The Impact of Magnetic Water Application for Improving Common Bean (*Phaseolus vulgaris* L.) Production

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Abstract: The technology of magnetic water has widely studied and adopted in field of agriculture in many countries (Russia, Australia, USA, China and Japan), but in Egypt available review on the application of magnetize water in agriculture is very limited. Therefore, the present work was carried out to study the response of some growth characteristics, yield and some chemical constitute of common bean for irrigation with magnetized and tap water. 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*, chlorophyll *b*, and carotenoid), photosynthetic activity ($^{14}CO_2$–fixation), and translocation efficiency of photoassimilates ($^{14}CO_2$–assimilation) as compared with control plants. Treatment with magnetized water had no significant effect on water content, malondialdehyde, and H_2O_2 contents as compared with the control. Also, there is a stimulation effect in the activities of the antioxidant enzymes (catalase, peroxidase, and superoxide dismutase) in the magnetized plants over the control. It appears that utilization of magnetized water (30 mT) can led to improve quantity and quality of common bean crop. It suggests that magnetic water could stimulate defense system, photosynthetic activity, and translocation efficiency of photoassimilates in common bean plants. So, using magnetic water treatment could be a promising technique for agricultural improvements but extensive research is required on different crops.

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1. Introduction

Common bean is one of five cultivated species from the genus Phaseolus and is a major grain legume crop, third in importance after soybean and peanut, but first in direct human consumption as a valuable source of protein, minerals and vitamins (Broughton *et al.*, 2003). However, living organisms have experienced the action of the Earth's magnetic field, which is a natural component of our environment (Belyavskaya, 2001). It was shown that the natural geomagnetic field has an important role on the normal functions of plants. Magnetic fields are widely distributed in the environment and their effects are increasing due to various instruments that are used in industry and medicine. This increases the concern about the possible risk of functional disorders in biological systems. Several studies have shown that magnetic field exert influence on a large variety of cellular functions, nevertheless the exact mechanism of interaction with living cells is still unclear (Yano *et al.,* 2001). The magnetic field affected the various characteristics of the plants like germination of seeds, root growth, rate seedlings growth, reproduction and growth of the meristem cells and chlorophyll quantities (Reina *et al.,* 2001; Aladjadjiyan, 2002). The researchers have shown that magnetic field changed the characteristics of cell membrane, effected the cell reproduction and caused some changes in cell metabolism. At the same time, it was put forward that magnetic field affected the growth characteristics and various functions like mRNA quality, gene expression, protein biosynthesis and enzyme activities and caused the changes concerning the various functions at the organ and tissue levels (Atak *et al.,* 2003). The reason of this effect can be searched in the presence of paramagnetic properties in chloroplast which can cause an acceleration of seeds metabolism by magnetic treatment (Aladjadjiyan and Ylieve, 2003). In addition to, there were magnetic field increased yield and yield parameters of soybean (Özalpan *et al.,* 1999). Tenforde (1990) showed that through treatments with magnetic field the plant metabolism is changed and it is possible to induce some phenotypic and genotypic effects able to stimulate the plant productivity. Magnetic field treatment of seeds leads to acceleration of plant growth activates proteins formation and root development (Rakosy-Tican *et al.,* 2005). A magnetic field was shown to induce seed germination, shoot development, fresh weight and plant length, fruit yield per plant and average fruit weight (Aladjadjıyan, 2002; Esitken, 2003). Many authors have reported the effects of static magnetic fields on the metabolism and growth of different plants (Kato *et al.,* 1989). Roots seem much more susceptible to the magnetic field than shoots (Kato *et al.,* 1989). Electromagnetic fields can alter plasma membrane structures and functions (Blank, 1995). A marked increase in the germination percentage of lettuce seeds by treatment with a 10mT stationary magnetic field was observed by Reina *et al.* (2001). Magnetically treated tomato seeds improved the leaf area, leaf dry weight and yield under field conditions (De Souza *et al.*, 2006).

In the present study, we investigated the effects of magnetic water on some growth characteristics, assimilatory pigments content, photosynthetic activity, translocation efficiency of photoassimilates, potassium, GA_3, Kinetin, nucleic acid (DNA and RNA), malondialdehyde, H_2O_2 contents and enzyme activities (catalase, peroxidase and superoxide dismutases) in common bean plants.

2. Material and Methods

Plant material and growth conditions.

A homogenous lot of clean-healthy common bean grains (*Phaseolus vulgaris* L.), cv. Master; was obtained from the Crop Institute, Agricultural Research Center, Giza, Egypt. The caryopsis was kept at 4°C. They were surface sterilized in 0.1 % (w/v) sodium dodecyl sulphate solution and then thoroughly rinsed with sterile deionized water. Two pot experiments were conducted to study the response of growth, yield and some biochemical constituents of common bean plant for irrigation with tap and magnetized water (30 mT). The grains were planted in pots (40 cm in diameter and 50 cm depth) containing a mixture of clay and sandy soil (2:1). Half of the pots were irrigated once a week interval with tap water, while the other half pots were irrigated with the tap water after magnetization through passing in magnetic device (U050 mg, 0.5 inch, output 4-6m^3/hr, 30mT, production by Magnetic Technologies L.C.C., Russia, branch United Arab Emirates). Pots were kept in a controlled-growth chamber at photo flux density of 340 µmole $M^{-2}S^{-1}$ (12/12 h day/night period) at relative humidity of 55-60%, and 25±2°C temperature. Cultural practices, such as weed control, NPK fertilizers and irrigation, were performed as needed through the period of the experiment. The experiments conducted four times in complete randomization replicated design. At 60 days from sowing (flowering stage), growth characteristics and the biochemical analysis of common bean plants were determined. At harvest, the effects of treatment with magnetic water on the total grain yield/plant were recorded.

