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Influence of magnetic treatments for seeds and saline irrigation water under two levels of NPK fertilizers on growth and productivity of spinach (*Spinacia oleracea* L.) plant

[1]Ibrahim, M. A. [1]Gomaa, F.A.; [2]Hozayn M and [1]Kotb, M.S.

[1] Soil Science Department, Faculty of Agriculture, Cairo University, Giza 12613, Egypt;
[2] Field Crops Research Department, Agricultural and Biological Research Institute, National Research Centre, 33 El-Behouth St., (Former El Tahrir St.) 12622 Dokki, Giza, Egypt.

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ABSTRACT

Two greenhouses experiment were conducted in Qalin Center, Kafr El-Sheikh Governorate, Egypt under the natural conditions of greenhouse during the two growing winter seasons of 2020/21 and 2021/22. The experiment aims to evaluate the effect of two magneto-priming seed treatments (Un-magnetized seeds (U-MS) and magnetized seeds (MS), two magnetized saline water (Un-magnetized saline water (U-MW) and magnetized saline water (MW) under two levels of NPK fertilizer (75 and 100% of recommended rate) on seedling emergence, vegetative growth and productivity of spinach plants. The eight treatments laid out in completely randomized design (CRD) with three replications. Results show that sowing magnetized spinach seeds and irrigation pots with magnetized saline water (2500 ppm) under both NPK fertilizer significantly out performed sowing un-magnetized spinach seeds and irrigated with un-magnetized water for all tested vegetative growth parameters at the age of 15, 30, 45, and 55 days. Regarding magnetized seeds treatment, the magnetized seed treatments significantly surpassed the untreated seed in all recorded leaves growth parameters (i.e., leaves numbers plant^{-1}, leave length (cm), leave width (cm) and Leave area (LA; cm^2), plant growth parameters (i.e., plant height (cm), plant fresh and dry weight in gram), root growth parameters (root length and width (cm), root fresh and dry weights in gram) and total chlorophyll (Spad) at the age of 15, 30, 45, and 55 days. The percent of improvement, ranged from 0.61 to 18.04% in leaves growth parameters, 2.09, -4.52% in plant growth, 2.93, -12.09% in root growth and 1.56, -3.45% in total chlorophyll in leaves. Similar positive effects were recorded under magnetized water compared to untreated water treatments. Where the positive effects, ranged from 7.36-36.02% in leaves growth parameters, 9.89, -15.72% in plant growth, 24.23-33.46% in root growth and 1.16-8.80% in total chlorophyll in leaves at the age of 15, 30, 45, and 55 days. As well as both factors (magnetized seed or water) caused positive effects on nutrition value of Spinach leaves (N, P and K %) and micro nutrients (Fe, Mn, Zn and Cu ppm). Under the conditions of this experiment, sowing magnetized spinach seeds and irrigation with magnetized saline water resulted in a positive and a significant effect on all investigated vegetative growth measurements, yield and macro (N, P and K %) and micro nutrients (Fe, Mn, Zn and Cu ppm) minerals content for soil and plant compared to control treatment.

Keywords: *Spinacia Oleracea*, Magnetized water; Magnetized seeds; NPK fertilizers; Growth; Nutrition values

2. INTRODUCTION

Spinach (*Spinacia Oleracea*) is a main vegetable crop that is wealthy in beta carotene, vitamins A, C, E, and folic acid, oxalic acid, a lot of minerals e.g. (Ca, K, Fe, Mg, P, S and Na); proteins, and secondary metabolites, which has antioxidant and stimulant structures **Muchate *et al*. (2019)**. Spinach leaves containing a high concentration of oxalates and phytates **Gabr *et al*. (2022)**. Also, *Spinacia oleracea* L. is an extensively using leafy plant, its leaves and shoots fulfill the merit of raw and boiled vegetables. It can hunt free radicals as it is opulent in minerals and antioxidants. So, it has numerous medical and food uses. The Spinach plant also has a lot of antibacterial combinations and folic acid which is beneficial for the treatment of anemia **Zafar *et al*. (2022)**. It is a reasonably salt-tolerant glycophyte in the winter, but is sensitive to temperately sensitive if cultivated in the spring and summer seasons **Ferreira *et al*. (2020)**. Research conducted on spinach indicates a lower yield produced after the crop is cultured in salinity stress conditions. The disagreeable impact of salts on growth and yield attributes, physiological considerations, and discrepancy of nutrients (mainly K^+, Na^+ and Cl^-) in spinach tissues were observed **Xu and Mou, (2016); Ferreira *et al*. (2018 & 2020**). Salinity adversely reduced water uptake efficiency, seed vigor, hypocotyl and radicle length, total phenolic content and total flavonoid content of water spinach. The seedling height reduction of water spinach increased significantly relative to increasing salinity **Ibrahim *et al.* (2019)**. This disagrees with the latest studies that explosion no momentous loss in spinach yield and nutritional value with saline water levels up to 9 ds m^-1 **Ferreira *et al*. (2018)**. Moreover, **Ors and Suarez (2017)** cleared that spinach yield was augmented at moderate salinity levels and then dropped at high levels (more than EC 9.0 ds m^-1). Also, **Ferreira *et al*. (2020)** proposed the portal level for spinach growth ranged between 4500 to 6500 mg/l when water is saline, and from 3500 to 5600 mg/l when soil is saline. The alteration in spinach performance to salinity in this research may be accredited to many causes comprising adaptable saltwater levels, crop cultivars, climate, growth media, harvesting time, soil EC values, and soil physio-chemical characteristics. Spinach requires pH 7 ±0.5 for healthier growth and greater production **Parwada *et al*. (2020)** and **Salama *et al*. (2022)**.

