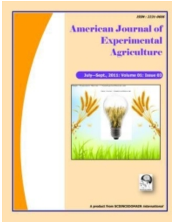

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Impact of Magnetic Water Irrigation for Improve the Growth, Chemical Composition and Yield Production of Broad Bean (*Vicia faba* L.) Plant

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Authors' contributions

The author HEAE solely performed this research. Author HEAE designed the study, performed the experiments and statistical analysis, wrote the protocol, and wrote the manuscript.

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ABSTRACT

Magnetic water is considered one of several physical factors affects plant growth and development. Magnetic water fields are known to induce biochemical changes and could be used as a stimulator for growth related reactions. The seeds of broad bean (*Vicia faba*, L. cv. Giza 3) were irrigated with water passed through magnetic device (*Magnetic Funnel - MAGNETIC TECHNOLOGIES DUBAI, UAE, LLC. PATENT* No. 1826921). Two pot experiments were conducted during season 2010-2011 at greenhouse to study the impact of magnetized water on growth, some chemical constituents and yield productivity of broad bean plants. The stimulatory impact of magnetic water may be ascribed to the increasing of plant growth (plant height, leaf area, leaves, stems, roots fresh and dry weights) and yield production, which increase absorption and assimilation of nutrients. It appears that irrigation with magnetic water may be considered a promising technique to improving the growth and water content of broad bean plant. Magnetic water treatment could be used to enhance growth, chemical constituents (chlorophyll a and b, carotenoids, total available carbohydrates, protein, total amino acids, proline contents, total indole, total phenol, GA3, kinetin, RNA, DNA,) and inorganic minerals (K^{+}, Na^{+}, Ca^{+2} and P^{+3}) contents in all parts of broad bean plant under greenhouse condition. Results indicated that, irrigation with magnetic water induced positive significant effect on all studied parameters.

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1. INTRODUCTION

Broad bean (*Vicia faba*, L.) is an important tropical and subtropical grain legume providing protein, vitamins and minerals. Water is the most important factor for plant growth. The attempts to increase food and energy production for satisfying growing needs led to intensive development of plant production through the use of chemical additives, which in its turn caused more and more pollution of soil, water and air [1]. Irrigation with magnetic water increase seed germination [2]. The water treated by the magnetic field or pass through a magnetic device called magnetic water, when water is magnetized, some physical and chemical properties changed that may be causing changes in plant characteristics, growth and production. Grewal and Maheshwari [3] showed magnetic treatment of seeds and irrigation had a potential to improve the early seedling growth and nutrient contents of seedlings. Utilization of magnetic water improved quantity and quality of common bean crop. It was detected that the magnetic field stimulated the shoot development and led to the increase of the germinating energy and fresh weight, and shoot length of maize [4].

Some beneficial effects of the magnetic treatment of irrigation water for the plant yield and water productivity possibly suggested by Maheshwari and Grewal [5]. The understanding of the stimulating effect requires availability of rich experimental material [6]. Recently the use of physical methods for plant growth stimulation is getting more popular due to the less harmful influence on the environment. Moreover, magnetized water for irrigation is recommended to save irrigation water [7]. Irrigation of common bean plants with magnetic water increased significantly the growth characteristics, potassium, GA_3, kinetin, nucleic acids (RNA and DNA), photosynthetic pigments (chlorophyll a & b and carotenoids), photosynthetic activity and translocation efficiency of photo-assimilates as compared with control plants [8].

However, the available studies and application of this technology in agriculture is very limited. Therefore, the aim of the present work for evaluate study the effect of irrigation by magnetized water on growth, yield, yield components, organic and inorganic (uptake of mineral elements) components of broad bean (*Vicia faba*, L. cv. Giza 3) under greenhouse condition.

2. MATERIALS AND METHODS

In order to evaluate the effects of magnetic water on broad bean (*Vicia faba*, L.) plant, two pots group experiments were conducted in the screen green house during winter season (2010/2011) to study the response of growth, yield, organic and inorganic components of broad bean plant after irrigated with normal tap water and magnetic water. A homogenous lot of clean-healthy common broad bean seeds (*Vicia faba* L. cv. Giza 3) was obtained from the Crop Institute, Agricultural Research Center, Giza, Egypt. The Seeds of broad bean (*Vicia faba*, L. cv. Giza 3) were surface sterilized in 0.1% (w/v) sodium hypo-chloride solution and then thoroughly rinsed with sterile deionized water. Two pots group experiments were conducted to study the response of growth parameters, yield and some biochemical constituents of broad bean plant for irrigation with magnetic and tap water. Selected the seeds and planted in pots (40 cm in diameter and 60 cm depth) containing a mixture of clay and sandy soil (½ ≈ v/v). Seedlings were irrigated two weeks after sowing into plastic growth bags with the same soil as indicated above in a glasshouse (at 10ºC/17ºC), with supplementary lighting (red electric bulb, 20 w at night), at relative humidity of 75-80%. One group from the pots were irrigated twice a week interval with normal tap water needed with full strength Hoagland nutrient solution [9], while the other pots were irrigated with the tap water after magnetization through passing in magnetic device (Magnetic Funnel - *MAGNETIC TECHNOLOGIES DUBAI, UAE, LLC. PATENT* No. 1826921) also, needed with full strength Hoagland nutrient solution, and allowed to grow for about 110 - 120 days post sowing

