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Magnetic Treatment Of Salted Irrigation Water And Seeds: Its Effects On Vegetable Crop Yield And Nutrition Value Of Spinach (*Spinacia Oleracea* L*)*

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ABSTRACT

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), two magnetized water (Un-magnetized water (U-MW) and magnetized water (MW) under two levels of irrigation water salinity stresses (2500 and 5000 ppm) 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 or 5000 ppm) 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 seed 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 weight in gram) and total chlorophyl (spam) at the age of 15, 30, 45, and 55 days. The percent of improvement, ranged from 2.95 to 20.92% in leaves growth parameters, 8.80-20.45% in plant growth, 13.21-17.18% in root growth and 4.40-4.82% in total chlorophyl in leaves. Similar positive effects were recorded under magnetized water compared to untreated water treatments. Where the positive effects, ranged from 3.17 to 39.96% in leaves growth parameters, 3.88-24.81% in plant growth, 27.77-66.01% in root growth and 1.95-6.48% in total chlorophyl 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. Results also show that, the magnetized treatments (seeds and water; T_4) under 2500 or 5000 ppm salinity level significantly improved all the above-

mentioned parameters compared to untreated treatment (T_1) at 15, 30, 45 and 55 days. Under the conditions of this experiment, the results suggest applying irrigation with magnetized water and seeds can be recommended for reducing salinity stress which reflected in improvement productivity of spinach crops.

Keywords: *Magnetized water; Magnetized seeds; Salinity stress; Growth; Nutrition values; Spinacia Oleracea*

1- Introduction

Extreme changes in climate encouraged the appearance of dissimilar biotic and abiotic stresses. This effectuates the variations in morpho-physiological, and bio-molecular tasks in plants disturbing their development as well as crop yield [1]. Due to water scarcity and drought, unusual water fonts, such as brackish water, reused water, stormwater and seawater have been applied for irrigation in numerous parts of the world and for a multiplicity of aims, containing irrigating agricultural crops [2]. In several areas of the world, irrigation with saline water is an essential stress factor that deters the growth and yield of various crops [3].

Agriculture areas in Egypt are 100% watered since precipitation is very rare and evaporation is very high. The rigorous irrigation of cropland under an arid climate is the focal cause of secondary soil salinization in Egypt [4]. Salinity is one of the greatest widespread abiotic stresses disturbing crop growth and productivity, principally when soil and irrigation water are salty [5]. Saline soil leads to diminished soil richness, plant growth, plant productivity and lowered food security, particularly in arid and semiarid areas [6 & 7]. Recently, increasing soil salinity has been a main challenge in Egypt soil. Nearby 30 to 40% of the soils of the Nile Delta can be categorized as salt-affected. Sources of salinity in Egypt are assumed to be an outcome of the increase of salt in the upper soil layers due to unsuitable irrigation management and scanty drainage conditions, high water table levels, and seawater incursion, particularly in the coastal area of the Nile Delta, [8].

Resistance of crops to salinity is varied and encourages the requisite to do inquiries to record the ability of various plants to stand salinity and emanate the variations that might occur in their physiological activities under this condition [9]. Controlling the salinity of irrigation water through several applied techniques as management of water, hydraulic engineering, biological, chemical, and physical procedures and also via several inclusive processes are achieved successfully [10 & 11].

Water exposed to a magnetic field of a specific flow rate and intensity is called magnetic water, magnetized water, magnetic field-treated water or magnetically treated water [12]. All water properties, biophysical, chemical, physical, and physicochemical can change after being handled with a magnetic field. Water can have a significant role in regulating biological materials' reactions with magnetic fields. Water is the main medium in which miscellaneous reactions occur, so, exposure to magnetic fields could modify cellular metabolism by utilizing water as a basic magnetic field receptor [13]. Magnetic water varied in several properties as the activation energy, creation of hydrogen bonds, conductivity, dissolved gases, evaporation, mobility of salts, size of water molecules, structural regularity and surface tension as compared with non-magnetized water [14]. Magnetic water technique can be applied as a promising method to improve plant growth via enhanced absorption of important metals from wastewater [15]. Magnetic water irrigation technology avoided soil salinization. So, it has been applied to seep certain ions from the soil, as a promising tool [16]. Enhancing the agriculture sector through magnetic water treatment techniques has become one of the most widely used methods [17 & 18]. Modern technologies and practices used in agriculture with the water calamity inducing many countries, are significant for raising water efficiency. Conserving water and surpassing agricultural productivity and quality using magnetized water has been achieved [19].

