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

Hameda El Sayed Ahmed El Sayed

Department of Biology, Faculty of Applied Science, Umm Al Qura University, Makkah Al Mukaramah, Kingdom of Saudi Arabia. E. Mail, heelsayed@uqu.edu.sa & E. Mail, D.Hameda@hotmail.com

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. FATENT 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. Magnetic water increased leaf area than that the tap water (control). 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+, Ca2+ and P3+) 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..

Keywords: Magnetic water, Growth, Chemical Composition and Yield Production of Broad Bean (Vicia faba L.) Plant. Nat Sci 2015;13(1):107-119. (ISSN: 1545-0740). http://www.sciencepub.net/nature. 16

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 (Aladjadjiyan, 2012). Irrigation with magnetized water increase seed germination (Ijaz et al., 2012). The water treated by the magnetic field or pass through a magnetic device called magnetized 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 (2011) showed magnetic treatment of seeds and irrigation had a potential to improve the early seedling growth and nutrient contents of seedlings. Utilization of magnetized 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 (Aladjadjiyan, 2002).

Some beneficial effects of the magnetic treatment of irrigation water for the plant yield and water productivity possibly suggested by Maheshwari and Grewal (2009). The understanding of the stimulating effect requires availability of rich experimental material (Aladjadjiyan, 2010). 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 (Mostafazadeh-Fard et al., 2011). Irrigation of common bean plants with magnetic water increased significantly the growth characteristics, potassium, GA3, kinetin, nucleic acids (RNA and DNA), photosynthetic pigments (chlorophyll a & b and carotenoid), photosynthetic activity and translocation efficiency of photoassimilates as compared with control plants (Moussa, 2011).

However, the available studies and application of this technology in agriculture is very limited. Therefore, the aim of the present work to study the effect of irrigation with magnetized water on growth, yield, yield components and some chemical constitute of broad bean (Vicia faba, L. cv. Giza 3) under greenhouse condition.

2. Material 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 hypochloride 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 twice a week interval with normal tap water on branches number/plant, pods number/plant, pods weight (g)/plant, seeds number/plant, total seeds (yield/plant), seeds yield weight (g)/plant and straw yield (g)/plant were recorded.

**Physiological Studies**

**Photosynthetic Pigments:**

Chlorophyll a, chlorophyll b and carotenoids) of leaves were determined spectrophotometrically as the method described by Metzner et al. (1965). An 85% aqueous acetone extract of a known F.W. of leaf was assayed Spectrometrically (LKB NOVASPEC) at 664, 645, 420 nm. The following equations were used to determined the concentration of the pigment fractions as γ/ml.

\[
\text{Chlorophyll a} = 10.3 E_{664} - 0.918 E_{645} \quad (4) \\
\text{Chlorophyll b} = 19.7 E_{645} - 3.870 E_{664} \quad (5) \\
\text{Carotenoids}=403 E_{452}-0.0264 \text{ Chl. a+0.426 Chl.b} \quad (6)
\]

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

**Photosynthetic Activity:**

Chloroplasts were prepared by the method of Aronoff (1949) and Osman, *et al.* (1982). 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 MgCl₂, 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 (Osman *et al.*, 1982). The levels of chlorophyll a & chlorophyll b were determined by the method described by Mackinney (1941). 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 was determined according to a modification of the method of Weatherly (1950); Slattery (1957); Weatherly and Barr (1962).

The relative water content (RWC%) was measured according to a modification of the method of Weatherly (1950); Slattery (1957); Weatherly and Barr (1962). Detached leaf samples were weight immediately and floated on distilled water in a darkened refrigerator (5°C). 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 80°C to constant weight in an air – circulation oven to constant weight. The relative water content of leaves was expressed according to the following equation:

\[
\text{R W C % (S. Wt. %)} = \left( \frac{\text{Oven D. Wt.}}{\text{F. wt.}} - \text{Oven D. Wt.} \right) \times 100 \quad (3)
\]

(Maturated Wt.- Oven D. Wt.)