Growth characteristics.

Plant morphological parameters such as fresh weight of leaves, stem and root were recorded. Leaves, stem and root biomasses were oven-dried for 24 h at 80-90°C to obtain dry weights. Relative water content was calculated according to Henson *et al.* (1981).

Biochemical assays.

The amount of total chlorophyll (*a*+*b*) and carotenoid were determined according to the method of Lichtenthaler and Wellburn (1983). The leaves and roots were dried in a ventilated oven for approximately 78 h at 60 °C to a constant weight and then ground. For the measurement of potassium, samples were digested in a nitric-perchloric acid mixture (Miller, 1998) and analyzed with Atomic Absorption Spectrometer (Carl Zeiss Jena, Germany). Growth regulators (GA_3 and kinetin) were estimated by HPLC following the procedure of Shindy and Orrin (1975). To determine H_2O_2 concentration, 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 (Hsu and Kao, 2007). Lipid peroxidation was measured in terms of malondialdehyde (MDA) content using the thiobarbituric acid reaction as described by Madhava Rao and Sresty (2000). The extraction of nucleic acids (DNA and RNA) carried out by the method cited by Mohamed and Capesius (1980).

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 (1991). Peroxidase (POD, EC 1.11.1.7) following the method of Macheix and Quessada (1984), and superoxide dismutases (SOD, EC 1.15.1.1) as described by Dhindsa *et al.* (1981).

Photosynthetic activity ($^{14}CO_2$–fixation).

Photosynthetic activity was measured in the Atomic Energy Authority, Radioisotope Department, Cairo, Egypt, with the method of Moussa (2011). The seedlings from each treatment were placed under a Bell jar, which was used as a photosynthetic chamber. Radioactive $^{14}CO_2$ was generated inside the chamber by a reaction between 10% HCl and 50 µCi (1.87×10^6 Bq) $NaH^{14}CO_3$ + 100 mg Na_2CO_3 as a carrier. Then the samples were illuminated with a tungsten lamp. After 30 min exposure time, the leaves were quickly detached from the stem, weighed and frozen for 5 min to stop the biochemical reactions, then subjected to extraction by 80% hot ethanol. The ^{14}C was assayed from the ethanolic extracts in soluble compounds using a Bray Cocktail (Bray, 1960) and a liquid scintillation counter (LSC2-Scaler Ratemeter SR7, Nuclear Enterprises, Edinburgh, UK).

Translocation efficiency of photoassimilates ($^{14}CO_2$–assimilation).

It was assayed according to Moussa (2011). The plants from each treatment were removed from the chamber and left for 2 and 4 h in the normal air to assimilate CO_2. After the assigned period had elapsed the leaves were quickly detached from the stem, weighed and frozen for 5 min to stop the biochemical reactions, then subjected to extraction by 80% hot ethanol. The ^{14}C was assayed from the ethanolic extracts by the same steps described in the photosynthetic activity.

Statistical analysis.

Statistical analysis was conducted using SPSS program Version 16. A student test (*t*-test) was done to find the significant differences between magnetic and nonmagnetic water treatments.

3. Results and Discussion

Treatment with magnetic water increased significantly the growth characteristics of common bean (fresh and dry weight of leaves, stem, and root) as compared to the control (Table 1). These results are correspondence with the result of Morejon *et al.* (2007). Aladjadjıyan (2002) showed that exposure of seeds of *Zea mays* has a favorable effect on the development of shoots in the early stages. Meanwhile, treatment with magnetic water had no effect on the water content as compared with the control (Mahmoud and Amira, 2010). 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 (Vashisth and Nagarajan, 2008) on chickpea. Regarding to yield, the results clear that total yield increased significantly when irrigation occurred by using magnetic water (Table 1). These results are the logical to improvement growth parameters, growth hormone, photosynthesis, and translocation efficiency. These results are in agreement with that of De Souza *et al.* (2006); Mahmoud and Amira (2010).

Table (1): Effects of magnetic water treatment on growth characteristics, water content, potassium, GA_3, kinetin, nucleic acids (RNA and DNA), H_2O_2 and malondialdehyde (MDA) contents in common bean plants. Data presented are the means of four separate experiments.