Application of the magnetic water technique is commonly used in the field of agriculture as a prospective and eco-friendly new technology [20]. Treatment with magnetized water encourages valuable changes to its macro and micro chemical and physical characteristics. The activity of magnetized water (i.e., the aptitude of water to interrelate with other constituents, such as reaction rate, solubility, etc.) is clearly augmented [21], which is more considerable in ameliorating water availability and crop stress resistance [22]. Magnetic water irrigation improved soil water content by about 8.0% compared to non-magnetized water, it had greater soil water content after frequent irrigation as pronounced by [23]**.** Irrigation with magnetized water can contemplate the most appreciated recent technologies that can recover crop production and diminish the salinity of water and soil, and can contribute to thrift irrigation water [24]. In this regard, **Selim et al. [25]** explored that, treatment with magnetic water promoted the drought resistance of wheat and improved dry weight, total soluble sugar content, total water content, total free amino acids and proline by about 32%, 17%, 12%, 73%, and 27%, respectively.

Magnetic water treatment (MWT) removes the excess soluble salts; moderates pH values, via manipulating the soil salts, and seeps the salts away from the roots zone [26]. The magnetized saline water irrigation had an optimistic effect in decreasing soil salinity after the harvest of the plants. This treatment decreased the gain of relative change (%) of soil salinity, sodium adsorption ratio, Na^+, Cl^- and SO_2, and increased relative change (%) of Mg^{++}, Ca^{++} and K^+ in the soil extraction after gathering in magnetic usage of irrigation water, matched to irrigation with magnetized fresh water [27]. Magnetic water management is a remarkable research field because it is consuming zero energy [28] and has a great perspective as physical water management, which is additional environmentally friendly associated to chemical water treatment, which is not appropriate [29]. Also, MWT rise the fertilizers use efficiency, consequently, considerably improving the vegetative growth and yield considerations besides the macronutrient contents of wheat plants [30]. Magnetic usage of water can also diminish the surface tension coefficient and viscosity coefficient, which benefits in recovering the physical and chemical properties of water, such as conductivity, dissolved oxygen content, osmotic pressure, pH and wettability [28]. Numerous studies have explored the constructive effects on crop growth and yield irrigated with magnetically treated water [14, 31-35].

The seed priming process allows seed germination and seedling evolution to be upgraded under several hostile circumstances/containing salinity stress. Seed drenching is a pre-sowing approach, for inducing seedling progress, by controlling pre-germination metabolic activity previous to the beginning of the radicle and commonly augments germination rate and plant performance. Priming is the drenching of seeds in a solution, of any priming mediator followed by the drying of seeds that initiates, germination-related processes without radical emergence [36]. Drenching of seeds in solutions comprising diverse combinations, such as salts, metals, growth regulators or phytohormones enforced the germination to occur. This method is an exceptional method that promotes rapid and tedious germination, seed quality and seedling inception that enhance plant growth [37 &38]. Seed drenching has been documented as a prospective method of successful plant yield by rising plant forbearance to abiotic and biotic stresses [39, 40 & 35]**.** The other advantages of seed priming include harmonized and prompt germination, enriched water use efficiency, recovered nutrient uptake, a higher scope of germination temperature, and upgraded concomitant development of plants [40 & 41]. One of the main confront of today's plant production system is the aptitude to produce food products that encounter the needs of the growing global population in an environmentally sustainable way. In this connection, [42] proved that palliating the hazardous salinity effects via cost-effective seed priming procedures recovers the production of wheat under saline conditions. Hence, seed drenching can be the greatest and best-fit solution for more germination, growth, and plant production goods, particularly in opposing conditions [43 & 35].

Spinach (*Spinacia Oleracea*) is a main vegetable crop that is wealthy in beta carotene, vitamins A, C, E, and, K calcium, folic, iron, magnesium, oxalic acid, potassium, phosphorus, sulfur, sodium, and proteins, and secondary metabolites, which has antioxidant and stimulant structures [44]. Spinach leaves comprise a high concentration of oxalates and phytates [45]. In addition, *Spinacia oleracea* L. is an extensively used 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 [46]. It is a reasonably salt-tolerant glycophytic in the winter, but is sensitive to temperately sensitive if cultivated in the spring and summer seasons [47]. 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 [48, 47 & 49]. 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 [50]. 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} [49]. Moreover, **Ors and Suarez, [51] documented 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., [47]** 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 [52 & 53].
Consequently, the impartial goal of this research was to estimate spinach vegetative growth and yield parameters, after treatment of irrigation water and/or seeds with magnetic under diverse concentrations of salinity.