**Magnetic Water and Yield Production:**

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

**Water Relations:**

**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 80°C after constant weight, and calculated as the following equation:

\[
\text{Succulence} = \frac{\text{F. Wt.}}{\text{Oven D. Wt.}} \quad (1)
\]

\[
\text{D M C %} = \left( \frac{\text{Oven D. Wt.}}{\text{F. Wt.}} \right) \times 100 \quad (2)
\]

**Measurement of Relative Water Content (Relative Turgidity):**

\[
\text{R W C %} = \left( \frac{\text{Oven D. Wt.}}{\text{F. wt.}} - \text{Oven D. Wt.} \right) \times 100 \quad (3)
\]
measured at 652 nm. The chlorophyll content was calculated according to the following equation:

\[ C = E_{652} \times 1,000/34.5 \text{ mg chl/L} \]  

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 spectrophotometrically (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}), 3.8 ml 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 ferricyanide mg chl^{-1} h^{-1} (Arnon and Shavit, 1963).

**Organic Components:**

**Carbohydrate:** 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 80°C for determination of polysaccharides (Naguib, 1963 & 1964).

**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 (Naguib, 1964). 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 (Nelson, 1944) 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).

**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 37°C for 0.5 hr. Thereafter, the reducing value was determined as described before for DRV (Naguib, 1963 & 1964). 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 28°C and then centrifuged. **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 (Naguib, 1963).

**Nitrogenous Components:**

**Proteins contents:**

Dry samples collected during the growth study were analyzed for protein content, after precipitation by precipitating the protein with 15% TCA at 4°C according to Lowry et al. (1951).

**Total Free Amino Acids contents:**

These were determined by the method described by Ya and Tunezaki (1966). An aliquot of 0.1 ml plant extract was heated in a test tube with 1.9 ml of ninyhydrin 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 standard curve obtained with 0.005 to 0.2 mM g Glycine.

**Proline contents:**

This was estimated using the acid ninhydrin method described by Bates et al. (1973). Two ml of water extract were mixed 10 ml of 3% aqueous sulfoalicylic 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 100°C; 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.

**Total indole acetic acid (IAA) as described by Bates et al. (1973), and total phenol, as described by Malik and Singh (1980), were estimated in the fresh shoots. 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) was 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
Magnetic water treatments: Growth parameters

Hozayn, 2010 a & b) and wheat (Hozayn and Abdul Maheshwari reported on snow pea and chick pea (Grewal and enhancing effect of magnetized irrigation water were tomato and common bean respectively. Similar increased leaf, stem and root fresh and dry weight of ma who observed that pretreatment of seeds with those of De Souza et al. 

| Growth Parameter Treatments | Plant Height (cm) | Leaf Area (Cm²/Leaf) | Fresh weight (g) | Dry weight (g) |
|-----------------------------|-------------------|----------------------|-----------------|---------------|
|                             |                   |                      | leaves          | stem          | root          | Total F. Wt. | leaves          | stem          | root          | Total D. Wt. |
| Tap water                   | 59.21             | 34.12                | 6.78            | 9.15          | 4.71          | 20.64        | 0.759           | 0.897         | 0.325         | 1.981        |
| Magnetic water              | 75.42             | 58.32                | 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.

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. (2006) and Moussa (2011) 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 were reported on snow pea and chick pea (Grewal and Maheshwari, 2011), flax and lentil (Abdul Qados and Hozayn, 2010 a & b) and wheat (Hozayn and Abdul Qados, 2010 b). 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 (Sadeghipour and Aghaei, 2013). Better root growth and development in young seedlings might lead to better root systems throughout the lifetime of a plant (De Souza et al., 2006).
Jones et al. (1986) found that the electromagnetic fields amplify the plant growth regulator induced Phenylnalanine 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 (Alexander and Doijode, 1995; Carbonell et al., 2000), on plant growth and development (De Souza et al., 1999; Martinez et al., 2000), on tree growth (Ruzic et al., 1998) and on crop yield (Pietruszewski, 1993); some review papers also mention a number of controversial, early results (Findlay and Hope, 1976; Frey, 1993).

