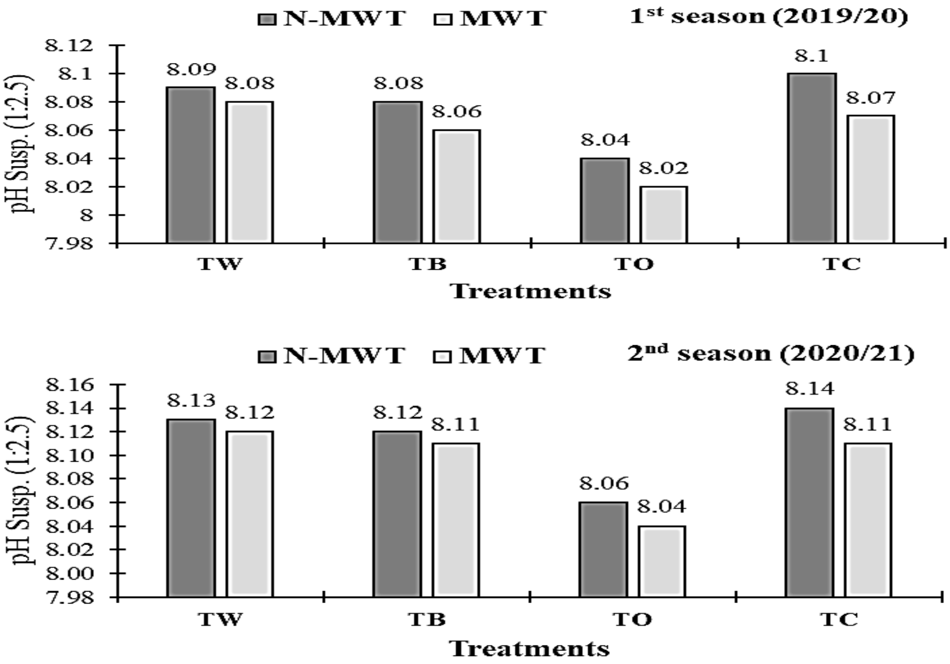

Figure (3): Synergistic effects of irrigation water magnetization and fertilization on soil reaction pH at surface layer after wheat harvest in two seasons (2019/20-2020/21).

Regarding the effects of irrigation water magnetically treatment, Data also in Figure (3). Show that, the widespread use of sources of fertilizers with water magnetization decreased the pH in the soil treated by T_O treatments at both season by 0.74 and 0.99%, respectively. While the highest value of pH under magnetically treated was observed 8.12 at T_W treatment in the second season. In general, the magnetically treatments significantly affected pH compared to control (UN-MWT), the decreasing values for water magnetically treated were 0.25 and 0.22%, respectively over control (UN-MWT) at both two seasons. The reduction in soil pH may be due to the effect of magnetic field on organic matter in the soil where it releases relatively greater of organic acids in rhizosphere due to the increased microbial activity in the soil as deduced by Maheshwari and Grewal (2009). The magnetism effect causes changes in the physical properties of water, decreasing vaporization rate, soil pH and desalinizing alkaline soils (Amor *et al.*, 2017). Obtained results are in accordance with those reported by Al Khazan *et al.* (2011) and El Yazied *et al.* (2012).

3.1.3 Soil organic matter

Results obtained for the soil organic matter SOM varied significantly with the application of fertilization (T_B, T_O and T_C fertilizers) with un-magnetically treated irrigation water shown in Figure (4). Data observed SOM in the soil treated by T_O treatments at both two seasons under without magnetically treated showed increasing by 66.67 and 64.94%, respectively over the T_W treatment under without magnetically treated. This increase in SOM might be due these increases in soil organic carbon due to the addition of FYM which increased the microbial and enzymatic activity in soil and resulting in increased soil organic matter and ultimately improve the soil quality (Bulluck *et al.,* 2002). The application of FYM caused increasing of SOM because organic manure contains soil organic carbon that considerably increase organic matter content in soil (Murad *et al.*, 2022).