Treatments	Tap water	Magnetic water	*t*-sign
Fresh weight of stem (g)	9.518	14.583	**
Dry weight of stem (g)	0.726	0.998	*
Fresh weight of leaves (g)	6.718	10.052	**
Dry weight of leaves (g)	0.539	0.887	*
Fresh weight of root (g)	4.718	7.352	**
Dry weight of root (g)	0.225	0.763	**
Total yield/plant (g)	58	83	**
Water content (%)	69	68	ns
Potassium (mg/gDW)	88	93	*
GA_3 (µg/gFW)	86	113	**
Kinetin (µg/gFW)	68	95	**
RNA (µg/gFW)	80	104	**
DNA (µg/gFW)	47	53	*
H_2O_2 (µM/gFW)	2.1	2.0	ns
MDA (µM/gFW)	3.2	3.4	ns

*, ** *t* is Significant at the 0.05 and 0.01 levels, respectively, ns: non significant.

It was found out that chloroplasts have paramagnetic properties (Campbell, 1977). 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. Magnetic treatment of 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 (Amiri and Dadkhah, 2006; Otsuka and Ozeki, 2006). These changes in water properties may be capable of affecting the growth of plants. Magnetized water treatment increased significantly the GA_3 and kinetin contents as compared with the control (Table 1). Turker *et al.* (2007) showed that an increase in GA_3 in sunflower plants treated with magnetic water. Also, Mahmoud and Amira (2010) stated that, the treatment of wheat with magnetic water increase the cytokinine content which is effective on some events causing mitosis. The stimulatory effect of magnetic water in the nucleic acid contents (DNA and RNA) as compared with the control (Table 1), have also been reported (Ozge *et al.,* 2008; Mihaela *et al.,* 2009). However, H_2O_2 and MDA contents of plants treated with magnetic water seem to be non-significantly different as compared with the control plants (Table 1). Also, the magnetized water treatment exhibited an increase in the potassium content as compared with the control (Table 1). These results are in agreement with that of Harsharn *et al.* (2011); they observed an increase in potassium content in pea after irrigation with magnetic water. Also, Moussa (2001) demonstrated that, there is a direct effect of potassium upon translocation efficiency, because potassium ion 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 (Haeder *et al.,* 1981).

Irrigation with magnetic water exhibited marked significant increase in the photosynthetic pigments (chlorophyll *a*,chlorophyll *b*, and carotenoid), photosynthetic activity, and translocation efficiency of the photoassimilates over the control (Table 2). These results for increasing photosynthetic activity are in good agreement with that of (Atak *et al.,* 2003; Constantin *et al.,* 2003; Mihaela *et al.,* 2007; Mihaela *et al.,* 2009). They showed an increase in chlorophyll and carotenoid content specifically appeared after treatment with magnetic water. Irrigation with magnetic water increased significantly the translocation rate after 2 hr (62%) as compared with the control (28%). Also, the translocation rate after 4 hr by magnetized water increased significantly (77%) over the control (53%).

Table (2): Effects of magnetic water treatment on total chlorophyll (*a+b*), carotenoid, photosynthetic efficiency and translocation rate in common bean plants. Data presented are the means of four separate experiments. *kilo Becquerel (10^3 Bq).

Treatments	Tap water	Magnetic water	*t*-sign
Total chlorophyll (*a*+*b*) (mg/gFW)	3.8	5.9	**
Carotenoid (mg/gFW)	6.3	8.1	**
Photosynthetic activity (*KBq/mgFW)	55420	76459	**
Translocation efficiency after 2 hr (*KBq/mgFW)	40108	29418	**
Translocation rate (%)	28	62	**
Translocation efficiency after 4 hr (*KBq/mgFW)	26126	17893	**
Translocation rate (%)	53	77	**

*, ** *t* is Significant at the 0.05 and 0.01 levels, respectively, ns: non significant.

Table (3): Effects of magnetic water treatment on enzyme activities in common bean plants. Data presented are the means of four separate experiments.

Treatments	Tap water	Magnetic water	*t*-sign
Catalase (μMH_2O_2/min.gFW)	1.8	3.7	**
Peroxidase (units mg^{-1}protein)	7.7	10.2	**
Superoxide dismutases (units mg^{-1}protein)	2.8	5.1	**

*, ** *t* is Significant at the 0.05 and 0.01 levels, respectively, ns: non significant.

Irrigation with magnetized water caused a significantly increased in the activities of the antioxidant enzymes (catalase, peroxidase, and superoxide dismutase) over the control plants (Table 3). These results are in accordance of Pintilie *et al.* (2006). The magnetic field had a stimulation effect on peroxidase activity (Badea *et al.,* 2002) and superoxide dismutase (Hassan *et al.,* 2007). Opposite to this result

Hassan *et al.* (2007), stated that magnetic field treatment decreased the catalase activity in tobacco.

4. Conclusion

It appears that utilization of magnetized water (30 mT) can led to improve quantity and quality of common bean crop. It suggests that magnetic water could stimulate defense system, photosynthetic activity, and translocation efficiency of photoassimilates in common bean plants. We hope to attract the attention of scientific community to study this important phenomenon. Collaboration with physicists; biologists and physiologists are necessary in order to understand the mechanism of magnetic water action. Generally, using magnetic water treatment could be a promising technique for agricultural improvements but extensive research is required on different crops.

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