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 irrigation water salinity stresses (2500 and 5000 ppm) on seedling emergence, vegetative growth 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 levels of irrigation water in this study were equipped by adding measured amounts of NaCl salt to potable water to accomplish the required salinity levels (2500 ppm and 5000 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 was evaluated before treatments applying according to **Page et al., [54]** and are shown in Table 2.

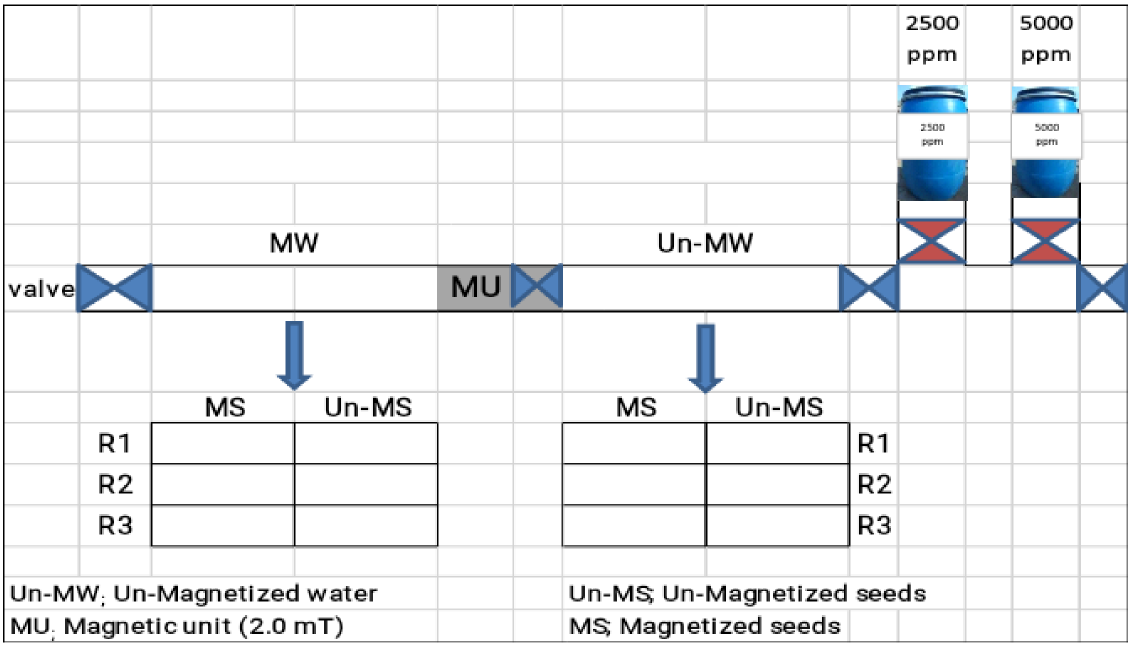

Fig 1. Layout of experimental treatment

Table 1. Description of experimental treatment

Treat. No.	Treatment description
T_1	Sowing un-magnetized seeds and irrigated with un-magnetized saline water (2500 ppm)
T_2	Sowing magnetized seeds and irrigated with un-magnetized saline water (2500 ppm)
T_3	Sowing un-magnetized seeds and irrigated with magnetized saline water (2500 ppm)
T_4	Sowing magnetized seeds and irrigated with magnetized saline water (2500 ppm)
T_5	Sowing un-magnetized seeds and irrigated with un-magnetized saline water (5000 ppm)
T_6	Sowing magnetized seeds and irrigated with un-magnetized saline water (5000 ppm)
T_7	Sowing un-magnetized seeds and irrigated with magnetized saline water (5000 ppm)
T_8	Sowing magnetized seeds and irrigated with magnetized saline water (5000 ppm)

Table 2: Some physical and chemical properties of investigated soil

Particle size distribution < 2mm (%)				pH (1:2.5)	ECe (ds/m) (1:2.5)	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	1	3.60	19.84	7.80	6.40	6.10	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 and potassium fertilizers were supplementary to the soil before sowing in the form of calcium super phosphate (15.5% P_2O_5) at the rates of 200g/pot, and potassium sulfate (48% K_2O) at the rates of 40g/pot, respectively and the nitrogen was also added in the form of ammonium sulfate (20.5% N) at the rates of 35g /pot in different doses. The irrigation planning scheme used in the study was to apply adequate water to bring the soil back to saturation and start to drain the little excess water at the end of each irrigation treatment.