2.1 Growth Parameters

The experiments conducted five times in complete randomization replicated design. At 75 days from sowing (flowering stage), growth characteristics and the biochemical analysis of broad bean plants were determined. Plant growth parameters such as plant height, fresh and oven dried weight (80-85ºC for 48 h) of leaves stem and roots were determined. Also, leaf area was calculated using (*Leaf Area Meter* - *Laser Leaf Area* Meters CI-202), CID, Bio-Science, USA.

2.2 Water Relations

2.2.1 Succulence and dry matter content (%)

The percentage of the Succulence content and dry matter content (DMC%) was determined after drying the shoot and root samples in air – circulation oven at 80ºC after constant weight and calculated as the following equation:

Succulence = Fresh Weight/Oven Dry Weight …………………….………..………. (1)
% Dry Matter Content = (Oven Dry Weight /Fresh Weight) x 100…….…….…….. (2)

2.2.2 Relative water content (relative Turgidity)

The relative water content (RWC%) was measured according to a modification of the method of Weatherly [10]; Slatyer [11]; Weatherly and Barr [12]. Detached leaf samples were weight immediately and floated on distilled water in a darkened refrigerator (5ºC). Saturation of the leaves was attained after 24 h. and the leaves were rapidly and thorough blotted and weighed immediately. The leaves were then dried at 80ºC to constant weight in an air – circulation oven to constant weight. The relative water content of leaves was expressed according to the following equation:

$$\text{Relative Water Content \%} = \frac{(\text{Fresh weight - Oven Dry Weight}) \times 100}{(\text{Saturated Weight- Oven Dry Weight})} \quad \ldots\ldots(3)$$

2.3 Yield Production

At harvest, the effects of magnetic water and normal tap water on number of branches/plant, number of legumes/plant, weight of legumes/plant, number of seeds/plant, weight of 100 seeds, total seeds yield/plant and straw yield/plant were recorded.

2.4 Physiological Studies

2.4.1 Photosynthetic pigments

Chlorophyll a, chlorophyll b and carotenoids of leaves were determined spectro photometrically as the method described by Metzner, et al. [13]. An 85% aqueous acetone extract of a known F.W. of leaf was assayed Spectro metrically *(LKB NOVASPEC)* at 664, 645, 420 nm. The following equations were used to determine the concentration of the pigment fractions as γ/ml.

Chlorophyll a = 10.3 E_{664} – 0.918 E_{645}………………………………………………… (4)
Chlorophyll b = 19.7 E_{645} – 3.870 E_{664}…………………………………………………. (5)
Carotenoids = 403 E_{452}-(0.0264 Chl. A + 0.426 Chl. b)………………………………. (6)

The pigment fractions were calculated as µg Chl./mg D.W.

2.4.2 Photosynthetic activity

Chloroplasts were prepared by the method of Aronoff [14] and Osman, et al. [15]. Fresh leaves were shredded, ground for one min in a blender using a buffered solution of 0.4 M sucrose, 20 mM HEPES-KOH (pH 7.8), 3 mM $MgCl_2$, 4 mM sodium ascorbate and 0.1% bovine serum albumin (BSA). The much was strained through cheese-cloth, filtered and the suspension centrifuged (1 min at 8,000 X g). The pellet was re-suspended in the isolation medium, centrifuged (5 min at 300 X g) and the supernatant re-centrifuged (10 min at 1,000 X g). The sediment was re-suspended in a 2 ml buffer solution at pH 6.8 and the aggregates dispersed [15]. The levels of chlorophyll a & chlorophyll b were determined by the method described by Mackinney [16]. An aliquot of 0.2 ml of the chloroplast suspension was extracted with 3.8 ml of 85% cold aqueous acetone and the density of the extract measured at 652 nm. The chlorophyll content was calculated according to the following equation:

C = E652 X 1,000/34.5 mg Chl. L^{-1} ………………………………………………….(7)

Where c = chlorophyll a & b.

The photosynthetic activity of the isolated chloroplasts was measured using potassium ferricyanide (5 X 10^{-4}M) as an electron acceptor. Reduction of ferricyanide was monitored spectro photometrically (*LKP NOVASPEC*) at 420 nm at room temperature. The reduction mixture contained 0.2 ml of chloroplast suspension, (0.2–0.8 mg chl. ml^{-1}), 3.8ml HEPES buffer (pH 7.8), and 5 X 10^{-4}M potassium ferricyanide. The mixture was illuminated at 300 Wm-2 using a slide projector provided with a heat filter with a 24 v, 250 w quartz halide bulb, 15-45 cm from the well. The photosynthetic activity of the isolated chloroplasts was calculated from the standard curve and expressed as µmol fericyanide mg chl^{-1} h^{-1} [17].