For many years up to now studies have been carried out on showing the effects of magnetic fields on biological systems. Magnetized water is obtained by passing of water through the permanent magnets or through the electro magnets installed in/on a feed pipeline. The literature review refers that there are some beneficial effects of magnetic field treatments either the pre-sowing seed treatment or irrigation with magnetized water. Magnetized water which naturally produce electromagnetic waves leaching salt ions from the soil, increasing mobility of macro-and microelements to the roots shocking nematodes and microbes found on the roots and making water of 10000 ppm salinity proper for irrigation **Hozyan and AbdulQados (2010**). It is a key factor in reducing hazards of Na^{+} and Cl^{-} toxicity and in increasing root growth, soil water retention and fertilizer efficiency **Mostafazadeh *et al*. (2012**). Magnetic field improved the plant growth characteristics **Esitken and Turan (2004); Maheshwari and Grewal (2009); Mostafazadeh *et al*. (2011); Carbonell *et al*. (2011); Radhakrishnan and Kumari (2012**), root function **Vashisth and Nagarajan (2010); Aladjadjiyan (2010**) influenced the chemical composition of plants **Harari and Lin (1992); Maheshwari and Grewal (2009); Radhakrishnan and Kumari (2012**), affect soil nutrient availability (**Harari and Lin, 1992); Noran *et al*. (1996); Maheshwari and Grewal (2009); Mostafazadeh *et al*. (2011**), activate plant enzymes **Alikamanoglu and Sen (2011); Shabrangi *et al*. (2011**) and increased the yield of cabbage **Podlesny and Gendarz.(2008**), wheat **Hozayn and Abdul Qados (2010**), Maize **Zepeda *et al*. (2011**) and soybean **Radhakrishnan and Kumari (2012**). In a few words, irrigation with magnetically treated water or/and magnetic seed treatment are friendly environmental techniques. **Podleoeny *et al*. (2004)** studied the effects of magnetic treatment by exposing the broad bean seeds to variable magnetic strengths before sowing and observed marked beneficial effects on seed germination, emergence rate and seed yield. Plant emergence was more regular after the use of the magnetic treatment and the emergence occurred 2–3 days earlier in comparison with the control treatment. They attributed the higher number of pods per plant and the fewer plant losses per unit area for broad bean during the growing season and consequently the yield increase to the pre-sowing treatment of seeds with magnetic field. Magnetic fields can also influence the root growth of various plant species **Belyavskaya, (2001), (2004); Muraji *et al*. (1992), (1998); Turker *et al*. (2007**). **Muraji *et al*. (1992)** demonstrated an enhancement in root growth of maize (Zea mays) by exposing the maize seedling to 5 mT magnetic fields at alternating frequencies of 40–160 Hz. However, there was a reduction in primary root growth of maize plants grown in a magnetic field alternating at 240–320 Hz. Highest growth rate of maize roots was achieved in a magnetic field of 5 mT at 10 Hz **Muraji *et al*. (1998**). **Turker *et al*. (2007)** reported an inhibitory effect of static magnetic field on root dry weight of maize plants, but there was a beneficial effect of magnetic field on root dry weight of sunflower plants. Moreover, Magnetized water for irrigation is recommended to save irrigation water **Mostafazadeh *et al*. (2011**). Wherefore, bio-magnetic stimulation is applied widely in agricultural fields **Balouchi and Sanavy (2009**). For all this, the magnetic field application should be recommended for applying in agriculture fields in our country.

In this study we attempted to investigate the possible effects of pre-sowing magnetized seeds and magnetized irrigation water on plant growth and soil characteristics, as well as, utilization the positive effects of magnetic field to reduce fertilizer additions for spinach (*Spinacia oleracea* L) plants.

3. MATERIALS AND METHODS

Pot experiment was conducted in Qalin Center, Kafr El-Sheikh Governorate, Egypt under the natural conditions of greenhouse during the two growing winter seasons of 2020/21 and 2021/22. The experiment aims to evaluate the effect of two magneto-priming seed treatments (Un-magnetized seeds (U-MS) and magnetized seeds (MS)), tow magnetized water (Un-magnetized water (U-MW) and magnetized water (MW)) under two levels of NPK fertilizers (75 and 100% from recommended rate) on seedling emergence, vegetative growth, nutritional value and productivity of spinach plants. Description of eight treatments is tabulated in Table 1. The treatments laid out in completely randomized design (CRD) with three replications. The layout of Experiments is shown in Fig 1. The diameter of pots used was 30 cm, and filled with equal amount of soil (12 kg per pot). Salinity level (2500 ppm) which used in irrigation water in this study were equipped by adding measured amounts of NaCl salt to potable water to accomplish the required salinity level (2500 ppm). Magnetized water was getting by passing it through magnetic unit (with flow rate 2 liters per minute, one inch diameter, intensity 3000 Gauss; produced by Delta Water Company, Industrial Zone, Alexandria, Egypt). Magnetized seeds were getting by soaking into magnetized water for 24 hours, then air dried and sown immediately. The studied soil and irrigation water were evaluated before treatments applying according to **Page *et al*., [54]** and are shown in Table (2).

