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Applications of Magnetic Technology in Agriculture, A Novel Tool for Improving Water and Crop Productivity: 4. Lentil

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Abstract: In Egypt, the cultivated area of lentil crop is decreasing due to competition from other winter crops, especially wheat and clover. Hence, improving its productivity from unit area is essential either with traditional and/or untraditional treatments. Magnetic treatment is considered one of uncommon factor which has positive effects on yield of many crops. Two field trials using Lentil (var. Giza-9) were conducted at Research and Production Station, National Research Centre, Alemam Malek village, Al Nubaria district, Behaira Governorate, Egypt during 2009/10 and 2010/11 winter seasons to study and evaluate the effects of magnetizing irrigation water on water and lentil productivity. Results indicated that, irrigation lentil plants with water passed through magnetic device (2 inch, production by Magnetic Technologies L.C.C., Russia, branch United Arab Emirates) induced positive significant effect on all studied parameters i.e., growth, pigments, yield, yield components, macro and micro elements and amino acids in the yielded seeds and water productivity (WP) compared to irrigation with normal water. The percent of increase in seed, straw and biological yields per feddan (feddan=4200 m^2 i.e.0.42ha) were 25.50, 43.51 and 37.30%, respectively compared with normal water (average over both seasons). Magnetic water treatment could be used to improve water and lentil crop productivity under newly reclaimed sand soil condition.

Key words: Magnetized water · Lentil yield · Nutrition value · Amino acids · Water productivity.

INTRODUCTION

Lentil (*Lens culinaris* Medik.) is cultivated in as many as 52 countries across the world with an area and production of 4.4 million ha and 4.9 million t during 2013, respectively [1]. In Egypt, it is cultivated on 600 ha area with production and productivity of 1300 and 2.17 t ha^{-1} during 2013, respectively [1]. Lentil and others pulses crops especially Faba bean, Chickpea, Pigeon pea constitute the major component of low-input agriculture in the semi-arid tropics, including Egypt. These crops play an important role in alleviating malnutrition by way of forming an inseparable component to the dietary proteins for millions of peoples living below poverty line in these regions. In Egypt, lentil also share other pulses crops especially Faba bean and chick-pea as a main sources of protein for a large sector of Egyptian people. Their annual domestically is insufficient to meet demand, which necessitates the import of substantial amount, especially in recent years, to meet the rapidly increasing population and rise in price of animal protein. Moreover, the area planted of lentil crop is decreasing due to competition from other winter crops, especially wheat and clover. Moreover, its yield is generally poor and unstable from year to year especially under newly reclaimed soil. So, agriculture researchers take an interest not traditional agricultural practices i.e. cultivation methods, fertilizers, weed control, etc. but also un-conmen factors that improvement productivity from unit area like magnetic and magnetic water treatment.

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Several studies reported that magnetic or magnetic water treatments have been a positive effect on the germination of seeds, plant growth and development, the ripening, yield and quality of different crops [2-11]. In addition, many authors have established the positive influence of the stationary magnetic field on the plant seeds. The treatment fastens plants development [12-13], improves germination and seedling growth [14-15], activates protein formation and enzymes activity [16-17], induces cell metabolism and mitosis meristematic cells of pea, lentil, onion and flax [18-19], improvement photosynthetic pigments [3-6; 9]. Also, the investigations have shown that the treatment of the seeds with magnetic field increases the germination of nonstandard seeds and improves their quality [19-20].

Generally the positive and promising results which obtained under laboratory and pots experiments led to numerous of researchers to test application of magnetic water treatments under filed condition. In abroad, application of magnetic water treatment, variable electro and static magnetic fields with different frequency in a macro trial with potato showed a yield increase up to 144.8% in potato [21], pepper by 64.9% [22], soybean from 5 to 25%, with a higher quantity of oil and protein and at sunflower from 13.2 to 17.3% [23], wheat by 6.3 – 10.6% [24], broad bean and pea by 10 and 15%, respectively [25], rice by 13-23% [26]. In addition, [27] shows a 94% increase of the root mass of sugar beet, leaf surface up to 52%, yield to 12.88 t/ha and the percentage of sugar was increased for 0.70%. In similar trials performed with corn a higher root mass (55%), vegetative mass (57%) and yield (18.70%) was achieved. De-Souza *et al*. (2006) [28] showed that magnetic treatments on tomato increased significantly the mean fruit weight; the fruit yield per plant; the fruit yield per area and the equatorial diameter of fruits in comparison with the controls. Similar positive trend were obtained under Egyptian conditions by [8-9; 29] where reported that the percent of increase in economic yield (ton ha^{-1}) in response to magnetized water application reached to 13.71% at wheat, 8.25% at faba bean, 21.8% at chick pea, 36.02% at canola, 22.37% at flax, potato at 33.12% and 19.05% at sugar beet crop as compared with normal water application. In this work we study the impact of magnetic water on lentil crop productivity in newly reclaimed sandy soil.