**Magnetic Water and Water Relations:**

Data presented in Table (2), 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 (Amiri and Dadkhah, 2006; Otsuka and Ozeki, 2006). Sadeghipour and Aghaei (2013) 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. (2011) found that irrigation with magnetic water increased water use efficiency in jojoba and also Maheshwari and Grewal (2009) 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 (Hozayn and Abdul Qados, 2010a).

### Table (2): Impact of Magnetic Water Irrigation on Water Relations (Succulence, Dry Matter Content %, Relative Water Content %) of Broad bean (*Vicia faba*, L. Giza 3) plant.

| Water Relations | Succulence (F. W./D. W.) | Dry Matter Content (DMC) % (D.W./F.W. X100) | Relative Water Content (RWC)% (F.W.-D.W./F.W.-D.W. x100) |
|-----------------|--------------------------|---------------------------------|---------------------------------|
|                 | leaves | Stems | Roots | Total Plant | leaves | Stems | Roots | Total Plant | leaves | Stems | Roots | Total Plant |
| Tap water       | 8.93   | 10.2  | 14.49 | 10.42       | 11.12  | 9.8   | 6.9   | 9.6        | 75.07  | 80.49 | 71.43 | 80.32       |
| Magnetic water  | 8.17   | 10.6  | 13.02 | 10.10       | 12.25  | 9.43  | 7.60  | 9.91       | 82.19  | 86.83 | 81.51 | 83.23       |
| *F* values      | *      | N.S.  | *     | 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.

**Magnetic Water and Yield Production:**

Data presented in Table (3) 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, were increased significantly compared to control treatment (tap water). 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); Hozayn and Abdul Qados (2010a). 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 (Vashisth and Nagarajan, 2008).

### Table (3): Impact of Magnetic Water Irrigation on Yield Production of Broad Bean (*Vicia faba*, L. Giza 3) Plants.

| Yield Parameter Treatments | Branches No./Plant | Pods No./Plant | Pods Wt. (g/Plant) | Wt. (g) | Seeds No./Plant | 100 Seeds Wt. (g) | Seeds Yield g/plant | Straw Yield g/Plant |
|---------------------------|-------------------|---------------|-------------------|--------|----------------|-------------------|---------------------|-------------------|
| Tap water                 | 4.61              | 5.1           | 2.12              | 66.13  | 66.13          | 10.82             | 7.91                | 5.81              |
| Magnetic water            | 5.82              | 6.9           | 2.75              | 22.11  | 22.11          | 17.65             | 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.
Magnetic Water and Photosynthetic Pigments, Chloroplast activity:

Results presented in Table (4) 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. (2003); Constantin et al. (2003); Mihaela et al. (2007); Mihaela et al. (2009) they showed an increase in chlorophyll content and carotenoids content specifically appeared after treatment with magnetic water. Sadeghipour and Aghaei (2013) 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. (2006); Hoff (1981) and Davies (1996) also revealed an increase in photosynthetic rate and influx of water as a result of magnetic treatments.

Table (4): Impact of Magnetic Water Irrigation on Chloroplast Pigments (Chlorophyll a, Chlorophyll b, Carotenoids) and Photosynthetic Efficiency of Broad Bean (Vicia faba, L. Giza 3) Plants.

| Treatments | Chloroplast Pigments (mg/100 g F. W.) | Photosynthetic efficiency Chloroplast activity (μmol fericyanide mg chl⁻¹ h⁻¹) |
|------------|--------------------------------------|---------------------------------------------------------------------------------|
| Tap water  | Chlorophyll a 5.14, Chlorophyll b 2.32, Chl. a + Chl. b 7.46, Carotenoids 4.03, Total Pigments 11.49, Photosynthetic activity 68.95% | N.S. ***                                                                         |
| Magnetic water | Chlorophyll a 7.04, Chlorophyll b 3.87, Chl. a + Chl. b 10.91, Carotenoids 4.59, Total Pigments 15.50, Photosynthetic activity 93.81% | **                                                                             |
| 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.