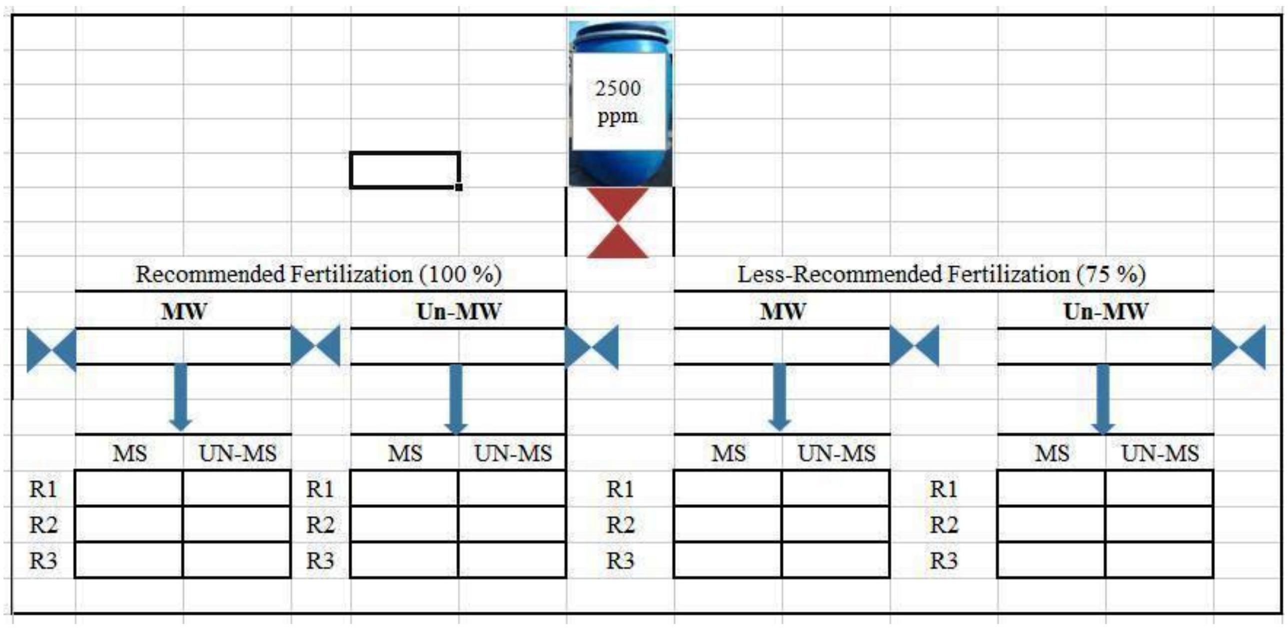

Fig 1. Layout of experimental treatment

Table 1. Description of experimental treatment

Treat. No.	Treatment description

T_1	Sowing un-magnetized seeds (Un-MS) and irrigated with un-magnetized saline water (Un-MW; 2500 ppm) and application of NPK fertilizers with 100% recommended dose (200 g P_2O_5 + 40 g S + 35 g NH_4NO_3 + 40 g K_2SO_4).
T_2	Sowing magnetized seeds (MS) and irrigated with un-magnetized saline water (Un-MW; 2500 ppm) and application of NPK fertilizers with 100% recommended dose (200 g P_2O_5 + 40 g S + 35 g NH_4NO_3 + 40 g K_2SO_4).
T_3	Sowing un-magnetized seeds (Un-MS) and irrigated with magnetized saline water (MW; 2500 ppm) and application of NPK fertilizers with 100% recommended dose (200 g P_2O_5 + 40 g S + 35 g NH_4NO_3 + 40 g K_2SO_4).
T_4	Sowing magnetized seeds (MS) and irrigated with magnetized saline water (MW; 2500 ppm) and application of NPK fertilizers with 100% recommended dose (200 g P_2O_5 + 40 g S + 35 g NH_4NO_3 + 40 g K_2SO_4).
T_5	Sowing un-magnetized seeds (Un-MS) and irrigated with un-magnetized saline water (Un-MW; 2500 ppm) and application of NPK fertilizers with 75% recommended dose (140 g P_2O_5 + 30 g S + 25 g NH_4NO_3 + 30 g K_2SO_4).
T_6	Sowing magnetized seeds (MS) and irrigated with un-magnetized saline water (Un-MW; 2500 ppm) and application of NPK fertilizers with 75% recommended dose (140 g P_2O_5 + 30 g S + 25 g NH_4NO_3 + 30 g K_2SO_4).
T_7	Sowing un-magnetized seeds (Un-MS) and irrigated with magnetized saline water (MW; 2500 ppm) and application of NPK fertilizers with 75% recommended dose (140 g P_2O_5 + 30 g S + 25 g NH_4NO_3 + 30 g K_2SO_4).
T_8	Sowing magnetized seeds (MS) and irrigated with magnetized saline water (MW; 2500 ppm) and application of NPK fertilizers with 75% recommended dose (140 g P_2O_5 + 30 g S + 25 g NH_4NO_3 + 30 g K_2SO_4).

Table 2: Some physical and chemical properties of investigated soil

Particle size distribution < 2mm (%)				pH	ECe (ds/m)	Soil past extract analysis (meq/l)						
						Anions			Cations			
Sand	Silt	Clay	Texture			HCO_3^-	Cl	SO_4^{--}	Ca^{++}	Mg^{++}	Na^+	K^+
75.52	18.00	6.48	Sandy loam	7.74	2.43	2.5	3.60	18.34	8.80	6.40	7.10	1.14

Cultivation methods:

Twenty-five of Spinach (Spinacia Oleracea) seeds (The seed was obtained from an importer of the hybrid variety (Saif Jaar)) were sown in plastic pots 30 cm diameter and depth and was filled by 12 kg soil in each pot. The pot has a drainage hole where the drained water is collected and its quantity is estimated after each irrigation. Phosphorus, potassium and nitrogen fertilizers (NPK) were supplementary to the soil with tow levels: i) Recommended level of NPK fertilizers (200 g P_2O_5 + 40 g S + 35 g NH_4NO_3 + 40 g K_2SO_4), and ii) 75 % of the recommended dose (140 g P_2O_5 + 30 g S + 25 g NH_4NO_3 + 30 g K_2SO_4) were used according to the Ministry of Agriculture and Land Reclamation for spinach crop. The irrigation planning scheme used in the study was to apply adequate water to bring the soil back to field capacity at the end of each irrigation treatment.