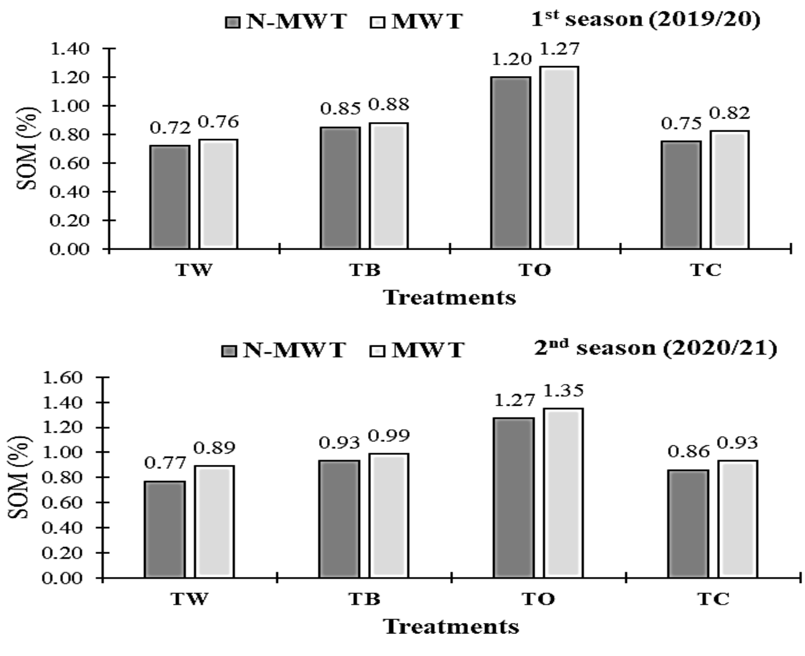

Figure (4): Synergistic effects of irrigation water magnetization and fertilization on soil organic matter SOM at surface layer after wheat harvest in two seasons (2019/20-2020/21).

Regarding the effects of irrigation water magnetically treatment, Data also in Figure (4) show that, the widespread use of aforementioned sources of fertilizers with water magnetization increased the SOM in the soil treated by T_O treatments at both season by 67.11 and 51.69 %, respectively. Also, data in Fig. (4) obtained the effects of irrigation water magnetically treatments significantly affected on SOM compared to control treatment (N-MWT), the results showed that the increasing SOM values for magnetically treated by 5.97 and 8.62%, respectively over control (N-MWT) at both two seasons. While the highest value of SOM under magnetically treated was observed 1.27 and 1.35%, respectively were obtained with T_O treatment at both seasons. This increase in SOM might be due the majority of microorganisms that degrade organic compounds are aerobic in nature. Thus, with increased oxygen concentration in magnetized liquids, their growth is more intense as is the degradation of organic matter (Goldsworthy *et al.*, 1999; Szczypiorkowski and Nowak, 1995).

3.1.4 Soil leaching requirement (L.R.)

The effect of magnetically treated irrigation water and fertilization applied either alone or in combination on leaching requirement (L.R.) after post-harvest soil properties are presented in Table (6). Data observed the L.R. in the soil treated by T_O treatments at both two seasons under un-magnetically treated irrigation water showed significantly increasing by 34.55 and 41.00%, respectively increase over T_W treatment under without magnetically treated. In generally the application of organic manures caused high levels of in L.R. in wheat soil in comparison to the other fertilizers. These increases may be due to the high salt leaching in comparison to the other FYM the presence of organic substances associated with salts that move from the surface layer to the bottom in the soil profile. Chang *et al*. (2007) showed that leaching requirement in soil received FYM treatment was generally higher than those received chemical fertilizer treatment. Increased leaching requirement in the soil due to the application of organic fertilizer reported by many investigators (Kannan *et al.,* 2005; Muhammad and Khattak, 2011; Qadir *et al.,* 2002; Zia *et al.,* 2007). Regarding the effects of irrigation water magnetically treatment, Data also in Table (6) show that, the widespread use of aforementioned sources of fertilizers with water magnetization increased the L.R. in the soil treated by T_O treatments at both season by 45.18 and 47.20 %, respectively. Also, data in Table (6) obtained the effects of irrigation water magnetically treatments significantly affected on L.R. compared to control treatment (N-MWT), the results showed that the increasing L.R. values for magnetically treated by 7.68 and 12.37%, respectively over control (N-MWT) at both two seasons. Zlotopolski (2017) reported that the removal soluble salts and fading of slightly soluble components such treatment in soil increased by magnetically treatments The L.R. increasing may be due to the magnetic water has small molecules, less viscosity, faster water movement and permeability at soil pores leaching as cleared by (Al Khazan *et al.*, 2011; Amiri and Dadkhah, 2006; Babu, 2010).

