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, kinetin, nucleic acids (RNA and DNA), photosynthetic pigments (chlorophyll a, chlorophyll b, and carotenoid), photosynthetic activity (14CO2–fixation), and translocation efficiency of photoassimilates (14CO2–assimilation) as compared with control plants. Treatment with magnetized water had no significant effect on water content, malondialdehyde, and H2O2 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 lead 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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Key Words: Common bean, Magnetic water, Photosynthetic pigments, Photosynthesis

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; Aladjadjıyan, 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 (Aladjadjıyan 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, GA₃, Kinetin, nucleic acid (DNA and RNA), malondialdehyde, H₂O₂ 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. It was assayed according to Moussa (2011). The plants from each treatment were removed from the controlled-growth chamber and left for 2 and 4 h in the normal air to determine 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 (GA₃ and kinetin) were estimated by HPLC following the procedure of Shindy and Orrin (1975). To determine H₂O₂ concentration, the root extract was mixed with 0.1% titanium chloride in 20% (v/v) H₂SO₄. 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 H₂O₂ 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 (¹⁴CO₂–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 ¹⁴CO₂ was generated inside the chamber by a reaction between 10% HCl and 50 μCi (1.87×10⁶ Bq) NaH¹⁴CO₃ + 100 mg Na₂CO₃ 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 ¹⁴C 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 (¹⁴CO₂–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 CO₂. 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 ¹⁴C 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). Aladjadjyan (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 (Vashishth 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, GA₃, kinetin, nucleic acids (RNA and DNA), H₂O₂ and malondialdehyde (MDA) contents in common bean plants. Data presented are the means of four separate experiments.**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Tap water</th>
<th>Magnetic water</th>
<th>t-sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh weight of stem (g)</td>
<td>9.518</td>
<td>14.583</td>
<td>**</td>
</tr>
<tr>
<td>Dry weight of stem (g)</td>
<td>0.726</td>
<td>0.998</td>
<td></td>
</tr>
<tr>
<td>Fresh weight of leaves (g)</td>
<td>6.718</td>
<td>10.052</td>
<td>**</td>
</tr>
<tr>
<td>Dry weight of leaves (g)</td>
<td>0.539</td>
<td>0.887</td>
<td></td>
</tr>
<tr>
<td>Fresh weight of root (g)</td>
<td>4.718</td>
<td>7.352</td>
<td>**</td>
</tr>
<tr>
<td>Dry weight of root (g)</td>
<td>0.225</td>
<td>0.763</td>
<td>**</td>
</tr>
<tr>
<td>Total yield/plant (g)</td>
<td>58</td>
<td>83</td>
<td>**</td>
</tr>
<tr>
<td>Water content (%)</td>
<td>69</td>
<td>68</td>
<td></td>
</tr>
<tr>
<td>Potassium (mg/gDW)</td>
<td>88</td>
<td>93</td>
<td></td>
</tr>
<tr>
<td>GA₃ (µg/gFW)</td>
<td>86</td>
<td>113</td>
<td>**</td>
</tr>
<tr>
<td>Kinetin (µg/gFW)</td>
<td>68</td>
<td>95</td>
<td>**</td>
</tr>
<tr>
<td>RNA (µg/gFW)</td>
<td>80</td>
<td>104</td>
<td>**</td>
</tr>
<tr>
<td>DNA (µg/gFW)</td>
<td>47</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>H₂O₂ (µM/gFW)</td>
<td>2.1</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>MDA (µM/gFW)</td>
<td>3.2</td>
<td>3.4</td>
<td></td>
</tr>
</tbody>
</table>

*, **P 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 GA₃ and kinetin contents as
compared with the control (Table 1). Turker et al. (2007) showed that an increase in GA3 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, H2O2 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 \((10^3 \text{ Bq})\).

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Tap water</th>
<th>Magnetic water</th>
<th>t-sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total chlorophyll ((a+b)) (mg/gFW)</td>
<td>3.8</td>
<td>5.9</td>
<td>**</td>
</tr>
<tr>
<td>Carotenoid (mg/gFW)</td>
<td>6.3</td>
<td>8.1</td>
<td>**</td>
</tr>
<tr>
<td>Photosynthetic activity ((*\text{KBq/mgFW}))</td>
<td>55420</td>
<td>76459</td>
<td>**</td>
</tr>
<tr>
<td>Translocation efficiency after 2 hr ((*\text{KBq/mgFW}))</td>
<td>40108</td>
<td>29418</td>
<td>**</td>
</tr>
<tr>
<td>Translocation rate (%)</td>
<td>28</td>
<td>62</td>
<td>**</td>
</tr>
<tr>
<td>Translocation efficiency after 4 hr ((*\text{KBq/mgFW}))</td>
<td>26126</td>
<td>17893</td>
<td>**</td>
</tr>
<tr>
<td>Translocation rate (%)</td>
<td>53</td>
<td>77</td>
<td>**</td>
</tr>
</tbody>
</table>

*, ** 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.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Tap water</th>
<th>Magnetic water</th>
<th>t-sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Catalase ((\mu \text{MH}_2\text{O}_2/\text{min.gFW}))</td>
<td>1.8</td>
<td>3.7</td>
<td>**</td>
</tr>
<tr>
<td>Peroxidase ((\text{units mg}^{-1}\text{protein}))</td>
<td>7.7</td>
<td>10.2</td>
<td>**</td>
</tr>
<tr>
<td>Superoxide dismutases ((\text{units mg}^{-1}\text{protein}))</td>
<td>2.8</td>
<td>5.1</td>
<td>**</td>
</tr>
</tbody>
</table>

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