Data recorded:

Growth parameters: During the experimental period of both seasons at 15, 30 and 45 days after sowing, ten plants were randomly chosen from each treatment to record plant height (cm), number of leaves per plants, leaf length and width (cm) for each plant.

Total Chlorophyll: Total Chlorophyll in leaves was determined using SPAD Chlorophyll meter **[55].**

Yield: Fifty-five days after sowing, a random sample of ten plants was chosen from each experimental unit to determine plant height (cm), leaf length (cm), leaf width (cm) and number of leaves for each plant in different treatments. The plants were harvested from the surface of the soil, air-dried, and then oven-dried at 70 $^{\circ}$C to calculate the dry weight. At the end of season root length (cm), plant height (cm), number of leaves per plant, fresh and dry weights of root (dried in an electric oven at 70 1C for72h (g $plant^{-1}$), leaf area (cm^2 $plant^{-1}$) using the disk method **[56].**

Macro-elements contents in leaves: Macro-minerals contents in dry leaves were determined according to **[58].** Total N content was determined by using Micro-Kjeldahl method. Sodium, Potassium, and calcium concentrations were determined using flame photometer (Genway model 3031) according to Sparks, 1996. While, P, content was determined using the atomic absorption spectrophotometer (Perkin Elemer 100-B).

Soil analysis: Soil samples were collected and mixed to analysis after applied treatments (55 days after sowing), air drying, passed through a 2 mm sieve and analyzed for soil properties (EC, pH, concentrations of N, P, K, Fe, Mn, Zn, and Cu determined according to standard methods **Konica Mo.(2012)**.

Data analysis: Data were statistically analyzed using MSTAT-C computer package (Freed et al., 1989). The least significant difference (LSD5%) test was used to compare among the eight means. Independent t test was used to comparison between magnetized and un-magnetized seeds, as well as the differences between magnetized and un-magnetized saline water treatments Using SPSS program.

4- RESULTS AND DISCUSSION

4.1. Leaves growth characters at 15, 30, 45 and 55 days after sowing:

The data in Table (3) show that sowing magnetized spinach seeds and irrigation pots with NPK fertilizer (100 % or 75% recommended dose) significantly out-performed sowing un-magnetized spinach seeds and irrigated with un-treated water for all tested vegetative growth parameters at the age of 15, 30, 45, and 55 days.

Under 75 % recommended level, the magnetized treatments (seeds and water; T_8 or T_6) significantly improved all the above-mentioned vegetative growth parameters compared to untreated treatment (T_1). The percent of improvement at 15, 30, 45 and 55 days, respectively, reached 0.00, 16.67, 20.00 and 16.67% in leaves numbers plant^{-1}; 22.43, 9.36, 8.32 and 9.61% in leave length (cm); 17.99, 11.20, 2.37 and 4.91% in leave width (cm) and reached 15.63 and 11.42% in Leaves area (LA; cm^2) at 45 and 55 days after sowing, respectively.

Similar positive and significant trends were recorded under NPK fertilizer (100 % recommended rate), where the magnetized treatments (seeds and water; T_8) significantly improved all the above-mentioned vegetative growth parameters compared to correspondence untreated treatment (T_5). The percent of improvement at 15, 30, 45 and 55 days, respectively, reached 22.22, 20.00, 16.13 and 10.53% in leaves numbers plant^{-1}; 5.38, 19.49, 11.67 and 18.29% in leave length (cm); 4.35, 11.64, 14.96 and 22.08% in leave width (cm) and reached 44.96 and 54.10% in Leave area (LA; cm^2) at 45 and 55 days after sowing, respectively. The results also show that the use of magnetized seeds or magnetized water separately leads to improving all the studied growth parameters, but to a lesser extent than the double use of magnetized water and magnetized seeds under different of NPK fertilizers rates.

Data presented in Table (4) show the differences between magnetized and un-magnetized seeds, as well as differences between magnetized and un-magnetized saline water treatments under NPK fertilizer rates according to independent *t*-test. Regarding magnetized seed treatment, the magnetized seed treatments significantly surpassed the untreated seed in all recorded vegetative growth parameters at the age of 15, 30, 45 and 55 days. The percent of improvement at 15, 30, 45 and 55 days, respectively, ranged from 0.60 to 2.53% in leaves numbers plant^{-1}; from 2.12 to 6.54% in leave length (cm); from 3.05 to 39.78% in leave width (cm) and reached 3.49 and 6.42% in Leave area (LA; cm^2) at 45 and 55 days after sowing, respectively. Regarding magnetized water treatment, the magnetized water treatments significantly surpassed the untreated treatment in all recorded vegetative growth parameters at the age of 15, 30, 45, and 55 days. The percent of improvement at 15, 30, 45 and 55 days, respectively, ranged from 8.33 to 16.12% in leaves numbers plant^{-1} from 7.36 to 20.68% in leave length (cm); from 8.37 to 56.30% in leave width (cm) and reached 26.07 and 36.02% in Leave area (LA; cm^2) at 45 and 55 days after sowing, respectively.