MATERIALS AND METHODS

Two field trials using lentil (var. Giza-9) were conducted at Research and Production Station, National Research Centre, Alemam Malek village, El-Nubaria district, Behaira Governorate, Egypt during 2009/10 and 2010/11 winter seasons to study and evaluate the effects of irrigation with magnetized water on growth, chemical constituent and Lentil yield and its components. The experimental soil and water were analyzed according to the method described by [30] (Table 1).

Cultivation Method and Layout of Experiment: Seeds of the lentil crop were obtained from Legume Research Department, Field Crop Research Institute, Agricultural Research Centre, Giza, Egypt. Recommended rates of lentil seeds were planted in plots (10 length m x 12 width m) at the first week of November in both seasons. Control treatment was irrigated with normal water, while the other treatment (magnetized water) was irrigated with water after magnetization through passing a two inch Magnetic device [U.T.3, Magnetic Technologies LLC PO Box 27559, Dubai, UAE]. Four replications were used in each treatment. The recommended NPK fertilizers for Lentil crop were applied through the period of experiment. Sprinkler irrigation was applied as plants needed. The layout of experiment is shown in (Fig. 1).

Table 1: Soil and water analysis for site experiments.

Parameters	Soil depth 0-15	Soil depth 15-30	Irrigation water Before magnetic	Irrigation water After magnetic
Particle size distribution				
Coarse sand	48.2	54.75	..	…
Fine sand	49.11	41.43	..	…
Clay + Silt	2.69	3.82	..	…
Texture	Sandy	Sandy	..	…
pH (1:2.5)	8.22	7.94	7.25	7.13
EC(dSm^{-1})(1:5)	0.20	0.15	0.50	0.40
Organic matter (%)	0.67	0.43	…	
Soluble cations (meq/l)				
Ca^{++}	0.60	0.50	2.15	2.05
Mg^{++}	0.50	0.30	0.50	0.65
Na^{++}	0.90	0.80	3.00	3.0
K^{+}	0.20	0.10	0.31	0.31
Soluble anions (meq/l)				
CO_3^{-}	-	-	0.01	0.01
HCO_3^{-}	0.60	0.40	2.33	2.46
Cl^{-}	0.75	0.70	2.17	1.72
SO_4^{-}	0.85	0.60	1.45	1.82

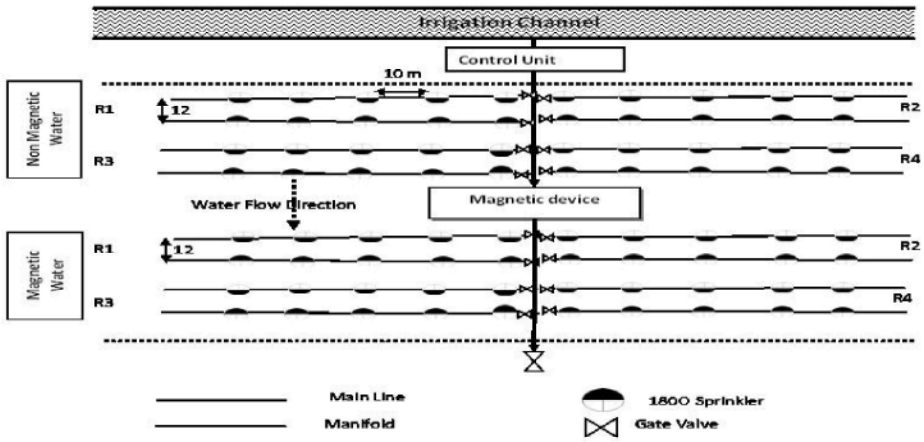

Fig. 1: Layout of experiment design under solid set sprinkler system.