Organic Components:
Total Available Carbohydrates:

In these investigation, irrigated broad bean plant with magnetic water increased significantly total available carbohydrates (Monosaccharide, Disaccharides, polysaccharides) contents compared to irrigated with tap water as shown in Table (5). 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 (De Souza et al., 2006). 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 (Aladjadjiyan, 2010).

Table (5): 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.

| Carbohydrates treatments | DRV (Glucose) (mg glucose/100gDW) | TRV- Sucrose (mg glucose /100gDW) | Polysaccharides (mg glucose /100gDW) | Total Available Carbohydrates (TAC) (mg glucose /100gDW) |
|-------------------------|-----------------------------------|----------------------------------|-------------------------------------|--------------------------------------------------------|
|                         | leaves | Stems | Roots | Total Plant | leaves | Stems | Roots | Total Plant | leaves | Stems | Roots | Total Plant | leaves | Stems | Roots | Total Plant |
| Tap water               | 250.1  | 220.3 | 190.4 | 660.8       | 306.6  | 290.9 | 186.8 | 778.3       | 69.5   | 65.4  | 45.9  | 180.8       | 620.2  | 643.4 | 423.1 | 1686.7       |
| Magnetic water          | 325.3  | 260.2 | 201.4 | 786.9       | 360.7  | 340.4 | 191.5 | 892.6       | 89.9   | 82.7  | 65.4  | 238.0       | 775.9  | 683.3 | 458.3 | 1917.5        |
| F values                | **     | **    | N.S.  | **          | **     | **    | N.S.  | **          | **     | **    | 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.
Protein, Total Amino Acids, Proline Contents:

Results presented in Table (6) 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.

Table (6): 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.

| Nutrogenous Components | Treatments    | Total Proteins (mg/100g DW) | Total Amino Acids (mg/100g DW) | Proline (mg/100g DW) |
|------------------------|---------------|-----------------------------|-------------------------------|----------------------|
|                        |               | leaves | Stems | Roots | Total Plant | leaves | Stems | Roots | Total Plant | leaves | Stems | Roots | Total Plant |
| Tap water              |               | 15.32  | 10.43 | 6.54  | 32.29       | 7.91   | 7.54  | 3.27  | 18.72       | 3.93   | 4.02  | 3.98  | 11.93       |
| Magnetic water         |               | 17.86  | 13.03 | 7.76  | 38.65       | 13.52  | 13.01 | 5.87  | 32.40       | 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 (2000) found that IAA effect on DNA replication. Moreover, Celik et al. (2008) and Shabrangi and Majd (2009) 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 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 (Pittman,1972; Gubbels,1982; Vakharia et al., 1991; Pietruszowski, 1993; Namba et al., 1995; Atak et al., 1997; Özalpan et al., 1999; Yurttas et al., 1999; Pietruszowski 1999 a & b; Reina et al., 2001; Oldaçay and Erdem, 2002; Takac et al., 2002; Cmobarac et al., 2002; Marinkovic et al., 2002). 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. This results are in line with Hozayn and Abdul Qados (2010a). In this respect, Celik et al. (2008) 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 (2009) concluded that, biomass increasing needs metabolic changes particularly increasing protein biosynthesis. It was found out that chloroplasts have paramagnetic properties (Campbell, 1977).

Total Phenols, Total Indole:

Also, from these results recoded in Table (7), 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 (Goodman et al., 1995; Atak et al., 2003; Moussa, 2011).