Table (6): Synergistic effects of irrigation water magnetization and fertilization on soil leaching requirement rate L.R in soil depth from 0 to 30 cm after wheat harvest in two seasons (2019/20-2020/21).

Treatments		L.R. (%)			
		1st season (2019/20)		2nd season (2020/21)	
		UN-MWT	MWT	UN-MWT	MWT
T_W		18.87±0.31	19.20±0.14	18.01±0.55	19.86±1.83
T_B		22.82±0.30	25.79±0.79	23.61±0.57	27.96±1.66
T_O		25.39±0.63	27.88±1.62	25.40±0.32	29.24±2.81
T_C		20.02±0.57	20.92±0.99	19.80±2.21	20.50±2.80
Mean		21.78	23.45	21.71	24.39
L.S.D. 0.05	A =	1.58		3.57	
	B =	2.23		5.05	
	AB =	3.16		7.15	

Each value in this table as mean of three replicates N-MWT= Non-magnetic water treatment, MWT = Magnetic water treatment. T_W = Without fertilizer (Control), T_B = Bio-fertilizer, T_O = Organic fertilizer (FYM), T_C = Chemical fertilizer, L.S.D. = Least Significant Difference, value stander error.

3.2 Effects of magnetic technology and fertilization on wheat plant

3.2.1 1000-Grain weight (g)

Data of 1000 grain weight in Table (7) and R.I. in Figure (5) observed that T_C treatments at both seasons irrigated with MW improved both characters by 26.53 and 27.36%, respectively over the T_W treatment under without magnetically treated. The current results are similar to the findings of Baloch *et al.* (2015) they found that increase in 1000-grain weight was mainly due to the balanced supply of nitrogen in combination with P and K from both inorganic and organic sources during the grain filling development and growth stage. Regarding the effects of irrigation water magnetically treatment, Data also in Table (7) show that, the widespread use of aforementioned sources of fertilizers with water magnetization increased the 1000-grain weight in the soil treated by T_C treatments at both season by 31.49 and 34.35%, respectively. While, the highest value of 1000-grain weight under magnetically treated was observed 58.67 g at T_C treatment. This increase in 1000-grain weight might be higher uptake of nutrients by the plant (Zainuddin *et al.*, 2022). In general, the magnetically treatments significantly affected on 1000-grain weight compared to control (N-MWT), the increasing values for water magnetically treated were 5.93 and 7.68%, respectively over control (N-MWT) at both two seasons. These results are in agreement with many other workers (El-Kholy *et al.*, 2015; Patil, 2014). The most significant relative increase in weight of 1000 seed weight (g) was found for the bio-fertilized with MWT dry seeds at the 75 percent N-P-K fertilization by 60.96%, as reported by Rashad *et al.* (2022).

Table (7): Synergistic effects of irrigation water magnetization and fertilization on 1000-grain weight of wheat in two seasons (2019/20-2020/21).

Treatments		1000-Grain weight (g)			
		1st season (2019/20)		2nd season (2020/21)	
		UN-MWT	MWT	UN-MWT	MWT
T_W		39.73±1.13	40.97±0.71	42.14±0.55	43.67±0.70
T_B		43.27±0.71	44.73±0.71	46.67±0.36	48.67±0.57
T_O		48.87±1.00	53.40±0.63	50.11±0.58	56.40±0.90
T_C		50.27±0.47	53.87±0.71	53.67±0.29	58.67±1.75
Mean		45.54	48.24	48.15	51.85
L.S.D. 0.05	A =	1.33		1.39	
	B =	1.89		1.96	
	AB =	2.67		2.78	

Each value in this table as mean of three replicates N-MWT= Non-magnetic water treatment, MWT = Magnetic water treatment. T_W = Without fertilizer (Control), T_B = Bio-fertilizer, T_O = Organic fertilizer (FYM), T_C = Chemical fertilizer, L.S.D. = Least Significant Difference, value stander error.