Data Recorded: Growth parameters: After 85 days from sowing plant height, fresh and oven dry weight of 10 plants from each treatment were determined. Water content was determined according to [31] Henson *et al*. (1981) using the following formula: WC = 100×(fresh mass – dry mass)/fresh mass.

Photosynthetic Pigments: Total chlorophyll a and b and carotenoids contents in fresh leaves were estimated using the method of [32]. The fresh tissue was ground in a mortar and pestles using 80% acetone. The optical density (OD) of the solution was recorded at 662 and 645 nm (for chlorophyll a and b, respectively) and 470 nm (for carotenoids) using a spectrophotometer (Shimadzu UV-1700, Tokyo, Japan). The values of photosynthetic pigments were expressed in mg/100g FW.

Lentil Yield And Its Components: At harvest stage, 20 plants were selected randomly to determined lentil yield components. The whole plot was harvested to determine the above ground biomass (biological yield), pods were threshed to determine seed yield, straw yield was calculated by subtracting seed yield from biological yield.

Water Productivity (WP): Water productivity (WP) values were calculated with the fowling Eqs: WUE =[(E_y/E_t], [33]. Where WP is the water productivity (kg $_{seeds}$/m^3); Ey is the economical yield (kg $_{seeds}$/fed. /season); Et is the total applied of irrigation water, m^3/fed./season.

Nutritional Value In Yielded Seeds: Macro (N, P, K, Ca and Mg) and microelement (Fe, Mn, Zn and Cu) contents in dried seeds were determined. Total N was determined by using micro-Kjeldahl method as described in [34]. Phosphorus was determined using a Spekol spectrocolorimeter (VEB Carl Zeiss; Jena, Germany, while, estimation of K^+ contents were done using a flame photometer. Mg, Fe, Mn, Zn and Cu were determined using the Atomic absorption spectrophotometer (Perkin Elemer 100 B).

Free Amino Acids: Amino acids compositions of lentil protein were analyzed by hydrolysis according to Catalog of amino acid analyzer (1999) LC 3000 as follow: 50 mg of dry powdered of wheat shoot was put into hydrolysis tube that containing 10 ml of HCl (6 N). The tube was closed (by melting the glass with a suitable gas- burner). The tube was put in an oven at 110°C for 72 hours and then cooled down in an ice- bath. The solution was centrifuged (4000 rpm for 5 min) and the supernatant collected and evaporated in a rotary evaporator at 40°C. The residues was dissolved in 1- 2 ml distilled water and evaporated near dryness to remove traces of acid. The amino acid was determined with an Eppendorff - Germany LC 300 analyzer. The flow rate 0.2 ml/min, pressure of buffer, from 0.0 to 50 bar, pressure of reagent from 0.0 to 150 bar and reaction temperature 123°C.

Statistical Analysis: Statistical analysis was carried out using SPSS program Version 16 [35]. T-test (Independent *t*-test) was also carried out to find the significant differences between magnetic and nonmagnetic water treatments.

RESULTS AND DISCUSSIONS

Lentil Growth: The results presented in Table 2 indicated that irrigation of lentil plants with magnetic water induced high significant increases in plant height, fresh and dry weight per plant as compared with plants irrigated with normal water. The percent of increase over control reached to 23.52%, 19.72% and 17.39% in the abovementioned parameters, respectively. This increment may be attributed to the overall increase in plant growth induced by magnetic treatment through increases in photosynthetic pigments (Table 3); minerals (Table 4) and amino acids (Table 5). These results are in good harmony with those obtained by [36], they found that in studied paulownia tissue cultures and showed the positive effect of magnetic field on regeneration percentage. Also, [37] suggested that, magnetic water treatment improved seed vigor and germination rate and seedling treatment promoted NPK absorption and increased root no, stem thickness, dry weight/100 plants and tillers number. Moreover, [38] concluded that, magnetized water increased growth and consider an important factor for inducing chick pea plant growth. In this connection, [9] concluded that, the stimulatory effect of MW on growth criteria may be also attributed to the increase in photosynthetic pigment, endogenous promoters (IAA), total phenols and increase in protein biosynthesis in some crops.