2.5 Biochemical Analysis

2.5.1 Organic components

2.5.1.1 Carbohydrate analysis

In the current investigation 300 mg of oven dry plant material was extracted with 5 ml of borate buffer (28.63 g boric acid + 29.8 g KCl + 3.5 g NaOH in a liter of hot distilled water), left for 24 hr, then centrifuged and filtered. The filtrate was used for the determination of the direct reducing value (DRV-including all free monosaccharide) and total reducing value (TRV-including sucrose), while the residue was dried at 80ºC for determination of polysaccharides [18,19].

2.5.1.1.1 Direct reducing value (DRV)

Was carried out by evaporation, 0.1 ml of extracted cleared borate buffer was reduced to dryness and then mixed with 1 ml of modified Nelson solution [19].The mixture was maintaining on a boiling water-bath for 15 min, after which it was cooled rapidly using running tap water. Thereafter 1 ml of arsenomolybdate [20] was added, the mixture was diluted to a definite volume and its intensity measured at 700 nm using colorimeter (*LKP NOVASPEC Surplus Model 4049 Spectrophotometer*).

2.5.1.1.2 Total reducing value (TRV)

For determination of total reducing value (TRV), 0.2 ml of cleared extract was mixed with deionized water up to 5 ml then 0.2 ml of the diluted extract was mixed with 0.1 ml of 1% invertase enzyme solution and the mixture maintained at 37ºC for 0.5 hr. Thereafter, the reducing value was determined as described before for DRV [18,19]. The difference between the value obtained from this step and that of the DRV is an estimated of sucrose, in terms of glucose made up to 3 ml left overnight at 28ºC and then centrifuged.

2.5.1.1.3 Polysaccharides

10 mg of the remaining residue was mixed with 0.2 ml of 1% taka diastase enzyme and 0.1 ml acetate enzyme and ml acetate buffer (6 ml acetic acid 0.2N+4 ml sodium acetate buffer 0.2 N). The reducing value of 1ml of filter was estimated as above [18].

2.5.1.2 Proteins contents

Dry samples collected during the growth study were analyzed for protein content, after precipitating the protein with 15% TCA at 4ºC according to Lowry, et al. [21].

2.5.1.3 Total free amino acids contents

These were determined by the method described by Ya and Tunekazu [22]. An aliquot of 0.1 ml plant extract was heated in a test tube with 1.9 ml of ninhydrin citrate buffer-glycerol mixture in a boiling water bath for 12 min and cooled at room temperature. Then the tube was well shaken and the optical density read at 570 nm. A blank was determined with 0.1 ml of distilled water and a standard curve obtained with 0.005 to 0.2 mM g Glycine.

2.5.1.4 Proline contents

This was estimated using the acid ninhydrin method described by Bates, et al. [23]. Two ml of water extract were mixed 10 ml of 3% aqueous sulfosalicylic acid. Two ml of this mixture was allowed to react with 2 ml acid ninhydrin-reagent and 2 ml of glacial acetic acid in a test tube for 1 h at 100ºC; the reaction was terminated by cooling the mixture in an ice bath. The reaction mixture was extracted with 4 ml toluene, and mixed vigorously for 15-20s. The chromatophore - containing toluene was aspirated from the aqueous phase, warmed to room temperature, and the absorbance read at 520 nm using toluene as a blank. The proline concentration was determined from a standard curve.

2.5.1.5 Total indole acetic acid (IAA)

The determination of IAA as described by Larsen, et al. [24] and total phenol, as described by Malik and Singh [25] were estimated in the fresh shoots.

2.5.1.6 Growth regulators (GA_3 and kinetin)

Estimated of GA3 and kinetin were described by HPLC following the procedure of Shindy and Orrin [26].

2.5.1.7 To determine H_2O_2 concentration

The determine H2O2 concentration from the root extract was mixed with 0.1% titanium chloride in 20% (v/v) H_2SO_4. The mixture was then centrifuged at 6 000 *g* for 15 min. The absorbance was measured at 410 nm [27].

2.5.1.8 Lipid peroxidation

Lipid peroxidation was measured in terms of malondialdehyde (MDA) content using the thiobarbituric acid reaction as described by Madhava Rao and Sresty [28].

2.5.1.9 The extraction of nucleic acids

The extraction of nucleic acids (DNA and RNA) carried out by the method cited by Mohamed and Capesius [29].

2.5.1.10 Determination of antioxidant enzyme activities

The catalase (CAT, EC 1.11.1.6) activity was assayed from the rate of H_2O_2 decomposition following the method of Cakmak and Horst [30]. Peroxidase (POD, EC 1.11.1.7) following the method of Macheix and Quessada [31] and superoxide dismutases (SOD, EC 1.15.1.1) as described by Dhindsa, et al. [32].