Data recorded:

Growth parameters: During the experimental period of both seasons and at 15, 30, 45 and 55 days after sowing, ten plants were randomly chosen from each treatment to record plant height (cm), number of leaves per plants, leaf width and length (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 $^{\circ}$C 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 ($LSD_{5\%}$) 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.

3-Results

3.1. 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 magnetized saline water (2500 or 5000 ppm) 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 2500 ppm salinity level, the magnetized treatments (seeds and water; T_4) 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 0.0, 20.83, 16.33 and 16.67% in leaves numbers plant^{-1}; 30.37, 7.14, 28.55 and 25.65% in leave length (cm); 40.16, 27.45, 23.23 and 33.75% in leave width (cm) and reached 51.02 and 52,61% in Leaves Area (LA; cm^2) at 45 and 55 days after sowing, respectively.

Similar positive and significant trends were recorded under salinity water stress level (5000 ppm), 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 0.0, 33.33, 12.00 and 11.11% in leaves numbers plant^{-1}; 25.00, 19.27, 23.17 and 32.67% in leave length (cm); 32.67, 8.06, 43.60 and 26.14% in leave width (cm) and reached 80.97 and 37.96% 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 salinity levels.

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 all salinity levels 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 2.95 to 5.43% in leaves numbers $plant^{-1}$; from 8,61 to 10.89% in leave length (cm); from 7.94 to 15.92% in leave width (cm) and reached 14.91 and 20.92% 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 10.62 to 19.77% in leaves numbers $plant^{-1}$ from 3.17 to 16.96% in leave length (cm); from 9.20 to 19.23% in leave width (cm) and reached 39.96 and 19,03% in Leave Area (LA; cm^2) at 45 and 55 days after sowing, respectively.

3.2. 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 magnetized saline water (2500 or 5000 ppm) 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 chlorophyl in SPAD) at 15, 30, 45 and 55 days after sowing

Under 2500 ppm salinity level, the magnetized treatments (seeds and water, T_4) significantly improvement plant height (cm) by 25.56, 13.29, 40.36 and 25.50% 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 20.30, 26.63, 46.59, 77.05, 80.55 and 60.01%, respectively, at 55 days after sowing. Similar positive trends were recorded in total chlorophyll where the improvement reached 5.62, 6.52 and 8.05% at 30, 45 and 55 days after sowing respectively.

Similar positive and significant trends were recorded under salinity water stress level (5000 ppm), where the magnetized treatments (seeds and water; T_8) significantly improvement plant height (cm) by 21.11, 17.68, 24.96 and 28.00% 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 66.78, 104.35, 42.97, 70.68, 108.12, 95.52%, respectively, at 55 days after sowing. Similar positive trends were recorded in total chlorophyll where the improvement reached 16.96, 10.86 and 14.21% at 30, 45 and 55 days after sowing, respectively.

Data presented in table 6 show that 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 8.29 to 10.64% in plant height (cm), and reached 16.99, 20.54, 13.15, 17.27, 4.83 and 15.44% 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 4.83, 6.56 and 4.40% 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 6.15 to 20.25% plant height (cm) and reached 14.78, 24.82, 27.78, 48.12, 66.07 and 51.72% 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 5.88, 1.95 and 6.47% at 30, 45 and 55 days after sowing, respectively.

3-3.-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 2500 ppm salinity level, the magnetized treatment (seeds and water; T_4) significantly increased pH number (by 16.17%) and available concentration of some soil elements like N (by 81.89%), Fe (by 11.06%), Mn (by 18.99%) and Zn (by 10.19%) in ppm, while it was decreased of EC (by 30%) and available soil with P (by 17.41%) and K (by3.70%) 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 33.33%, 3.40 % and 19.64% in the above-mentioned parameters, respectively.

Under 5000 ppm salinity stress level, there was no change in soil pH number, while there was decrease in EC value by 16.36%, available N (by 22.4%), P (by 9.76%), K (by 16.21%). On another side, there was increase for Fe, Mn, and Zn by 16.83%, 0.47%, and 4.52% 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%,17.19 and 9.3% in ppm, respectively compared to (T_5) at 55 days after sowing.