Photosynthetic Pigments: Data in Fig. 2 show that, irrigation of lentil plants with magnetized water showed an increase in photosynthetic pigments content with variation in significant results ranged between significant to high significant increments as compared with control plants irrigated with normal water. The percent of increase recorded as follows 10.09% for Chl a, 8.24% for Chl b, 18.10% for carotenoids, 9.68% for Chl a + Cl b and 2.52% for Chl a/Chl b. The increase in photosynthetic pigments in this study may be due to the increase in N and Mg (Table 4) which have an essential role in chlorophyll biosynthesis. It also may be attributed to the increase in some amino acids (arginine and methionine) responsible on increasing production of endogenous phytohormones as auxins & cytokinins and endogenous polyamines which have an indirect role in improving plant metabolism. These results are in good agreement with those obtained by [39], who suggested that, increase all photosynthetic pigments through the increase in cytokinin synthesis which induced by MF. They also added cytokinin play an important role on chloroplast development, shoot formation, axillary bud growth and induction of number of genes involved in chloroplast development nutrient metabolism. They also added that, the increase in shoot regeneration, chloroplast rate, root formation and fresh weight were accompanied by the increase in auxin synthesis which induced by MF treatment of soybean plants. Also, [38] concluded that, MF stimulates protein synthesis via increase cytokinins and auxins and they can promote the maturation of chloroplast. Moreover, magnetic fields are known to induce biochemical changes and could be used as a stimulator for growth related reactions including affecting photosynthetic pigments [40]. In this regard [9] concluded that, the increase in photosynthetic pigments in some crops may be due to the effect of MT on alteration the key of cellular processes such as gene transcription which play an important role in altering cellular processes consequenly the increase in growth promoters.

Lentil Yield And Its Components: The results presented in Table 3 recorded the yield and yield components of lentil after irrigation with magnetized water. Generally irrigation with magnetized water induced high significant increases in most studied parameters (plant height, pods weight, seeds number and weight, biological yield /plant, 100-seed weight, seed, straw and biological yield/fed) as compared with control plant irrigated with normal water. The percent of increases ranged between 9.02 to 42.11% for yield components and reached to 25.81, 37.33 and 43.1 for seed, straw and biological yield respectively. The obvious significant increases in yield attributes of lentil seeds in this study may be attributed to the stimulatory effects of MW on different parameters as), increasing plant growth (Table 2), photosynthetic pigments (Table 3) and macro & microelements (Table 4). These results are in

Table 2: Effect of irrigation with magnetized and normal water on lentil growth at 85 days after sowing (average of 2009/10 and 2010/2011 seasons).

Treatment / Character	Mean ± SE: Normal water (control)	Magnetic water	*t*-test	Increase % over control
Plant height (cm)	33.00 ± 0.27	40.76 ± 1.33	***	23.52
Fresh weight (g plant $^{-1}$)	2.13 ± 0.02	2.55 ± 0.06	***	19.72
Dry weight (g plant^{-1})	0.46 ± 0.02	0.54 ± 0.02	*	17.39
Water contents (%)	78.28 ± 0.99	78.89 ± 0.77	ns	0.78

N=8, *, ***, *t* is significant at the $P > 0.05$ and 0.001 levels, respectively, ns: non significant

Table 3: Effect of irrigation with magnetized and normal water on lentil yield (ton fed^{-1}) and its components at harvest and water productivity (Kg $_{seed}$/m ^{3} water). (Average of 2009/10 and 2010/11 seasons).

Treatment / Character	Mean ± SE: Normal water (control)	Magnetic water	*t* test	Increases over control (%)
Plant height (cm)	36.61 ± 0.46	44.50 ± 1.28	***	21.55
Pods weight (g $plant^{-1}$)	0.32 ± 0.02	0.41 ± 0.02	**	28.13
Seed (number $plant^{-1}$)	7.54 ± 0.21	9.67 ± 0.37	***	28.25
Seed weight (g plant $^{-1}$)	0.19 ± 0.01	0.27 ± 0.01	***	42.11
Straw weight (g plant $^{-1}$)	0.36 ± 0.02	0.41 ± 0.02	ns	13.89
Biological weight (g plant $^{-1}$)	0.56 ± 0.02	0.66 ± 0.02	**	17.86
100-seed weight (g)	2.55 ± 0.04	2.78 ± 0.03	***	9.02
Seed yield (ton fed $^{-1}$)	0.62 ± 0.02	0.78 ± 0.03	***	25.81
Straw yield (ton fed $^{-1}$)	1.54 ± 0.04	2.21 ± 0.06	***	43.51
Biological yield (ton fed $^{-1}$)	2.17 ± 0.04	2.98 ± 0.05	***	37.33
Water productivity (Kg seed/m^3 water)	0.33 ± 0.01	0.44 ± 0.01	***	12.76