Table (3). Influence of fertilization, magnetic and un-magmatic "seeds & salinity water" treatments on leaves growth measurements of *Spinacia oleracea* at 15, 30, 45 and 55 days after sowing.

Treatment	T1	T2	T3	T4	T5	T6	T7	T8	LSD $_{5\%}$

		75% NPK				100NPK				
		Un-MW		MW		Un-MW		MW		
Parameter		Un-MS	MS	Un-MS	MS	Un-MS	MS	Un-MS	MS	
Leaves parameter (s) 15 DAS	**Number**	6.00	6.00	6.00	6.00	6.00	6.00	6.67	7.33	**0.289**
	length (cm)	7.13	7.25	9.23	8.73	7.43	7.40	9.43	7.83	**0.397**
	Width (cm)	2.32	2.03	2.73	2.73	2.68	2.65	2.78	2.80	**0.127**
Leaves parameter (s) 30 DAS	**Number**	8.00	8.67	9.00	9.33	8.33	8.00	10.00	10.00	**0.680**
	length (cm)	14.07	12.13	12.22	12.75	11.03	11.67	14.35	13.18	**0.481**
	Width (cm)	4.02	3.40	4.08	4.47	3.87	3.52	4.23	4.32	**0.358**
Leaves parameter (s) 45 DAS	**Number**	10.00	10.67	12.00	12.00	10.33	10.00	11.33	12.00	**0701**
	length (cm)	16.83	13.95	16.68	18.23	16.28	15.97	17.95	18.18	**1.001**
	Width (cm)	4.92	4.23	4.73	5.03	4.23	4.28	4.53	4.87	**0.447**
	Leave area (cm^2)	29.73	20.92	33.25	34.35	25.62	24.57	32.43	37.13	**2.276**
Leaves parameter (s) 55 DAS	**Number**	12.00	12.67	14.00	14.00	12.67	12.33	14.00	14.00	**0.564**
	length (cm)	17.87	15.95	19.10	19.58	17.95	16.88	20.30	21.23	**0.982**
	Width (cm)	5.77	4.62	13.92	6.05	5.13	4.78	5.53	6.27	**1.174**
	Leave area (cm^2)	38.10	27.82	35.70	42.45	30.87	28.58	32.32	47.57	**3.491**

Table (4): Effect of Magnetized seeds or water on leaves growth measurements of *Spinacia oleracea* at 15, 30, 45 and 55 days after sowing under 2500 salinity water stress.

	Treatment	Seed treatments		*t*-test	Water treatments		*t*-test
Parameter		Un-MS	MS		Un-MW	MW	
Leaves parameter (s) 15 DAS	**Number**	6.33	6.17	NS	6.00	6.50	**
	length (cm)	7.80	8.31	NS	7.30	8.81	***
	Width (cm)	2.55	2.63	NS	2.42	2.76	***
Leaves parameter (s) 30 DAS	**Number**	9.00	8.83	NS	8.25	9.58	**
	length (cm)	12.43	12.92	NS	12.23	13.13	***
	Width (cm)	3.93	4.05	NS	3.70	4.28	***
Leaves parameter (s) 45 DAS	**Number**	11.17	10.92	NS	10.25	11.83	***
	length (cm)	16.58	16.94	NS	15.76	17.76	***
	Width (cm)	4.60	4.60	NS	4.42	4.79	**
	Leave area (cm^2)	29.24	30.26	NS	25.21	34.29	***
Leaves parameter (s) 55 DAS	**Number**	13.25	13.17	NS	12.42	14.00	***
	length (cm)	18.41	18.80	NS	17.16	20.05	***
	Width (cm)	5.43	7.59	NS	5.08	7.94	NS
	Leave area (cm^2)	36.60	34.25	NS	31.34	39.51	***

4-2. Plant growth characters at 15, 30, 45 and 55 days after sowing:

The data in Table (5) show that sowing magnetized spinach seeds and irrigation pots with NPK fertilizers (75 or 100 recommended rates) significantly improvement sowing un-magnetized spinach seeds and irrigated with un-treated water for all tested plant growth characters i.e., (plant height (cm), plant fresh and dry weight (g), root length and width (cm) and total chlorophyll in SPAD) at 15, 30, 45 and 55 days after sowing

Under NPK fertilizers 75 % recommended level, the magnetized treatments (seeds and water, T_4) significantly improvement plant height (cm) by 22.06, -2.30, 22.45 and 9.13% at 15, 30, 45 and 55 days, respectively, plant fresh and dry weight (g), root length and width (cm), root fresh and dry weight (g) by 4.19, 10.78, 20.89, 60.61, 65.41 and 49.53%, respectively, at 55 days after sowing. Similar positive trends were recorded in total chlorophyll where the improvement reached -11.23, -13.53 and 0.00% at 30, 45 and 55 days after sowing respectively.

Similar positive and significant trends were recorded under NPK fertilizers 100 % recommended level, where the magnetized treatments (seeds and water; T_8) significantly improvement plant height (cm) by 11.78, 13.83, 13.99 and 16.04% at 15, 30, 45 and 55 days, respectively, plant fresh and dry weight (g), root length and width (cm), root fresh and dry weight (g) by 27.68, 34.74, 22.19, 61.44, 48.91 and 40.56%, respectively, at 55 days after sowing. Similar positive trends were recorded in total chlorophyll where the improvement reached -0.97, -8.97 and -0.80% at 30, 45 and 55 days after sowing, respectively.