Table (7): Impact of Magnetic Water Irrigation on Total Indole, Total Phenol, GA3, Kinetin, Nucleic Acids (RNA and DNA) Contents of Broad Bean (Vicia faba, L. Giza 3) Plants.

| Treatments       | Growth regulators | Total Indole (μg/100gFW) | Total Phenol (μg/100gFW) | GA3 (μg/g FW) | 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. *** = *** = P < 0.001 and N.S. = Not Significant. Data presented are the means of five replicate.

**GA3, Kinetin contents:**

Data presented in Table (7) showed that the irrigation of broad bean plant by magnetic water increased significantly the GA3 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. (2007) showed that an increase in GA3 in sunflower plants treated with magnetic water. Also, Hozyan and Abdul Qados (2010b) 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. (1991) and Atak et al. (2000 and 2003) who found an increase in chlorophyll content specifically appeared after exposure to a magnetic field for a short time. Moreover, Atak et al. (2003) 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 (Tian et al., 1991 and Nasher, 2008). As well as the improvement of photosynthetic pigments were recorded in Paulowria species (Atak et al., 2000), sunflower (Oldocay and Erdem, 2002), soy bean (Atak et al., 2003) when seeds or explants exposed to magnetic field (3.8 – 4.8 mt) for a short time.

**Nucleic acid (DNA and RNA):**

The results presented in Table (7) 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. (2008); Mihaela et al. (2009); Moussa (2011).

**Antioxidant Enzymes:**

**Catalase, Peroxidase, and Superoxide Dismutase:**

Data presented in Table (8) 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. (2006); Moussa (2011). The magnetic field had a stimulation effect on peroxidase activity (Badea et al., 2002) and superoxide dismutase (Hassan et al., 2007; Moussa, 2011). Opposite to this result Hassan et al. (2007) stated that magnetic field treatment decreased the catalase activity in tobacco.

Table (8): Impact of Magnetic Water Irrigation on antioxidant (enzyme activities) in Broad Bean (Vicia faba, L. Giza 3) Plants.

| Antioxidants   | Catalase (μH2O2/min. g F.W.) | Peroxidase (units mg-1 protein) | Superoxide dismutases (units mg-1 protein) |
|----------------|-------------------------------|---------------------------------|--------------------------------------------|
| Treatments     |                               |                                 |                                            |
| Tap water      | 1.32                          | 6.91                            | 2.93                                       |
| Magnetic water | 3.76                          | 11.32                           | 6.52                                       |

$F$ values: ** = P < 0.01. 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 (9): Impact of Magnetic Water Irrigation On Inorganic Minerals (K⁺, Na⁺, K⁺/Na⁺ Ratios, Ca²⁺, P³⁻) Contents as (mg/100 g D.W.) In All Parts Of Broad Bean (Vicia faba, L. Giza 3) Plants.

| Inorganic Minerals | Treatments | K⁺ (mg/100g D.W.) | Na⁺ | K⁺/Na⁺ Ratio | Ca²⁺ (mg/100g D.W.) | P³⁻ (mg/100g D.W.) |
|--------------------|------------|------------------|-----|--------------|---------------------|-------------------|
| Seeds              | Tap water  | 56.26            | 14.78 | 3.81         | 67.41               | 11.31             |
|                    | Magnetic water | 66.26          | 13.78 | 4.81         | 83.41               | 13.15             |
| F values           | *          | **               |       | **           | **                  | **                |
| Leaves             | Tap water  | 77.47            | 20.48 | 3.98         | 63.44               | 6.46              |
|                    | Magnetic water | 85.57          | 19.48 | 4.18         | 81.44               | 7.36              |
| F values           | ***        | *                | N.S.  | **           | N.S.                |                   |
| Stems              | Tap water  | 69.57            | 11.48 | 6.06         | 35.43               | 3.23              |
|                    | Magnetic water | 75.57          | 9.48  | 7.97         | 45.43               | 5.13              |
| F values           | *          | **               | N.S.  | **           | **                  |                   |
| Roots              | Tap water  | 57.39            | 15.65 | 4.31         | 39.90               | 3.23              |
|                    | Magnetic water | 63.39          | 10.65 | 5.95         | 49.90               | 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.