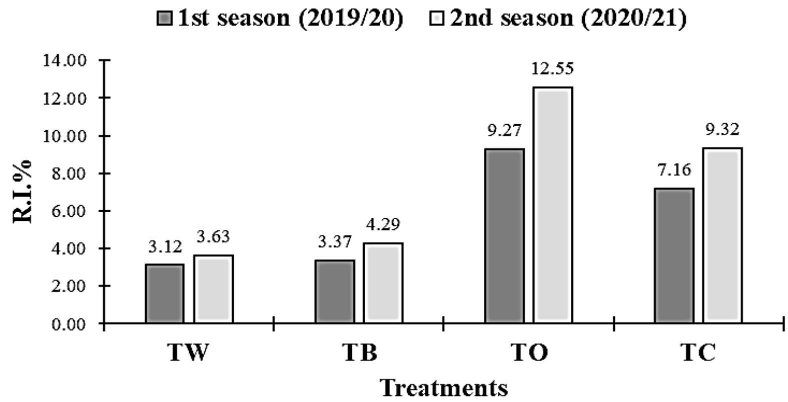

Figure (5): Relative increase R.I. in 1000-grain weight by irrigation water magnetization in two seasons (2019/20-2020/21).

3.2.2 Grain yield (ton feddan^{-1})

Data in Table (8) show that the grain yield, in the soil treated by T_C treatments at both season with irrigated normal water showed that increasing percent 111.81 and 116.82%, respectively over the T_W treatment under without magnetically treated. This increase in grain yield might be due to the fast effect of N in chemical fertilizer at the beginning period of plant growth through flowering and grain production. Subhan *et al*. (2017) who reported that using mineral fertilizer resulted in significantly higher grain and straw yields of wheat plants when compared to organic manures. Also, other study found that chemical fertilizers at rates of 75, 100 and 125% increase grain yield with increasing recommended dose rates (Rani *et al.*, 2020).

Table (8): Synergistic effects of irrigation water magnetization and fertilization on grain yield of wheat in two seasons (2019/20-2020/21).

Treatments		Grain yield (ton feddan^{-1})			
		1st season (2019/20)		2nd season (2020/21)	
		UN-MWT	MWT	UN-MWT	MWT
T_W		1.067±0.01	1.080±0.02	1.070±0.01	1.086±0.00
T_B		1.14±0.03	1.59±0.02	1.26±0.02	1.77±0.02
T_O		1.83±0.05	2.16±0.00	1.87±0.02	2.21±0.02
T_C		2.26±0.05	2.54±0.01	2.32±0.01	2.66±0.01
Mean		1.476	1.772	1.535	1.875
L.S.D. 0.05	A =	0.05		0.03	
	B =	0.07		0.04	
	AB =	0.10		0.06	

Each value in this table as mean of three replicates N-MWT= Non-magnetic water treatment, MWT = Magnetic water treatment. T_W = Without fertilizer (Control), T_B = Bio-fertilizer, T_O = Organic fertilizer (FYM), T_C = Chemical fertilizer, L.S.D. = Least Significant Difference, value stander error.

While the effects of irrigation water magnetically treatment, Data also in Table (8) show that, the widespread use of aforementioned sources of fertilizers with water magnetization increased the grain yield in the soil treated by T_C treatments at both season by 135.19 and 144.94%, respectively. While the highest value of grain weight under magnetically treated was observed 2.665-ton feddan^{-1} at T_C treatment. In general, the magnetically treatments significantly affected grain weight compared to control (N-MWT), the increasing values for water magnetically treated were 20.05 and 22.15%, respectively over control (N-MWT) at both two seasons. Magnetic treatment of seeds alters their nutrient uptake behavior due to biochemical changes that activate germination and growth and, as a result, affect the remaining available nutrients in the soil (Teixeira Da Silva and Dobresnski, 2014; Harb *et al.,* 2021).

3.2.3 Straw yield (ton feddan^{-1})

Regarding the effects of irrigation water magnetically treatment, Data also in Table (9) show that, the widespread use of aforementioned sources of fertilizers with water magnetization increased the straw yield in the soil treated by T_C treatments at both season by 142.11 and 156.61%, respectively. While the highest value of straw yield under magnetically treated was observed 3.744-ton feddan^{-1} at T_C treatment in the second season. The straw yield was also significantly increased under the effect of the studied factors with the most significant increase by 30.44% for the bio-fertilizer with magnetically treated at the 75% N-P-K fertilization relative to the minimum observed value (Rashad *et al.*, 2022). Obtained results are in agreement with those obtained by (Harb *et al.*, 2021; Hozayn and Qodos, 2010; Hozayn *et al.*, 2013; Rani *et al.*, 2020). In general, the magnetically treatments significantly affected on straw yield compared to control (N-MWT), the increasing values for water magnetically treated were 11.61 and 16.59%, respectively over control (N-MWT) at both two seasons.