Data presented in Table (6) show those differences between magnetized and un-magnetized seeds, as well as differences between magnetized and un-magnetized saline water treatments according independent *t*-test. Regarding magnetized seed treatment, the magnetized seeds treatments significantly surpassed un-treated seed in all recorded plant growth parameters at the age of 15, 30, 45, and 55 days. The percent of improvement at 15, 30, 45 and 55 days, respectively, ranged from 2.27 to 4.52% in plant height (cm), and reached -2.47, -6.01, 2.93, -8.62, -11.50 and -9.05% in plant fresh & dry weight (g), root length & width (cm), root fresh and dry weight (g), respectively, at 55 days after sowing. Similar positive trends were recorded in total chlorophyll where the improvement reached 2.22, 3.45 and 1.56% at 30, 45 and 55 days after sowing, respectively.

Regarding magnetized water treatment, the magnetized water treatments significantly surpassed un-treated treatment in all recorded plant vegetative growth parameters at the age of 15, 30, 45, and 55 days. The percent of improvement at 15, 30, 45 and 55 days, respectively, ranged from 9.80 to 19.14% plant height (cm) and reached 12.66, 15.21, 29.43, 47.22, 39.07 and 32.60 % in plant fresh and dry weight (g), root length and width (cm), root fresh and dry weight (g), respectively, at 55 days after sowing. Similar positive trends were recorded in total chlorophyll where the improvement reached -3.88, -8.09 and 1.16% at 30, 45 and 55 days after sowing, respectively.

Table (5). Influence of fertilization, magnetic and un-magmatic "seeds & salinity water" treatments on plant and root growth characteristics of *Spinacia oleracea* at 15, 30, 45 and 55 days after sowing.

Treatment	T1	T2	T3	T4	T5	T6	T7	T8	LSD $_{5\%}$
	75% NPK				100NPK				
	Un-MW		MW		Un-MW		MW		

Parameter		Un-MS	MS	Un-MS	MS	Un-MS	MS	Un-MS	MS	
Plant vegetative growth	**Plant height (cm; 15DAS)**	8.08	8.20	9.80	9.87	8.07	8.23	10.17	9.02	**0.494**
	Plant height (cm; 30DAS)	14.91	13.02	13.60	14.57	12.42	12.28	15.52	14.13	**0.666**
	Plant height (cm; 45DAS)	15.67	14.87	18.32	19.18	17.75	16.93	19.22	20.23	**0.839**
	Plant height (cm; 55DAS)	18.62	16.55	19.57	20.32	18.70	17.37	20.87	21.70	**1.075**
	Plant fresh wt. (g; 55DAS)	276.33	276.71	317.65	287.90	286.93	347.62	366.04	366.37	**7.824**
	Plant dry wt. (g; 55DAS)	22.06	20.97	23.72	24.43	21.51	25.37	26.47	28.99	**1.212**
Root characters at 55 DAS	**Root length (cm)**	11.10	10.52	14.13	14.31	11.79	11.30	15.02	14.41	**0.845**
	Root Width (cm)	8.94	8.77	13.83	14.35	9.56	11.54	13.48	15.44	**0.927**
	Root fresh wt. (g)	7.03	7.44	10.81	11.63	8.95	10.06	10.78	13.33	**1.003**
	Root dry wt. (g)	1.58	1.62	2.25	2.37	1.95	2.10	2.24	2.74	**0.252**
Total chlorophyll (Spad)	**at 30 DAS**	49.08	49.23	46.41	43.57	50.99	49.69	50.81	50.49	**1.353**
	at 45 DAS	60.73	58.13	56.52	52.51	61.68	61.72	57.45	56.15	**1.370**
	at 55 DAS	61.83	60.72	61.96	61.83	64.03	62.57	64.72	63.52	**1.318**

Table (6): Effect of magnetized seeds or water on plant and root growth characteristics of *Spinacia oleracea* at 15, 30, 45 and 55 days after sowing under 2500 salinity water stress.

	Treatment	**Seed treatments**		***t*-test**	**Water treatments**		***t*-test**
	Parameter	**Un-MS**	**MS**		**Un-MW**	**MW**	
Plant vegetative growth	**Plant height (cm; 15DAS)**	8.83	9.03	NS	8.15	9.71	***
	Plant height (cm; 30DAS)	13.50	14.11	NS	13.16	14.45	***
	Plant height (cm; 45DAS)	17.80	17.74	NS	16.30	19.24	***
	Plant height (cm; 55DAS)	18.98	19.44	NS	17.81	20.61	***
	Plant fresh wt. (g; 55DAS)	319.65	311.74	NS	296.90	334.49	**
	Plant dry wt. (g; 55DAS)	24.94	23.44	NS	22.48	25.90	***
Root characters at 55 DAS	**Root length (cm)**	12.64	13.01	NS	11.18	14.47	**
	Root Width (cm)	12.53	11.45	NS	9.70	14.28	***
	Root fresh wt. (g)	10.61	9.39	NS	8.37	11.64	***
	Root dry wt. (g)	2.21	2.01	NS	1.81	2.40	***
Total chlorophyll (Spad)	**at 30 DAS**	48.25	49.32	NS	49.75	47.82	**NS**
	at 45 DAS	57.13	59.10	NS	60.56	55.66	***
	at 55 DAS	62.16	63.13	NS	62.29	63.01	**NS**

4.3. Chemical analysis in soil and spinach leaves at 55 days:

The data in Table (7) show that significant differences among magnetic treatments (T_1-T_8) in Soil pH, Soil EC, available soil with some macro-elements (i.e., N, P and K in ppm) and micro-elements (Fe, Mn, Zn and Cu in ppm) and concentration of (NPK in ppm) in leaves of spinach at 55 days after sowing.