Data presented in table 8 show that 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 by14.05%, P by 14.28%, K by 7.67%, Fe by 8.35%, Mn by 2.62%, Zn by 4.07% and Cu by 7.35% in ppm) and concentration of (N by 9.76%, P by 2.73% and K by 8.16% in ppm) in leaves of spinach at 55 days after sowing. While was increased pH number and decreased EC in soil by 2.05% and 14.73%, 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 0.41%, P decreased by 21.43%, K decreased by 16.36%, and Cu decreased by 9.45% in ppm at 55 days after sowing. While was decreased EC in soil by 10.38% and available soil Fe increased by 5.33%, Mn by 5.96% and Zn by 3.15% in ppm. Similar trends were recorded in the contents of NPK in Spanish leaves where it was decreased by 2.38, 6.48 and 9.64%, in the previous parameters, respectively.

4- Discussion:

Alterations in morphological and physiological patterns of plants, irrigation water and soil properties resulting from the application of different magnetic treatments are ultimately focused on the productivity of the tested crops. In this study, irrigation with magnetized salt water (2500 and 5000 mg/l) caused significant improvement in all growth parameters of spinach plants compared to either priming seeds with magnetic water or irrigation with untreated water treatment at all stages of growth. The results also cleared that, priming seeds in both magnetic saline water induced marked increases in all growth criteria at all studied stages of spinach plants as compared with untreated plants. These results may be attributed to the stimulatory role of magnetic treatments (priming of seeds in magnetized water or irrigation with magnetized saline water) in increasing the availability of nutrients consequently increasing mineral uptake and photosynthetic pigment contents which are reflected in the growth, fresh and dry weights improvements of spinach plant. The same results are in good harmony with those obtained by [61] on cucumber; [62] on wheat and rice seedlings; [63, 14 & 31] on wheat and alfalfa plants and [2] on spinach and [64] on soybean plants. In this regard, **Elhindi *et al*. [65]** 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.

Application of MW meaningfully lowered the levels of Na^+ and Cl^- ions in the leaves of plants demonstrating the role of magnetization in ameliorating the injurious effects of salinity. Also, **Nofal *et al*. [66]** postulated that, the optimistic effect of magnetic iron on the growth of plants suffering from salinity stress may be owing to its function in encouraging the uptake of N, P, K and Fe which rouses plant growth alongside the toxicity of Na+ and Cl- ions that deter it. Recently, **Alattar *et al*., [67]** revealed that, plant progression and progress can be enhanced on both levels of quality and quantity by using magnetized irrigation water. Magnetic water can encourage seed germination, seedling early vegetative expansion, enhancement of the mineral content in the fruits and seeds, stimulate the enzyme activity of the soil, increase water use efficiency, greater nutrient content and recover alteration and consumption competence of nutrients; it can also diminish soil salinity. Also, magnetized water had a considerable good impact on the flexibility and uptake of micronutrient concentrations, as well as endorsing healthier growth criteria. Moreover, **Selim *et al*., [3]** stated that, the application of magnetic technology on seawater for irrigation was established to have valuable effects on plant growth, biochemical characteristics, water relations, and yield constituents as compared to the control plants. Magnetic seawater treatment enhanced the germination % of wheat seeds 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.* [35]** 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, [68] 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. [69]** 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. [39]** 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. [70]** 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 & Ahmed [40]** suggested that, magneto priming of barley grains can improve germination characteristics and seedling growth under different salinity levels. **Hozayn *et al*. [35]** 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 & Akhkha [71]** 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.

5-Conclusion

Under the conditions of this experiment, the results suggest applying irrigation with MW and MS-MW can be recommended for spinach crops to reduce salinity stress, as well as produce the best quality, highest yield of fresh weight. Magneto-priming treatment could hunt or alleviate the destructive effects of salinity stress under field conditions and enhance growth features, containing extended shoots and roots, more leaf area, additional root hairs, greater water content, and the plants becoming further tolerant to salinity intensities.

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Table 3. Effect of magnetized (seeds and water) under different salinity stresses on leaves growth characters of *Spinacia oleracea* at 15, 30, 45 and 55 days after sowing (DAS).