2.5.2 Inorganic components

2.5.2.1 Mineral elements

Ions content measurements were carried out after extraction with 0.1 nitric acid of the ashed (powdered) milled samples at 500ºC obtained after combustion in a muffle furnace, the milled samples were estimated following the "wet ashing procedure" [33]; the acid digests of the oven dried samples were analysed. Oven dried plants were subjected to acid digestion and sodium (Na^+) and calcium (Ca^{2+}) estimated photo-metrically using a corning-400 flame photometer [34,35]. Phosphor was estimated using the method of Sekine, et al. [36] by the Molybdenum-blue method [35]. Determination of potassium (K^+) content by Miller [37] methods, **t**he plant parts were dried in a ventilated oven for approximately 78 h at 60ºC to a constant weight and then ground, the samples were digested in a nitric-perchloric acid mixture and analyzed with Atomic Absorption Spectrometer (*Carl Zeiss Jena, Germany*).

2.6 Statistical Analysis

All data were subjected to *F* test *ANOVA* and the means were compared using Duncan's multiple range (*P*<0.05).Where relevant, the experimental data was subjected to analysis of variance. Percentage values were transformed into arcsines according to Bliss [38] and analysis of variance was carried out according to Snedecor and Cochran [39].

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Data presented in Tables (1and 2) showed that the irrigation of broad bean plant with magnetic water increased significantly the growth parameters as compared to pots which irrigated with tap water. The improvement over control treatment reached to 27.39; 60.27; and 65.42 for plant height, fresh and dry weight (g/plant) respectively. Irrigated broad bean plant with magnetic water increased significantly the growth parameters (plant height, fresh and dry weight of leaves, stem, and root, leaf area) as compared to the tap water (control). Fast growing of world population affected negatively the environmental conditions of our life. Increasing number of earth population resulted in growing consumption of food and energy. Both tendencies seriously exhaust the natural resources. These results are correspondence with the result of Morejon, et al. [40]. Aladjadjıyan [4] showed that exposure of seeds of *Zea mays* has a favorable effect on the development of shoots in the early stages. These results are in agreement with those obtained by other researchers; Hilal and Hilal [41] they reported that magnetized water has more tripled seedling emergence of wheat than tap water. Renia, et al. [42] found significance increase in the rate of water absorption accompanied with an increase in total mass of lettuce with the increase of magnetic force. Moreover, Nasher [43] found that chick pea plants irrigated with magnetized water were taller than plants irrigated with tap water Significant increases in pigment fractions were recorded in chickpea plants irrigated with magnetized water compared to control treatment.

Table 1. Impact of magnetic water irrigation on plant height and leaf area of broad bean (*Vicia faba*, L. Giza 3) plants

Growth parameter Treatments	Plant height (cm)	Leaf area (Cm^2/Leaf)
Tap water	59.21	34.12
Magnetic water	75.42	58.32
F values	***	***

Statistical Analysis treatments, where relevant, the experimental data were subjected of One – Way analysis of variance (ANOVA).

*Note: F values * = P < 0.05, ** = P < 0.01, *** = P < 0.001 and N.S. = Not Significant. Data presented are the means of five replicate.*

Table 2. Impact of magnetic water irrigation on fresh and dry weights of broad bean (*Vicia faba*, L. Giza 3) plants

Growth parameter	Fresh weight (g)				Dry weight (g)			
Treatments	L	S	R	T.P. F. Wt.	L	S	R	T.P. D. Wt.
Tap water	6.78	9.15	4.71	20.64	0.759	0.897	0.325	1.981
Magnetic water	10.52	14.58	7.98	33.08	1.289	1.375	0.613	3.277
F values	**	**	*	**	*	*	N.S.	*

Statistical Analysis treatments, where relevant, the experimental data were subjected of One – Way analysis of variance (ANOVA).
*Note: F values * = P < 0.05, ** = P < 0.01, *** = P < 0.001 and N.S. = Not Significant. Data presented are the means of five replicate. Whereas, L = Leaves, S = Stem, R = Root, T. P. F. Wt.= Total Plant Fresh Weight & T.P. D. Wt. = Total Plant Dry Weight.*

Magnetic water increased significantly fresh and dry weight of leaf, stem, and root of broad bean as compared to tap water, these results are in line with those of De Souza, et al. [44] and Moussa [8] who observed that pretreatment of seeds with magnetic field or irrigation with magnetic water increased leaf, stem and root fresh and dry weight of tomato and common bean respectively. Similar enhancing effect of magnetized irrigation water was reported on snow pea and chick pea [3], flax and lentil [45,46] and wheat [47]. This improved growth may lead to an early canopy cover and a better competition against weeds, and thus more efficient use of nutrients and irrigation water. Positive effects of magnetized water on growth of root, stem and leaf of cowpea are very important since they appear to induce an improved capacity for nutrients and water uptake, providing greater physical support to the developing shoot [48]. Better root growth and development in young seedlings might lead to better root systems throughout the lifetime of a plant [44].

Jones, et al [49] found that the electromagnetic fields amplify the plant growth regulator induced Phenylalanine Ammonia-Lyrase during cell differentiation in the suspended cultured plant cell. Magnetic fields have been reported to exert a positive effect on the germination of seeds [50,51] on plant growth and development [52,53], on tree growth [54] and on crop yield [55]; some review papers also mention a number of controversial, early results [56, 57].