Table (9): Synergistic effects of irrigation water magnetization and fertilization on straw yield of wheat in two seasons (2019/20-2020/21).

Treatments		Straw yield (ton feddan^{-1})			
		1st season (2019/20)		2nd season (2020/21)	
		UN-MWT	MWT	UN-MWT	MWT
T_W		1.27±0.01	1.36±0.01	1.35±0.03	1.46±0.04
T_B		1.94±0.03	2.05±0.03	2.10±0.02	2.25±0.01
T_O		2.32±0.02	2.38±0.02	2.46±0.04	2.58±0.04
T_C		2.61±0.01	3.28±0.10	2.70±0.18	3.74±0.18
Mean		2.03	2.27	2.15	2.51
L.S.D. 0.05	A =	0.07		0.14	
	B =	0.10		0.19	
	AB =	0.14		0.27	

Each value in this table as mean of three replicates N-MWT= Non-magnetic water treatment, MWT = Magnetic water treatment. T_W = Without fertilizer (Control), T_B = Bio-fertilizer, T_O = Organic fertilizer (FYM), T_C = Chemical fertilizer, L.S.D. = Least Significant Difference, value stander error.

3.2.4 Protein (%)

Results shown in Table (10) and R.I. in Figure (6) data observed significantly variation in protein percent at both seasons due to application of T_B, T_O and T_C fertilizers to the treatments irrigated with (N-MWT). Data observed the protein, in the soil treated by T_C treatments at both season with irrigated normal water showed that increasing percent 64.79 and 64.71%, respectively over the T_W treatment under without magnetically treated. In general, the application of chemical fertilizers caused increasing of protein % same these results obtained by Rahimizadeh *et al.* (2010) found that the grain protein content of wheat indices fertilizer N rates (0, 50, 150% more than recommended rate) applied on preceding crops were significantly influenced grain protein content of wheat. The increases in grain protein content may be due to the superiority of T_C treatment. Also, the increase in protein content of grains may be due to the combined T_C with irrigation water magnetically treatments. These results are in close agreement with those found by Roy and Singh (2006), Abd El-Rahman (2009), Kabesh *et al.* (2009), and Sary *et al.* (2009).

Table (10): Synergistic effects of irrigation water magnetization and fertilization on the protein content by wheat grains in two seasons (2019/20-2020/21).

Treatments		Protein (%)			
		1st season (2019/20)		2nd season (2020/21)	
		UN-MWT	MWT	UN-MWT	MWT
T_W		6.93±0.02	7.08±0.15	7.00±0.07	7.15±0.10
T_B		7.53±0.05	7.90±0.17	7.61±0.05	7.99±0.05
T_O		8.33±0.10	9.73±0.32	8.40±0.16	9.88±0.12
T_C		11.42±0.03	12.57±0.06	11.53±0.03	12.73±0.11
Mean		8.55	9.32	8.64	9.44
L.S.D. 0.05	A =	0.28		0.18	
	B =	0.39		0.26	
	AB =	0.56		0.37	

Each value in this table as mean of three replicates N-MWT= Non-magnetic water treatment, MWT = Magnetic water treatment. T_W = Without fertilizer (Control), T_B = Bio-fertilizer, T_O = Organic fertilizer (FYM), T_C = Chemical fertilizer, L.S.D. = Least Significant Difference, value stander error.

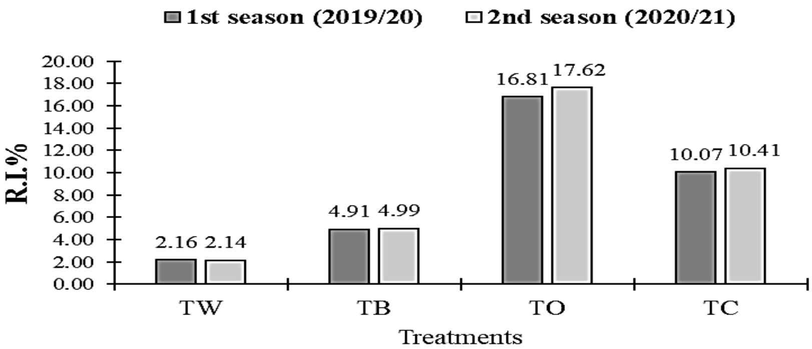

Figure (6): Relative increase R.I. in protein content of wheat grains by irrigation water magnetization in two seasons (2019/20-2020/21).