Inorganic Mineral Elements:

However, data presented in Table (9) indicated that the irrigation of broad bean plant by magnetic water exhibited an increase in potassium, calcium, phosphorus 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. (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 (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 (Haeder et al., 1981).

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 research 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 improvement 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.

Corresponding Author:
Dr. Hameda El Sayed Ahmed El Sayed
Department of Biology, Faculty of Applied Science, Umm Al Qura University, Makkah Al Mukaramah, Kingdom of Saudi Arabia.
E. Mail, heelsayed@uqu.edu.sa & E. Mail, D.Hameda@hotmail.com

References
1. Abdul Qados, A. M. S.; Hozayn, M. (2010a). Response of growth, yield, yield components and some chemical constituents of flax for irrigation with magnetized and tap water. World Applied Science Journal 8 (5), 630 - 634.
2. Abdul Qados, A. M. S.; Hozayn, M. (2010b). Magnetic water technology, a novel tool to increase growth, yield and chemical constituents of lentil under greenhouse condition. American-Eurasian Journal of Agriculture and Environmental Sciences 7 (4), 457 - 462.
3. Aladjadjiyan, A. (2002). Study of the influence of magnetic field on some biological characteristics of Zea mais. Journal of Central European Agriculture, 3(2): 89 - 94.

4. Aladjadjiyan, A. (2010). Influence of stationary magnetic field on lentil seeds. International Agrophysics, 24, 321-324.

5. Aladjadjiyan, A. (2012). Physical factors for plant growth stimulation improve food quality, food production-approaches, challenges and tasks, Anna Aladjadjiyan (Ed.), ISBN: 978-953-307-887-8, In Tech Publisher, Rijeka, Croatia, 270 p.

6. Alexandre, M. P. and Doijode, S. D. (1995). Electromagnetic field, a novel tool to increase germination and seedling vigour of conserved onion (Allium cepa L.) and rice (Oryza sativa L.) seeds with low viability. Plant Genetic Resources Newsletter, 104, 1-5.

7. Al-Khazan, M.; Abdullatif, B. M.; Al-Assaf, N. (2011). Effects of magnetically treated water on water status, chlorophyll pigments and some elements content of Jojoba (Simmondsia chinensis L.) at different growth stages. African Journal of Environmental Science and Technology 5 (9), 722-731.

8. Allen, S.; Grimshay, H. M.; Parkin Son, J. A.; Quarmby, C. (1974). Chemical Analysis of Biological Materials. Blackwell Scientific Publications, Osney, Oxford, London, p 565.

9. Amiri, M. C.; Dadkhah, A. A. (2006). On reduction in the surface tension of water due to magnetic treatment. Colloids Surf A Physicochem Eng. Aspects, 278: 252–255.

10. Arnon, M. M.; Shavit, N. (1963). A sensitive and simple methods for determination of ferricyanide. Anal. Biochem., 6 : 549 – 554.

11. Aronoff, S. (1949). Photochemical reduction of chloroplast grana. Journal of Plant Physiology, 21: 393 – 409.

12. Atak, Ç.; Danilov, V.; Yurttaslı, B.; Yalçın, S.; Mutlu, D.; Rzakoulieva, A. (1997). Effects of magnetic field on soybean (Glycine max L.Merrill) seeds. Com JINR. Dubna, 1-13.

13. Atak, Ç.; Danilov, V.; Yurttaslı, B.; Yalçın, S.; Mutlu, D.; Rzakoulieva, A. (2000). Effect of magnetic field on Paulownia seeds. Com JINR. Dubna. 1-14.