Under NPK fertilizer (75 % recommended rates), the magnetized treatment (seeds and water; T_4) significantly increased pH number (by 7.14%) and available concentration of some soil elements like N (by 39.41%) Cu (by 7.69%) in ppm, while it was decreased of EC (by -16.00 %) and available soil with P (by 1.49%) and K (by 18.17%) in ppm compared to un-magnetized spinach seeds and irrigated with un-treated water treatment (T_1). As well as, application of previous treatment (T_4) caused significant increases in contents spinach leaves of N, P, K, in ppm compare (T_1) at 55 days after sowing. The improvement reached 32.10%, 1.49 % and 18.17% in the above-mentioned parameters, respectively.

Under NPK fertilizer (100 % recommended rates), there was no change in soil pH number, while there was decrease in EC value by 6.47%, available N (by 54.89%), P (by -6.29%), K (by 0.12%). On another side, there was increase for Mn by 1.41% respectively, while there was no change in soil available Cu as a result of different treatments that when compared the magnetized treatment (seeds and water; T_8) to un-magnetized spinach seeds and irrigated with un-treated water treatment (T_5). As well as, application of previous treatment (T_8) caused significant increases in contents spinach leaves of P, K, and decrease in available N content by 18.42%,0.85 and 19.06%, respectively compared to (T_5) at 55 days after sowing.

Data presented in Table (8) show those differences between magnetized and un-magnetized seeds, as well as differences between magnetized and un-magnetized saline water treatments according independent *t*-test. Regarding magnetized seed treatment, the magnetized seeds treatments significantly surpassed un-treated seed in available soil with N by -16.03%, P by 0.00%, K by -9.41%, Fe by 4.15%, Mn by 0.24%, Zn by 0.00% and Cu by 0.45% in ppm) and concentration of (N by -2.27%, P by -0.83% and K by -4.58% in ppm) in leaves of spinach at 55 days after sowing. While was increased pH number and decreased EC in soil by 2.09% and -2.15%, respectively.

Regarding magnetized water treatment, the magnetized water treatments significantly surpassed un-treated treatment in Soil pH number by 5.30%, available soil N decreased by 30.06%, P decreased by -15.00%, K decreased by -8.54%, and Cu increased by 3.20% in ppm at 55 days after sowing. While was decreased EC in soil by -18.54% and available soil Fe increased by -2.59%, Mn by 0.36% and Zn by 3.20% in ppm. Similar trends were recorded in the contents of NPK in Spanish leaves where it was decreased by 23.08, 0.42 and 12.46%, in the previous parameters, respectively.

Table (7). Influence of fertilization, magnetic and un-magmatic "seeds & salinity water" treatments on pH, EC, nutrition values of soil and plant of *Spinacia oleracea* at 15, 30, 45 and 55 days after sowing.

	Treatment	T1	T2	T3	T4	T5	T6	T7	T8	LSD 5%
		75% NPK				100NPK				
		Un-MW		MW		Un-MW		MW		
Parameter		Un-MS	MS	Un-MS	MS	Un-MS	MS	Un-MS	MS	
ph		7.00	6.80	7.90	7.50	6.95	6.95	7.40	7.40	**0.004**
EC (ds m^{-1})		5.00	6.00	4.80	4.20	4.50	4.78	3.90	3.60	**0.004**
Macro-elements in soil (ppm)	N	134.50	98.50	134.50	187.50	117.50	118.50	106.00	182.00	**7.263**
	P	0.87	0.73	0.65	0.66	0.86	0.75	0.59	0.80	**0.020**
	K	815.00	810.50	682.50	829.00	834.00	847.50	678.00	835.00	**14.56**
Micro-elements in soil (ppm)	Fe	4.27	4.07	4.52	4.09	4.20	4.43	4.10	3.82	**0.110**
	Mn	8.29	7.35	8.16	8.19	8.45	8.91	8.22	8.57	**0.012**
	Zn	0.77	0.73	0.64	0.71	0.70	0.70	0.70	0.64	**0.059**
	Cu	2.21	2.16	2.22	2.38	2.17	2.23	2.30	2.12	**0.031**
Macro-elements in plant (%)	N	0.41	0.39	0.47	0.54	0.38	0.41	0.48	0.45	**0.024**
	P	2.35	2.43	2.43	2.39	2.35	2.41	2.40	2.37	**0.012**
	K	3.06	3.33	3.58	3.61	3.07	3.37	3.60	3.66	**0.004**

Table (8): Effect of magnetized seeds or water on pH, EC, nutrition values of soil and plant of *Spinacia oleracea* at 15, 30, 45 and 55 days after sowing under 2500 salinity water stress.

	Treatment	Seed treatments		*t*-test	Water treatments		*t*-test
Character		Un-MS	MS		Un-MW	MW	
pH		7.16	7.31	NS	6.93	7.55	***
EC (ds m^{-1})		4.65	4.55	NS	5.07	4.13	***
Macro-elements in soil (ppm)	**N**	146.63	123.13	*	117.25	152.50	***
	P	0.74	0.74	NS	0.80	0.68	***
	K	830.50	752.38	***	826.75	756.13	***
Micro-elements in soil (ppm)	**Fe**	4.10	4.27	*	4.24	4.13	NS
	Mn	8.26	8.28	NS	8.25	8.28	NS
	Zn	0.70	0.70	NS	0.73	0.67	***
	Cu	2.22	2.23	NS	2.19	2.26	*
Macro-elements in plant (%)	**N**	0.44	0.43	NS	0.39	0.48	***
	P	2.40	2.38	NS	2.38	2.39	NS
	K	3.49	3.33	*	3.21	3.61	***