3.2 Magnetic Water and Water Relations

Data presented in Table 3, indicated that the succulence significantly decreased in all parts (leaf, stem, root) of broad bean plant irrigated by magnetic water more than tap water. Whereas, dry matter content % (DMC%) and relative water content (RWC%) in all broad bean plant parts (leaf, stem, root) increased significantly with irrigated by magnetic water than tap water. Improved water use efficiency with magnetic water could help in the water resources conservation, particularly in arid and semi arid regions. Magnetic water has been reported to change some of the physical and chemical properties of water, mainly hydrogen bonding, polarity, surface tension, conductivity, pH and solubility of salts, these changes in water properties may be capable of affecting the growth of plants [58,59].

Table 3. Impact of magnetic water irrigation on water relations (succulence, dry matter content %, relative water content %) of broad bean (*Vicia faba*, L. Giza 3) plants

Water relations	Plant parts			
Treatments	**Leaves**	**Stem**	**Root**	**Total Plant**
	Succulence (F. W. / D. W.)			
Tap water	8.93	10.2	14.49	10.42
Magnetic water	8.17	10.6	13.02	10.10
F values	*	N.S.	*	N.S.
	Dry matter content % (DMC) (D.W./F.W. X100)			
Tap water	11.2	9.8	6.9	9.6
Magnetic water	12.25	9.43	7.68	9.91
F values	*	N.S.	*	*
	Relative water content % (RWC) (F.W.-D.W./S.W.–D.W.x100)			
Tap water	75.07	80.49	71.43	80.32
Magnetic water	82.19	86.83	81.51	83.23
F values	**	**	**	*

Statistical Analysis treatments, where relevant, the experimental data were subjected of One – Way analysis of variance (ANOVA).

*Note: F values * = P $<$ 0.05, ** = P $<$ 0.01, *** = P $<$ 0.001 and N.S. = Not Significant. Data presented are the means of five replicate.*

Sadeghipour and Aghaei [48] found that the water use efficiency (in term of total biomass produced to amount of water consumed), was increased in the plants irrigated with magnetic water as compared to the ordinary water, similarly to the result of Al-Khazan, et al. [60] found that irrigation with magnetic water increased water use efficiency in jojoba and also Maheshwari and Grewal [5] observed that water productivity in celery and snow pea was increased in magnetic water treatment than that control. Meanwhile, treatment with magnetic water had no effect on the water content as compared with the control [61].

3.3 Magnetic Water and Yield Production

Data presented in Table 4 show that the irrigation broad bean plants with magnetic water increased significantly the yield production. At harvest stage, the effect of magnetic water and normal tap water on number of branches/plant, number of legumes/plant was increased significantly compared to control treatment (tap water). These results are the logical to improvement growth parameters, growth hormone, photosynthesis and translocation efficiency and these results are in agreement with that of De Souza, et al. [44]; Hozayn and Abdul Qados [61]. The results explain the exposure of plants to magnetic water 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 of chickpea [62].

Table 4. Impact of magnetic water irrigation on yield production of broad bean (*Vicia faba*, L. Giza 3) plants

Yield parameter / Treatments	Branches No./plant	Legumes No./plant	Legumes Wt. (g/Plant)	Seeds No./ Plant	100 seeds weight(g)	Seeds yield g/plant	Straw yield g/Plant
Tap water	4.61	5.1	2.12	16.21	66.13	10.82	5.81
Magnetic water	5.82	6.9	2.75	22.11	79.81	17.65	7.91
F values	N.S.	*	N.S	**	*	**	*

Statistical Analysis treatments, where relevant, the experimental data were subjected of One – Way analysis of variance (ANOVA).

*Note: F values * = P < 0.05, ** = P < 0.01, *** = P < 0.001 and N.S. = Not Significant. Data presented are the means of five replicate.*

3.4 Magnetic Water and Physiological Studies

3.4.1 Photosynthetic pigments and chloroplast activity

Results presented in Tables (5 and 6) indicated that the irrigation of broad bean plant with magnetic water exhibited marked significant increase in the chloroplast pigments (chlorophyll *a*, chlorophyll *b* and carotenoids), photosynthetic activity, over the irrigated by tap water (control). Significant increases in the above mentioned characters were recorded from irrigated plants with magnetic water as compared to irrigated plants with tap water. These results agreement with that of Atak, et al. [63]; Constantin, et al. [64]; Mihaela, et al. [65]; Mihaela, et al. [66] they showed an increase in chlorophyll content and carotenoids content specifically appeared after treatment with magnetic water.

Sadeghipour and Aghaei [48] found that irrigation with magnetized water increased leaf area and specific leaf area in cowpea than that control, the enhancement in leaf area and specific leaf area in the plants irrigated with magnetic water must have increased photosynthetic rates due to the greater interception of light and the greater amount of assimilates available for vegetative growth. Similar results were found by De souza, et al. [44]; Hoff [67] and Davies [68] also revealed an increase in photosynthetic rate and influx of water as a result of magnetic treatments.