Treatment		T1	T2	T3	T4	T5	T6	T7	T8	LSD 5%
		2500 ppm				5000 ppm				
		Un-MW		MW		Un-MW		MW		
Parameter		**Un-MS**	**MS**	**Un-MS**	**MS**	**Un-MS**	**MS**	**Un-MS**	**MS**	
Leave (s) 15 DAS	**Number; 15DAS**	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	**ns**
	length (cm)	7.13	7.25	8.67	9.30	6.00	7.03	6.60	7.50	**0.46**
	Width (cm)	2.03	2.32	2.62	2.85	1.93	2.38	2.30	2.57	**0.13**
Leave (s) 30 DAS	**Number**	8.00	8.67	8.67	9.67	6.00	6.00	8.00	8.00	**0.79**
	length (cm)	12.13	14.07	11.97	13.00	8.73	9.17	10.12	10.42	**0.42**
	Width (cm)	3.40	4.02	4.22	4.33	3.10	3.25	3.13	3.35	**0.44**
Leave (s) 45 DAS	**Number**	10.33	10.33	12.00	12.00	8.33	8.67	8.33	9.33	**1.00**
	length (cm)	13.95	16.83	16.98	17.93	10.37	12.05	12.43	12.77	**1.03**
	Width (cm)	4.23	4.83	4.57	5.22	3.28	3.75	4.10	4.72	**0.51**
	Leave Area (cm^2)	22.82	29.73	32.84	34.46	14.49	15.54	22.05	26.22	**2.65**
Leave (s) 55 DAS	**Number**	12.00	12.67	14.00	14.00	9.00	9.67	10.00	10.00	**0.97**
	length (cm)	15.92	17.90	18.68	20.00	11.55	12.83	13.52	15.33	**1.03**
	Width (cm)	4.62	5.77	5.02	6.18	4.02	4.17	4.62	5.07	**0.51**
	Leave Area (cm^2)	27.82	38.10	35.70	42.45	22.83	28.43	29.83	31.50	**4.49**

Table 4. Magnetized seeds or water versus corresponding control on leaves growth characters of *Spinacia oleracea* at 15, 30, 45 and 55 days after sowing (DAS) under different salinity stresses.

Treatment Parameter		Seed treatments		*t*-test	Water treatments		*t*-test
		Un-MS	MS		Un-MW	MW	
Leave (s) 15 DAS	Number	6.00	6.00	ns	6.00	6.00	ns
	length (cm)	7.10	7.77	*	6.85	8.02	**
	Width (cm)	2.22	2.53	*	2.17	2.58	*
Leave (s) 30 DAS	Number	7.67	8.08	*	7.17	8.58	**
	length (cm)	10.74	11.66	*	11.03	11.38	*
	Width (cm)	3.46	3.74	*	3.44	3.76	*
Leave (s) 45 DAS	Number	9.75	10.08	*	9.42	10.42	*
	length (cm)	13.43	14.90	*	13.30	15.03	**
	Width (cm)	4.05	4.63	*	4.02	4.65	*
	Leave Area (cm^2)	23.05	26.49	**	20.64	28.89	**
Leave (s) 55 DAS	Number	11.25	11.58	*	10.83	12.00	**
	length (cm)	14.92	16.52	*	14.55	16.88	**
	Width (cm)	4.57	5.29	*	4.64	5.22	*
	Leave Area (cm^2)	29.05	35.12	**	29.30	34.87	**

Table 5. Effect of magnetized seeds and water under salinity stresses on plant growth characters and total chlorophyll content of *Spinacia oleracea* at 15, 30, 45 and 55 days after sowing (DAS).

Treatment		T1	T2	T3	T4	T5	T6	T7	T8	LSD 5%
		2500 ppm				5000 ppm				
		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)	8.10	8.18	9.50	10.17	6.87	8.15	7.53	8.32	**0.67**
	Plant height (cm; 30DAS)	13.02	14.91	14.42	14.75	9.73	11.13	11.07	11.45	**0.68**
	Plant height (cm; 45DAS)	13.75	16.78	18.05	19.30	11.22	12.18	13.48	14.02	**1.15**
	Plant height (cm; 55DAS)	16.55	18.62	19.12	20.77	12.25	13.57	14.13	15.68	**1.17**
	Plant fresh wt. (g; 55DAS)	265.22	287.83	286.50	319.05	108.22	137.03	130.23	180.49	**31.85**
	Plant dry wt. (g; 55DAS)	20.73	22.30	21.90	26.25	8.05	9.86	11.45	16.45	**1.77**
Root characters at 55 DAS	Roo length (cm)	9.98	11.65	13.81	14.63	8.61	9.63	10.19	12.31	**0.96**
	Root Width (cm)	8.19	9.52	13.69	14.50	6.31	7.83	8.19	10.77	**1.28**
	Root fresh wt. (g)	6.58	7.89	10.56	11.88	6.65	8.13	12.27	13.84	**1.60**
	Root dry wt. (g)	1.42	1.78	2.21	2.40	0.67	0.78	1.13	1.31	**0.28**
Total chlorophyll (SPAD)	at 30 DAS	48.54	49.77	50.52	51.27	45.23	50.01	50.28	52.90	**3.26**
	at 45 DAS	58.13	60.73	57.22	61.92	54.53	58.79	57.11	60.45	**3.27**
	at 55 DAS	60.64	61.90	63.23	65.52	59.90	62.49	63.65	68.41	**2.03**

Table 6. Magnetized seeds or water versus corresponding control on plant and root growth characters of *Spinacia oleracea* at 15, 30, 45 and 55 days after sowing (DAS).