Regarding the effects of irrigation water magnetically treated data in Table (10) Show that, the widespread use of aforementioned sources of fertilizers with water magnetization increased the protein in the soil treated by T_C treatments at both season by 77.54 and 78.04%, respectively. As well as the magnetically treatments significantly affected protein compared with N-MWT. The results showed that the increasing protein values for magnetically treated by 9.01 and 9.26 %, respectively over control at both two seasons. While the highest values of protein under magnetically treated was observed 12.73% at T_C treatment in the second season. Celik *et al.* (2008) who discovered that the effect of magnetic fields on cell division and protein synthesis in paulownia node cultures increases the percentage of plant regeneration. This increase in protein might be due to increasing biomass necessitating metabolic changes, particularly increased protein biosynthesis (Shabrangi and Majd, 2009).

3.3 Effects of magnetic technology and fertilization on fertilizer use efficiency (FUE)

Fertilizer uses efficiency FUE reflects the response of wheat plants to fertilization treatments. It was calculated as kg biomass per kg of N applied (Anderson *et al.*, 1997). The results of post-harvest soil properties significantly showed variation in FUE varied significantly with the application of fertilizers with irrigation water magnetically treated shown in Table (11). The obtained data reveal that the highest FUE was obtained by T_O treatments 14.83 and 14.99 (kg grain / kg fertilizer) in first and second seasons, respectively. Whereas the lowest was achieved by T_B treatment 3.67 and 4.30 (kg grain / kg fertilizer) first and second seasons respectively, data observed FUE in the soil treated by T_O treatments at both season under magnetically treated showed 17.37 and 17.73 (kg grain / kg fertilizer), respectively increase over T_W treatment under without magnetically treated. The high FUE may be due to the reason that organic manures change in soil quality after manure addition are linked to the effects of OM content on soil structure and biological activity will be reflected on an increase in FUE (Azam Shah *et al.*, 2009). Results illustrated that, the FUE of wheat plant due to FYM application at rate (5 and 10 tons/feddan), were increased by 6.55 and 5.56 (kg grain/ kg fertilizer), respectively compared with the control under 15:5:5 treatment (Abd El-Ghfar, 2022). This result is in agreement with (Ali *et al.*, 2020; Okunlola and Adeona, 2016) who observed an improvement in the growth parameters with applied fertilizer types, which might be due to the effective use of applied fertilizer at this rate by the plants.

Table (11): Synergistic effects of irrigation water magnetization and fertilization on nitrogen use efficiency FUE in two seasons (2019/20-2020/21).

Treatments		NUE (kg grain / kg N fertilizer)			
		1st season (2019/20)		2nd season (2020/21)	
		UN-MWT	MWT	UN-MWT	MWT
T_W		0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
T_B		3.67±0.03	6.07±0.03	4.30±0.02	7.15±0.02
T_O		14.83±0.05	17.37±0.01	14.99±0.01	17.73±0.02
T_C		6.17±0.05	6.72±0.01	6.26±0.00	7.01±0.01
Mean		6.17	7.54	6.39	7.97
L.S.D. 0.05	A =	0.05		0.03	
	B =	0.06		0.04	
	AB =	0.09		0.05	

Each value in this table as mean of three replicates N-MWT= Non-magnetic water treatment, MWT = Magnetic water treatment. T_W = Without fertilizer (Control), T_B = Bio-fertilizer, T_O = Organic fertilizer (FYM), T_C = Chemical fertilizer, L.S.D. = Least Significant Difference, value ± stander error.

Regarding the effects of irrigation water magnetically treated, data in Table (11) showed that the magnetically treatments significantly affected FUE compared to control treatment. The results showed that the increasing value for magnetically treated by 22.25 and 24.83%, respectively over control (UN-MWT) at both two seasons. While the highest value of NUE under magnetically treated was observed 17.73 (kg grain /kg fertilizer) into treatment at the second season. According to Rashad *et al.* (2022), the maximum relative increase in the NUE was 117.65% and respectively, obtained for the magnetically treated dry seeds with mineral fertilization compared to the minimum calculated value. The intercellular bio-chemical changes that accompany soaking the seeds before cultivation may facilitate the uptake of phosphorus available in soil solution by plant which improves its use efficiency (Harb *et al.,* 2021; Teixeira da Silva and Dobránszki, 2014). The increase in FUE these may be due to the intracellular biochemical changes that occur as a result of magnetically treated may aid in the uptake of available nutrients, plant in soil solution that improves its fertilizers use efficiency.