Table 5. Impact of magnetic water irrigation on chloroplast pigments (Chlorophyll a, Chlorophyll b, Carotenoids) of broad bean (*Vicia faba*, L. Giza 3) plants

Chloroplast pigmentation / Treatments	Chloroplast pigments (mg/100 g F. W.)				
	Chlorophyll *a*	Chlorophyll *b*	Chl. *a* + Chl. *b*	Carotenoids	Total pigments
Tap water	5.14	2.32	7.46	4.03	11.49
Magnetic water	7.04	3.87	10.91	4.59	15.50
F values	**	*	***	N.S.	**

Statistical Analysis treatments, where relevant, the experimental data were subjected of One – Way analysis of variance (ANOVA).

*Note: F values * = P < 0.05, ** = P < 0.01, *** = P < 0.001 and N.S. = Not Significant. Data presented are the means of five replicate.*

Table 6. Impact of magnetic water irrigation on chloroplast activity (photosynthetic efficiency) of broad bean (*Vicia faba*, L. Giza 3) plants

Chloroplast activity / Treatments	Photosynthetic efficiency (µmol fericyanide mg chl^{-1} h^{-1})
Tap water	68.98
Magnetic water	93.81
F values	***

Statistical Analysis treatments, where relevant, the experimental data were subjected of One – Way analysis of variance (ANOVA).

*Note: F values * = P < 0.05, ** = P < 0.01, *** = P < 0.001 and N.S. = Not Significant. Data presented are the means of five replicate.*

3.4.2 Organic Components

3.4.2.1 Total available carbohydrates

In these investigation, irrigated broad bean plant with magnetic water increased significantly total available carbohydrates (Monosaccharide, Disaccharides, polysaccharides) contents compared to irrigate with tap water as shown in Table 7. The increasing significantly in carbohydrates because of the close relationship between stomatal conductance and photosynthesis, thus lead to an increase in photosynthesis. The effects of magnetic exposure on plant growth still require proper explanation. They may be the result of bioenergetics structural excitement causing cell pumping and enzymatic stimulation [44]. The present study showed that magnetic water had the greatest effect on root weight. It suggests that enhancement the growth of stem and leaves was related to increasing of root growth which improved water and ions absorption. Ions in the cell have the ability to absorb magnetic energy corresponding to specific parameters related to their vibration and rotation energy sublevels. This phenomenon represents a kind of resonance absorption and could explain the stronger effect of applying definite values of magnetic field induction [6].

3.4.2.2 Protein, total amino acids, proline contents

Results presented in Table 8 indicated that the magnetic water irrigation exhibited marked significant increase in total protein, total amino acids, proline contents at all plant parts (leaves, stems, roots) of broad bean compared with control plants. Moreover, the protein, amino acids, proline contents increasing in broad bean plants irrigated with magnetic water more than irrigated with tap water may be responsible for the stimulation of growth. These results are in line with Hozayn and Abdul Qados [61]. In this respect, Celik et al. [69] found that the increase in the percentage of plant regeneration is due to the effect of magnetic field on cell division and protein synthesis in paulownia node cultures. Shabrangi and Majd [70] concluded that, biomass increasing needs metabolic changes particularly increasing protein biosynthesis. It was found out that chloroplasts have paramagnetic properties [71].

Table 7. Impact of magnetic water irrigation on total available carbohydrates (DRV, TRV, polysaccharides as mg /100g D.W.) of broad bean (*Vicia faba*, L. Giza 3) plants

Carbohydrate contents (mg /100g D.W.) Treatments	Plant parts			
	Leaves	Stem	Root	Total plant
	DRV (Glucose)			
Tap water	250.1	220.3	190.4	660.8
Magnetic water	325.3	260.2	201.4	786.9
F values	**	**	N.S.	**
	TRV- DRV = Sucrose			
Tap water	300.6	290.9	186.8	778.3
Magnetic water	360.7	340.4	191.5	892.6
F values	*	**	N.S.	*
	Polysaccharides			
Tap water	69.5	65.4	45.9	180.8
Magnetic water	89.9	82.7	65.4	238.0
F values	**	*	*	**
	Total Available Carbohydrates (TAC)			
Tap water	620.2	643.4	423.1	1686.7
Magnetic water	775.9	683.3	458.3	1917.5
F values	*	*	N.S.	***

Statistical Analysis treatments, where relevant, the experimental data were subjected of One – Way analysis of variance (ANOVA).

*Note: F values * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$ and N.S. = Not Significant. Data presented are the means of five replicate.*

Table 8. Impact of magnetic water irrigation on total proteins, total amino acids and proline (mg/100g D.W.) of broad bean (*Vicia faba*, L. Giza 3) plants

Nitrogenous components (mg /100g DW) Treatments	Plant parts			
	Leaves	Stem	Root	Total plant
	Total Proteins			
Tap water	15.32	10.43	6.54	32.29
Magnetic water	17.86	13.03	7.76	38.65
F values	*	**	*	**
	Total Amino Acids			
Tap water	7.91	7.54	3.27	18.72
Magnetic water	13.52	13.01	5.87	32.40
F values	**	**	*	***
	Proline			
Tap water	3.93	4.02	3.98	11.93
Magnetic water	7.52	7.76	4.02	19.30
F values	**	**	N.S.	**

Statistical Analysis treatments, where relevant, the experimental data were subjected of One – Way analysis of variance (ANOVA).