Treatment Character		Seed treatments		*t*-test	Water treatments		*t*-test
		Un-MS	MS		Un-MW	MW	
Plant growth	Plant height (cm; 15DAS)	8.00	8.70	*	7.83	8.88	*
	Plant height (cm; 30DAS)	12.06	13.06	*	12.20	12.95	*
	Plant height (cm; 45DAS)	14.13	15.57	*	13.48	16.21	**
	Plant height (cm; 55DAS)	15.51	17.16	**	15.25	17.47	**
	Plant fresh wt. (g; 55DAS)	197.54	231.10	**	199.57	229.07	**
	Plant dry wt. (g; 55DAS)	15.53	18.72	**	15.23	19.01	**
Root growth at 55 DAS	Root length (cm)	10.65	12.05	**	9.97	12.73	**
	Root Width (cm)	9.09	10.66	**	7.96	11.79	**
	Root fresh wt. (g)	9.02	10.43	**	7.31	12.14	**
	Root dry wt. (g)	1.36	1.57	**	1.16	1.76	**

Total chlorophyll (Spad)	**at 30 DAS**	48.64	50.99	**	48.39	51.24	**
	at 45 DAS	56.75	60.47	**	58.05	59.18	**
	at 55 DAS	61.86	64.58	**	61.24	65.20	**

Table7. Effect of magnetized seeds and water under salinity stresses on pH, EC, nutrition values of soil and plant (*Spinacia oleracea*) at 55 days after sowing (DAS).

Treatment		**T1**	**T2**	**T3**	**T4**	**T5**	**T6**	**T7**	**T8**	**LSD 5%**
		2500 ppm				**5000 ppm**				
		Un-MW		**MW**		**Un-MW**		**MW**		
Parameter		**Un-MS**	**MS**	**Un-MS**	**MS**	**Un-MS**	**MS**	**Un-MS**	**MS**	
pH		6.80	7.00	7.50	7.90	7.40	7.50	7.40	7.40	**0.002**
EC (ds m^{-1})		6.00	5.00	4.80	4.20	5.50	4.70	5.40	4.60	**0.002**
Macro-elements in soil (ppm)	**N**	98.50	134.50	142.83	179.17	187.50	189.00	139.50	145.50	**12.90**
	P	0.73	0.87	0.65	0.66	0.82	0.93	0.58	0.74	**0.010**
	K	810.50	815.00	731.00	780.50	801.50	913.50	611.00	671.50	**56.70**
Micro-elements in soil (ppm)	**Fe**	4.07	4.27	4.09	4.52	3.98	4.18	4.13	4.65	**0.15**
	Mn	6.90	7.28	8.14	8.21	8.56	8.77	8.44	8.60	**0.002**
	Zn	2.16	2.21	2.23	2.38	2.21	2.28	2.24	2.31	**0.007**
	Cu	0.73	0.77	0.66	0.69	0.73	0.72	0.59	0.73	**0.05**
Macro-elements in plant (%)	**N**	0.39	0.40	0.48	0.52	0.43	0.48	0.33	0.39	**0.021**
	P	2.35	2.44	2.39	2.43	1.90	1.95	2.15	2.25	**0.007**
	K	3.06	3.33	3.53	3.66	2.21	2.62	2.50	2.59	**0.002**

Table 8. Magnetized seeds or water versus corresponding control on pH, EC, nutrition value of soil and plant characters of *Spinacia oleracea* at 55 days after sowing (DAS).