3.4 Effects of magnetic technology and fertilization on economic evaluation of wheat crop productivity

Economic evaluation can use some criteria that are consistent with the conditions of field experiments and economic rationale. Data recorded in Table (12) shows the net return and profit cost ratio (P/C) for the field experiment of the wheat crop. The results showed an increase in the treatment of chemical fertilization with irrigation water magnetically treated compared to the same treatment with irrigation water non-magnetically treated in (P/C).

Table (12): Synergistic effects of irrigation water magnetization and fertilization on economic evaluation productivity of wheat in two seasons (2019/20-2020/21).

Treatments	N-MWT					MWT				
	Input	Output		Economic criteria		Input	Output		Economic criteria	
	Total costs	Revenue	Net revenue (L.E./feddan)	P/C ratio	Order	Total costs	Revenue	Net revenue (L.E./feddan)	P/C ratio	Order
1st season (2019/20)										
T_W	4200	6308	2108	0.33	4	4700	7241	2541	0.35	4
T_B	4650	10316	5666	0.55	3	5150	13066	7916	0.61	3
T_O	5800	14955	9155	0.61	2	6200	16979	10779	0.63	2
T_C	5200	17431	12231	0.70	1	5700	20896	15196	0.73	1
2nd season (2020/21)										
T_W	4550	6756	2206	0.33	4	5100	7883	2783	0.35	4
T_B	5000	11489	6489	0.56	3	5550	14549	8999	0.62	3
T_O	6200	16445	10245	0.62	2	6750	17984	11234	0.62	2
T_C	6300	18831	12531	0.67	1	6850	22597	15747	0.70	1

Each value in this table as mean of three replicates, N-MWT = Non-magnetic water treatment, MWT = Magnetic water treatment, T_W = without fertilizer (Control), T_B = Bio fertilizer, T_O = Organic fertilizer (FYM), T_C = chemical fertilizer.

The highest percentage was obtained under the treatment of soil irrigated by water irrigation magnetically treated with the chemical fertilizer compared to the same treatment irrigated by non-magnetically treated water. Data presented in Table (12) indicate that the economic evaluation of the grain and straw yields of wheat crop under chemical fertilizers at the recommended rates showed the best treatment (T_C) as the net revenue amounted to about 15747 L.E./feddan in the second season, perhaps chemical fertilizers will help to increase the yield of compared to a lower treatment T_W net income. Profitability is obtained from revenue minus total costs (which come from adding investment costs to operating costs), and the profit-to-cost ratio. Abd al-Rahman (2009) also reported that the cultivation of irrigated wheat using drip irrigation system is economically recommended. This is because it is characterized by the maximum values of total return with respect to grain, straw yield, cost-benefit ratio and net profit-cost ratio. Our results are in agreement with those of Youssef (2011). The higher output of the system may be the reason for the realization of higher net returns and benefit cost ratio. Abd El-Ghfar (2022) also noticed improvement in the net returns and profit cost ratio (P/C) parameter of wheat crop with the chemical fertilizer’s application. In terms of economic efficiency, the combined interaction treatment of magnetized water or magnetite plus magnetized water and 75% nano-potassium particles had the best results in both seasons, followed by 100% nano-potassium particles and bulk potassium. The lowest values, on the other hand, were obtained in both seasons from the combined interaction of non-magnetization and 25% nano-potassium particle treatment (EL-Zawily *et al.*, 2018).

4. Conclusion

Results of the current study showed the positive impacts of magnetic technology and fertilization on all studied soil properties and wheat yield components. Magnetic treatments of low-quality irrigation water after planting wheat with utilization of fertilizers were significantly efficient in improving the wheat yields and its quality under saline calcareous soil conditions. This recommended enhancing growth, yield, its component of wheat plants as well as significant increase in the soil SOM and L.R. Generally using magnetic technology could be a promising technique for agricultural improvements in case of a low-quality irrigation groundwater, soil salinity and wheat crop. Based on the results, it's recommended that magnetically treated irrigation groundwater and addition of organic manure FYM improved soil productivity and wheat production, this research achieves the goal compatible with the country 2030 plan for sustainable development.

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