N=8, *, **, *** *t* is significant at the $P > 0.05$, 0.01and 0.001 levels, respectively, ns: non significant

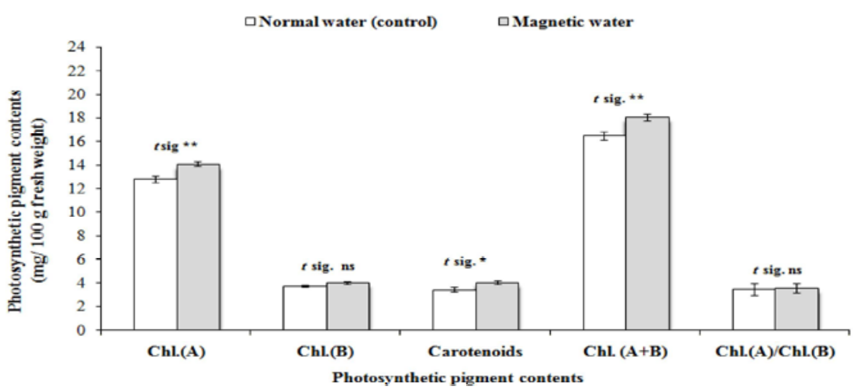

Fig. 2: Effect of irrigation with magnetized and normal water on photosynthetic pigment contents in lentil shoot at 85 days after sowing. (Average of 2009/10 and 2010/2011 seasons). N=8, *, **, *t* is significant at the $P > 0.05$ and 0.01 levels, respectively, ns: non significant

good harmony with those obtained by [9], who described that, the stimulatory effect of magnetic treatment may be attributed to their role in increasing growth, photosynthetic pigment and growth promoters consequently increasing yield characters. Also, [24] found that, the exposure of green tops and root systems of wheat plant to MF increased quantity of coarse grain by 10.6% and 6.3%, respectively. In this connection, [25,41] suggested that, the gain in seed yield resulting from the pre-sowing treatment of seeds with MF for broad bean and pea was due to the higher number of pods per plant and the fewer plant losses in the unit area in the growing season. Moreover, [28] showed that, MT on tomato increased significantly the mean fruit weight, the fruit yield/plant, the fruit yield per area and the equatorial diameter of fruits in comparison with the controls. Moreover, MF was shown to induce fruit yield per plant and average fruit weight [38]. Exposure of plants to MW is highly effective in enhancing growth characteristics. This observation suggests that there may be resonance-like phenomena which increase the internal energy of the seed that occurs. Therefore, it may be possible to get higher yield [42- 43] on chickpea and lentil respectively.

Water Productivity (WP): Data presented in Table 3 also cleared that the water productivity of magnetized water induced significant increase as compared with normal water. These results may be due to the mini changes occurred in some parameters of magnetic water as lowering pH, EC, CL and Ca. At the meantime MT increased Mg^{++}, HCO_3^- and SO_4^{--},as shown in Table (1). In this connection, [10-11; 30] recorded similar trend for wheat, canola and potato where obtained more value of water productivity under magnetic treatment than irrigation with normal water. As well as, [44] recorded similar trend for jojoba plants under normal and drought stress.

Table 4: Effect of irrigation with magnetized water on macro and micronutrients in seed yielded lentil compared with normal water. (Average of 2009/10 and 2010/11 seasons).

Treatment / Character		Mean ± SD Normal water (control)	Magnetic water	*t-test*	Increase (+) or decrease (-) % over control
Macro-nutrients (%)	N	2.53	2.72	*	7.51
	P	0.62	0.64	ns	3.23
	K	0.75	1.28	**	70.67
	Ca	1.08	1.53	**	41.67
	Mg	0.15	0.17	ns	13.33
Micro-nutrients (ppm)	Fe	81.00	83.70	ns	3.33
	Mn	22.00	11.00	***	-50.00
	Zn	58.50	46.80	**	-20.00
	Cu	10.50	12.00	*	14.29

N=3, *, **, *** *t* is Significant at the $P > 0.05$, 0.01and 0.001 levels, respectively, ns: non significant

Table 5: Effect of irrigation with magnetized water on amino acids contents of yielded Lentil compared with normal water. (Average of 2009/10 and 2010/11 seasons)..