Treatment		**Seed treatments**		***t*-test**	**Water treatments**		***t*-test**
Character		**Un-MS**	**MS**		**Un-MW**	**MW**	
pH		7.30	7.45	ns	7.18	7.55	*
EC (ds m^{-1})		5.43	4.63	ns	5.30	4.75	*
Macro-elements in soil (ppm)	**N**	142.08	162.04	*	152.38	151.75	*
	P	0.70	0.80	*	0.84	0.66	*
	K	738.50	795.13	**	835.13	698.50	**
Micro- elements in soil (ppm)	**Fe**	4.07	4.41	*	4.13	4.35	**
	Mn	8.01	8.22	ns	7.88	8.35	*
	Zn	2.21	2.30	ns	2.22	2.29	ns
	Cu	0.68	0.73	ns	0.74	0.67	ns
Macro-elements in plant (%)	**N**	0.41	0.45	ns	0.42	0.43	ns
	P	2.20	2.26	ns	2.16	2.30	*
	K	2.82	3.05	*	2.80	3.07	*

الملخص العربي

في تجربة أصص أجريتْ في مركز قلين، محافظة كفر الشيخ، جمهورية مصر العربية تحت الظروف الطبيعيةِ للصوبة الزجاجية أثناء فصل الشتاء لعامين 2021/2020 و2022/2021. وكانت التجربةُ تهدف لتقييم تأثير معالجةِ بذور نبات السبانخ باستخدام تكنولوجيا المعالجة المغناطيسية (بذور غير مُمَغنَطة، وبذور ممغنطة)، وأيضا تحت نوعيين من ماء الري (ماء ري ممغنط ،وماء غير ممغنط) تحت إثنان مِنْ مستويات الملوحة لماء الري (2500 و5000 جزء في المليون) على انبات الذور، النمو الخضري وإنتاجية نباتاتِ السبانخ. وشملت كل معاملة من المعاملات الثمانية تحت الدراسة على ثلاث مكررات وضعت في تصميم عشوائي تام. أظهرت النتائج أن أصص السبانخ المروية بماء ملحي معالج بتكنولوجيا المعالجة المغنطيسية سواء بتركيز (2500 جزء في المليون) أو (5000 جزء في المليون) ذات تأثير معنوي من الناحية الأحصائية أفضل من البذور المروية بالماء العادي (الغير ممغنط) وذلك في الفترات المختلفة من عمر النبات 15، 30، 45 ، 55 يوم على الترتيب. وبخصوص معاملة البذورة الممغنطة كانت معاملات البذور الممغنطة أعلى إحصائيا ومعنويا من البذور الغير ممغنطة في جميع خصائص نمو الأوراق المسجلة مثل (عدد الأوراق (نبات)، طول وعرض الورقة (سم)، ومساحة الورقة (سم2)، خصائص نمو النبات مثل (ارتفاع النبات (سم)، الوزن الطازج والجاف للنبات (جم)، خصائص نمو الجذور (طول وعرض الجذر (سم)، الوزن الطازج والجاف للجذر (جم) والكلوروفيلات الكلية وذلك عند عمر 15، 30، 45 و 55 يوم على التوالي، وكانت نسبة الزيادة للنمو تتراوح ما بين 2.95 & إلى 20.92 % في خصائص نمو الأوراق، و 8.80 إلى 20.45 % في خصائص نمو النبات، 13.21 إلى 17.18 % في خصائص نمو الجذور و 4.40 إلى 4.82 % للكوروفيلات الكلية في الأوراق. وعندما نقارن التأثيرات الإيجابية المسجلة تحت ظروف الري الممغنط ومقارنته بمعاملات الري الغير ممغنط يتضح الأتي: حيث أن التأثيرات الإيجابية تتروح النسبة من 3.17 % إلى 39.96 % لصفات نمو الأوراق، 3.88 إلى24.81 % لصفات نمو النبات، 27.77 إلى 66.01% لصفات نمو الجذر، 1.95 إلى 6.48% للكلوروفيلات الكلية في الأوراقِ وذلك عند عمر 15، 30، 45، 55 يوم على الترتيب. بالإضافة إلى كلا العاملين (مغنطة البذور والماء) كان لهما تأثير إيجابي على قيمة التغذيةِ

لأوراقِ السبانخِ. أظهرت النتائج أيضا أن معاملات المعالجة بتكنولوجيا المغنطة (بذور أو ماء؛ المعاملة 4) تحت مستويين هما (2500 أو 5000 جزء في المليون) حَسّنَت من جميع الخصائص المذكورة سابقا إذا ما قورنت بمعاملة المقارنة (الكنترول) (معاملة 1) وذلك عند 30،15، 45، 55 يوم على التوالي. تحت ظروف نفس التجربة ومن خلال النتائج المذكورة يمكن أن نوصى بزراعة وري نبات السبانخ باستخدام بذور وماء ري معالج مغناطيسيا وذلك لتقليل اثر الإجهاد الملحي لماء الري حيث كان هناك تأثير أيجابي في تحسينِ إنتاجية محصول السبانخِ تحت ظروف نفس الدراسة.