- Discussion:

This experiment demonstrated that, when compared to untreated plants, priming seeds in both magnetic saline water produced significant increases in all growth criteria at all stages of the spinach plants under study. The growth and improvements in fresh and dry weights of spinach plants can be attributed to the stimulatory effect of magnetic treatments, such as priming seeds in magnetized water or irrigating with magnetized saline water, which increase nutrient availability and, in turn, increase ions uptake and photosynthetic pigment contents. The same results are in good harmony with those obtained by **Shahin *et al*. (2016)** on cucumber**; Jasim *et al*. (2017)** on wheat and rice seedlings; **Alpsoy and Unal (2019),** on spinach and **Kataria *et al*. (2022)** on soybean plants. In this regard, **Elhindi *et al*. (2020)** concluded that, *Calendula officinalis* plants irrigated with magnetized water (MW) exhibited momentous augmentation in all vegetative and flowering growth parameters compared to plants irrigated with tap water. Additionally, mineral substances and survival of *C. officinalis* plants watered with MW treatments were greater than those watered with TW.

The application of MW significantly reduced the concentrations of Na+ and Cl-ions in plant leaves, indicating the function of magnetization in reducing the harmful effects of salt. According to **Nofal *et al*. (2021),** magnetic iron may also have a positive effect on plants under salinity stress since it promotes the uptake of N, P, K, and Fe, which stimulates plant development in addition to deterring it with the toxicity of Na+ and Cl- ions. Magnetized irrigation water has been shown to improve plant growth and progress on both a quality and quantity level **Alattar *et al*. (2022**). In addition to promoting seed germination and early vegetative growth in seedlings, magnetic water can also improve the mineral content of fruits and seeds, boost soil enzyme activity, improve water use efficiency, increase nutrient content, recover nutrient alteration and consumption competence, and reduce soil salinity. Additionally, the flexibility and uptake of vitamin concentrations were significantly improved by magnetized water, which also supported better growth criteria. Furthermore, compared to the control plants, **Selim *et al*. (2022)** reported that the use of magnetic technology in seawater irrigation was found to have positive effects on plant development, biochemical traits, water relations, and yield constituents. Treatment with magnetic seawater increased the percentage of wheat seeds that germinated by 13%.

The consumption of seawater up to 4800mg/l primarily treated with a magnetic device, as an alternative to tap water, is optional due to its aids to germination and seedling considerations, growth, yield, physiological, chemical, and anatomical characteristics. In addition, **Hozayn *et al.* (2022)** also summarized that irrigation with saline water passed through a magnetic device induced a positive significant effect in chickpea growth, pigments and physiochemical at 75 DAS.

The percentage of improvement reached 13.61-26.10% in morphological parameters, 9.64-12.35% in photosynthetic pigment contents and 8.35-23.03% in physiochemical parameters. They also concluded that, the application of magnetized water alleviates salinity water stress which resulted in the improvement of the growth of chickpeas under the Nubaria region.

Regarding the effect of seed priming in magnetized water on plant growth, **Rathod *et al*. (2016)** showed that, wheat seeds pretreated for 2 h with magneto-priming of static MF (50 mT) has the capability to rise in height, leaf area, dry weights, root growth parameters, rate of photosynthesis and chlorophyll content under non-saline and saline conditions. These may assist the plants to acclimate to salinity stress. Also, lesser Na^+/K^+ ratio in diverse wheat plant parts assisted in conveying tolerance to magneto-primed plants under salinity stress. **Kataria *et al*. (2017)** concluded that improved percentage germination and early seedling growth considerations (root and shoot length, and vigor indices) under different salinity levels (0–100 mM NaCl) specified that soaking in magnetic water was more operational in alleviating salinity stress at early seedling stage of both maize and soybean as compared to untreated seeds. **Hozayn *et al*. (2018)** decided that, the use of magneto-priming management could hunt or lessen the detrimental effects of salinity stress at the early seedling stage and field performance of barley plants. **Kataria *et al*. (2019)** reported that, pre-treatment with static magnetic field recompensed for the undesirable effects of salinity stress, accordingly soybean plants do not have to refract their metabolic energy in the detoxification of ROS formed under salt stress.

Thus, the use of magneto-priming technology could hunt or relieve the destructive effects of salinity stress at the field performance of soybean plants. It can be applied in agriculture to healthier grow and increase yield under antagonistic abiotic stress conditions. **Hozayn and Ahmed (2019)** suggested that, magneto priming of barley grains can improve germination characteristics and seedling growth under different salinity levels. **Hozayn *et al*. (2022)** explored that, significant increases were recorded with the application of different magneto-priming seed treatments compared to untreated (sowing dry seeds) in seed germination, germination rate, seedling length, seedling weight, seedling vigor-I and seedling vigor-II of Chickpea.

Recently, **Abhary and Akhkha (2023)** demonstrated that the seeds pretreated with magnetic technology exhibited a momentous rise in germination rate and speed, where the direction of the magnet was recognized as being decisive for germination rate and the orientation of seeds near the magnet was revealed to affect the germination speed. So, the pretreated plants presented greater growth characteristics, containing extended shoots and roots, bigger leaf area, additional root hairs, greater water content, and additional patience to salinity levels.

CONCLUSION

It could be concluded that treated spinach seeds with magnetic field by less recommended fertilization (75 or 100 %) with magnetic irrigation saline water technology treated and magnetized seeds improved vegetative growth, plant height fresh and dry plants and root growth as well as mineral composition content of spinach plants while reduced EC and pH value in soil extraction.

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