Note: F values * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$ *and N.S. = Not Significant. Data presented are the means of five replicate.*

The increasing of protein contents in plants irrigated with magnetic water was accompanied with increasing growth promoters (IAA). In this respect, Kuba and Kakimoto [72] found that

IAA effect on DNA replication. Moreover, Celik et al. [69] and Shabrangi and Majd [70] reported that magnetic field is known as an environmental factor which affects on gene expression. Therefore, by augmentation of biological reactions like protein synthesis of broad bean yield and its components were increased significantly under magnetic water irrigation. These results are logical to improvement growth parameters and growth promoters (IAA) and photosynthetic pigments. The remarkable improvement induced by the magnetic treatment was consistent with the results of other studies on other crops like cereal, sunflower, flax, pea, wheat, pepper, tomato, soybean, potato and sugar beet, in these studies the crop yield were increased [42,55,73-85]. It could be concluded from this study that, broad bean irrigation with magnetic water could effectively increase growth parameters, yield and some chemical constituents.

Magnetic water is considered one of several physical factors affects plant growth and its development. Results obtained showed that broad bean plants which irrigated with magnetic water grew taller and heavier than those irrigated with tap water. The stimulatory effect of the application of magnetic water on the growth parameters reported in this study may be attributed to the increase in photosynthetic pigments, endogenous promoters (IAA); increase protein biosynthesis. Abdul Qados and Hozayn [45] findings the stimulatory impact of magnetic water may be also ascribed to the increasing of stomatal conductance and root growth which increase absorption and assimilation of nutrients. In this connection, Formicheva et al. [86,87] and Belyavskaya [88] reported that magnetic water significantly induces cell metabolism and mitosis meristematic cells of pea, lentil and flax. Moreover, the formation of new protein bands in plants treated with magnetic water may be responsible for the stimulation of all growth, and promoters in treated plants.

In this respect, Celik et al. [69] found that the increase in the percentage of plant regeneration is due to the effect of magnetic field on cell division and protein synthesis in paulownia node cultures. Shabrangi and Majd [70] concluded that, biomass increasing needs metabolic changes particularly increasing protein biosynthesis. The stimulatory effect of magnetized water on growth parameters may be attributed to the induction of cell metabolism and mitosis [46]. Also, these results agreement with those obtained by Renia et al. [42] who found significance increase in the rate of water absorption accompanied with an increase in total mass of lettuce with the increase of magnetic force.

3.4.2.3 Total phenols, total indole

Also, from these results recoded in Table 9, the total phenols promotive significantly in broad bean plant irrigated by magnetic water compared to tap water plant (control). Whereas, the total indole the magnetic water irrigation no significant effects in broad bean plant compared with tap water (control). This improvement may be attributed to the role of magnetic water in changing the characteristic of cell membrane, effecting the cell reproduction and causing some changes in cell metabolism [8,63,89].

3.4.2.4 GA_3, kinetin contents

Data presented in Table 9 showed that the irrigation of broad bean plant by magnetic water increased significantly the GA_3 and kinetin contents compared to the tap water (control) plant. That means that, in the magnetic field, the magnetic moments of the atoms in them are oriented downwards the field direction, the influence of the magnetic field on plants, sensible to it, increases its energy. Later, this energy is distributed among the atoms and causes the accelerated metabolism and, consequently, to better germination. Turker et al.

[90] showed that an increase in GA_3 in sunflower plants treated with magnetic water. Also, Hozayn and Abdul Qados [47] stated that, the treatment of wheat with magnetic water increase the cytokinine content which is effective on some events causing mitosis. These results may be due to the effect of magnetic field on alteration the key of cellular processes such as gene transcription which play an important role in altering cellular processes.

In this respect Tian et al. [91] and Atak et al. [92,63] who found an increase in chlorophyll content specifically appeared after exposure to a magnetic field for a short time. Moreover, Atak et al. [63] suggested that, increase all photosynthetic pigment 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. It also may be due to the increase in growth promoters (IAA) (Table 2). Similar results were observed on rice and chick-pea when irrigated with magnetic water [43,91]. As well as the improvement of photosynthetic pigments were recorded in *Paulowria species* [92], sunflower [82] and soy bean [63] when seeds or explants exposed to magnetic field (3.8 – 4.8 m t) for a short time.

3.4.2.5 Nucleic acid (DNA and RNA)

The results presented in Table 9 indicated that the stimulatory effect of magnetic water significantly in the nucleic acid (DNA and RNA) contents in broad bean compared with the using tap water (control), similar results also have been reported by Ozge et al. [93]; Mihaela et al. [66]; Moussa [8].