Treatment / Amino acids (g/100 g seed dry weight)	Normal water (control)	Magnetic water	Increase (+) or Decrease (-) over control
Aspartic	0.328	0.538	39.01
*Threonine	0.140	0.189	25.68
Serine	0.185	0.289	35.96
Glutamic Acid	0.626	0.917	31.80
Glycine	0.080	0.104	22.60
Alanine	0.247	0.405	39.00
*Valine	0.226	0.340	33.45
*Methionine	0.016	0.017	5.80
*Isoleucine	0.136	0.190	28.06
*Leucine	0.373	0.530	29.56
Tyrosine	0.125	0.200	37.59
*Phenylalanine	0.336	0.474	29.05
*Histidine	0.181	0.214	15.42
*Lysine	0.290	0.347	16.59
Ammonia	0.219	0.252	13.21
Arginine	0.511	0.746	31.58
Proline	0.278	0.489	43.03
*Essential	1.70	2.30	26.14
Non-Essential	2.38	3.69	35.47
Total amino Acid	4.08	5.99	31.88
Ess./non-Ess.	0.71	0.62	-14.45

Nutritional Value In Yielded Seed: Results in Table 4 cleared the effect of irrigation with magnetized water on macro and micro nutrient in yielded lentil seed. The results showed that, magnetic water increased significantly macro elements (N, K and Ca). The same trend was observed in microelement (Cu). Magnetic treatment decreased significantly Mn and Zn as compared with control seed irrigated with normal water. The percent of increase in both macro and microelements reached to 70.67%, 41.67%, 14.29%, 13.33%, 7.51%, 3.33% and 3.23% in K, Ca, Cu, Mg, N and P, respectively. The reduction percent recorded 50% for Mn and 20% for Zn. These results may be attributed to role of MT in increasing membrane permeability, so plants increased the uptake of minerals, so accumulated in the produced seeds. It also may be attributed to the increase in WP in magnetic treatment (Table 3). These results are in agreement with those obtained by [44-45], they found that, irrigation with magnetically treated water lead to an increase in all elements content except sodium. This is because sodium is paramagnetic element, while other elements are diamagnetic which are slightly repelled by a magnetic field.

Amino Acids Contents In Yielded Seeds: Table 5 recorded the amino acid contents of seeds produced from plants irrigated with magnetic and non magnetic water. The data showed that, magnetic treatment increased essential (26.14%), nonessential (35.47%) and total amino acids (31.88%) as compared with seeds produced from irrigation with non magnetized water. The percent of increase in essential amino acids reached to 33.45%, 29.56%, 29.05%, 28.06%, 25.68%, 16.59%, 15.42% and 5.80% in Valine, Leucine, Phenylalanine, Isoleucine, Therionine, Lysine, Histidine and Methionine, respectively. The percent of increase in non essential amino acid ranged between 43.03% in proline and 22.60 % in Glycine. The increase in nonessential amino acids over essential amino acids induced the reduction in the ratio of essential/

nonessential by 14.45%. These results may be attributed to the stimulatory role of MT in increasing protein contents of treated plants as described by [3-], they indicated that, the number of protein bands got increased in some crops treated with magnetized water when compared to untreated control. The induction of new protein bands in response to MWT may be as a result of the effect of MFs in increases proliferation, gene expression and protein biosynthesis [46]. Also, [38] found that the increase in the percentage of plant regeneration is due to the effect of MF of cell division and protein synthesis in paulownia node cultures and concluded that, investigations of MF on biological systems have demonstrated generalized increases in gene transcription and changes in the levels of specific mRNAs. Moreover, [43] concluded that, biomass increasing needs metabolic changes particularly increasing protein biosynthesis.

CONCLUSION

The present study confirmed the promising and previous studies under greenhouse condition. Generally, the present findings have shown that irrigation with magnetized water can be considered as one of the most valuable modern technologies that can assist in saving irrigation water and improving water and lentil crop productivity under newly reclaimed sandy soil.

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