Table 9. Impact of magnetic water irrigation on total indole, total phenol, GA_3, kinetin, nucleic acids (RNA and DNA) contents of broad bean (*Vicia faba*, L. Giza 3) plants

Growth regulators / Treatments	Total indole (mg/100gFW)	Total phenol (µg/100gFW)	(µg /g FW) GA3	Kinetin	RNA	DNA
Tap water	9.88	312.28	76	64	73	49
Magnetic water	9.92	423.13	116	93	106	65
F values	N.S.	***	***	**	***	*

Statistical Analysis treatments, where relevant, the experimental data were subjected of One – Way analysis of variance (ANOVA).
*Note: F values * = P < 0.05, ** = P < 0.01, *** = P < 0.001 and N.S. = Not Significant. Data presented are the means of five replicate.*

3.4.2.6 Antioxidant enzymes

3.4.2.6.1 Catalase, peroxidase, and superoxide dismutase

Data presented in Table 10 showed that the irrigation of broad bean plant with magnetic water caused a significantly increased in the activities of the antioxidant enzymes (catalase, peroxidase and superoxide dismutase) over the irrigated with tap water (control) plants. These results agreement with Pintilie et al. [94]; Moussa [8]. The magnetic field had a stimulation effect on peroxidase activity [95] and superoxide dismutase [8,95]. Opposite to this result Hassan et al. [96] stated that magnetic field treatment decreased the catalase activity in tobacco.

Table 10. Impact of magnetic water irrigation on antioxidant (enzyme activities) in broad bean (*Vicia faba*, L. Giza 3) plants

Treatments / Antioxidant enzymes	Catalase (μMH_2O_2/min. g F.W.)	Peroxidase (units mg^{-1} protein)	Superoxide dismutases (units mg^{-1}protein)
Tap water	1.32	6.91	2.93
Magnetic water	3.76	11.32	6.52
F values	**	**	**

Statistical Analysis treatments, where relevant, the experimental data were subjected of One – Way analysis of variance (ANOVA).

*Note: F values * = P ＜ 0.05, ** = P ＜ 0.01, *** = P ＜ 0.001 and N.S. = Not Significant. Data presented are the means of five replicate.*

3.4.3 Inorganic components

3.4.3.1 Mineral elements

However, data presented in Table 11 indicated that the irrigation of broad bean plant by magnetic water exhibited an increase in potassium, calcium, phosphorous contents in all parts (roots, stems, leaves and seeds) of broad bean plant compared with the control (tap water) plant, whereas, sodium content tended to decreased significantly in all plant parts (roots, stems, leaves and seeds) irrigated with magnetic water than tap water (control) plants. These results agreement with that of Harsharn, et al. [97]; they observed an increase in potassium content in pea after irrigation with magnetic water. Also, Moussa [98] demonstrated that, there is a direct effect of potassium upon translocation efficiency, because potassium ion (K^+) is known to be one of the three largest constituents in sieve tube sap. Potassium may play a role on the synthesis of endogenous plant hormones [99].

Table 11. Impact of magnetic water irrigation on inorganic minerals (K^+, Na^+, K^+/Na^+ ratios, Ca^{+2}, P^{+3}) contents as (mg/100 g D.W.) in all parts of broad bean (*Vicia faba*, L. Giza 3) plants

Inorganic mineral(mg/100g D.W.) Treatments	Plant parts			
	Seeds	**Leaves**	**Stems**	**Roots**
	Potassium (K^+)			
Tap water	56.26	77.47	69.57	57.39
Magnetic water	66.26	85.57	75.57	63.39
F values	*	***	*	*
	Sodium ($Na^{+)}$			
Tap water	14.78	20.48	11.48	15.65
Magnetic water	13.78	19.48	9.48	10.65
F values	*	*	**	**
	K^+/Na^+ Ratio			
Tap water	3.81	3.98	6.06	4.31
Magnetic water	4.81	4.18	7.97	5.95
F values	*	N.S.	N.S.	N.S.
	Calcium (Ca^{+2})			
Tap water	67.41	63.44	35.43	39.90
Magnetic water	83.41	81.44	45.43	49.90
F values	**	**	**	*
	Phosphorus (P^{+3})			
Tap water	11.31	6.46	3.23	3.23
Magnetic water	13.15	7.36	5.13	5.65
F values	**	N.S.	*	N.S.

Statistical Analysis treatments, where relevant, the experimental data were subjected of One – Way analysis of variance (ANOVA).

*Note: F values * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$ and N.S. = Not Significant. Data presented are the means of five replicate.*

4. CONCLUSION

Results of the current study showed the positive impacts of magnetic water on root, stem and leaves growth of broad bean as well as water relations than that the control. The stimulatory effect of magnetic water on the growth in these researches may be due to the increase in root growth and stomatal conductance. So as a simple and safe method, irrigation with magnetic water can be used to improve plant growth and water used efficiency. It appears that utilization of magnetic water can led to improve quantity and quality of broad bean (*Vicia faba*, L.) crop. It suggests that magnetic water could stimulate defense system, photosynthetic activity and translocation efficiency of photo-assimilates in broad bean plants. Generally using magnetic water treatment could be a promising technique for agricultural improvements but extensive research is required on different crops.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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