14. Atak, Ç.; Emiroğlu, Ö.; Alikamanoğlu, S.; Rzakoulieva, A.; (2003). Stimulation of regeneration by magnetic field in soybean (Glycine max L. Merrill) tissue cultures. J. Cell and Mol. Biol., 2: 113–119.

15. Bates, L. S.; Waldren, R. P.; Teare, I. D. (1973): Rapid determination of free proline for water stress studied. Plant and Soil, 39 : 205 – 207.

16. Badea, E.; Babeanu, C.; Marinescu, G.; Corneanu, G. C.; Comeanu, M. (2002). Peroxidases as monitors of very low magnetic field effects, VI International Plant Peroxidase Symposium (3–7, July 2002) S5- P10.

17. Belyavskaya, N. A. (2001). Ultrastructure and calcium balance in meristem cells of pea roots exposed to extremely low magnetic field. Adv. Space Res., 28 (4): 645–650.

18. Bliss, C. I. (1973). Plant Protection. No. 12. Leningrad.

19. Cakmak, I.; Horst, W. J. (1991). Effect of aluminum on lipid peroxidation, superoxide dismutase, catalase and peroxidase activities in root tips of soybean (Glycine max). Plant Physiol., 83: 463–468.

20. Campbell, G.S. (1977). An introduction to environmental biophysics. Springer-Verlag, N.Y.,USA.

21. Carbonell, M. V.; Martinez, E.; Amaya, J. M. (2000). Stimulation of germination in rice (Oryza sativa L.) by a static magnetic field. Electro-Magnetobiol., 19(1):121–128.

22. Celik, O.; Atak, C.; Rzakulieva, A. (2008). Stimulation of rapid regeneration by a magnetic field in paulownia node cultures. Journal of Central European Agriculture 9 (2), 297-304.

23. Constantin, V.; Lucia, P.; Daniela, A.L. (2003). The influence of the magnetic fluids on some physiological processes in Phaseolus vulgaris. Rev. Roum. Biol. Veget., 48(1–2): 9–15.

24. Crnobarc, J.; Marinkovic, B.; Tatic, M.; Malesevic, M., (2002). The effect of REIS on startup growth and seed yield of sunflower and soybean. Biophysics in agriculture production, University of Novi Sad, Tamnogaf.

25. Davies, M. S. (1996). Effects of 60 Hz electromagnetic fields on early growth in three plant species and a replication of previous results. Bioelectromagnetics 17, 154-161.

26. De Souza, A.; Casate, R.; Porras, E. (1999). Effect of magnetic treatment of tomato seeds (Lycopersicon esculentum Mill.) on germination and seedling growth [in Spanish]. Invest Agr: Prod. Prot. Veg., 14(3): 67-74.

27. De Souza, A.; Garci, D.; Sueiro, L.; Gilart, F.; Porras, E.; Licea, L. (2006). Presowing magnetic treatments of tomato seeds increase the growth and yield of plants. Bioelectromagnetics, 27: 247–257.

28. Dhindsa, R. A.; Dhindsa, P. P.; Thorpe, T. A. (1981). Leaf senescence correlated with increased permeability and lipid peroxidation and decreased levels of superoxide dismutase and catalase. J. Exp. Bot., 126: 93–101.
29. Findlay, G. P.; Hope, A. B. (1976). Electrical properties cells: methods and findings. In: Encyclopedia of Plant Physiology, Vol. 2A (Luttge U., Pittman M. G., eds), Springer-Verlag, Berlin. 53-92 pp.

30. Formicheva, V. M.; Govorun, R. D.; Danilov, V. T. (1992a). Proliferative activity and cell reproduction in the root meristem of pea, lentil and flax in the conditions of screening the geomagnetic field. Int. Biophysics. 37: 645-648.

31. Formicheva, V. M.; Zaslavskii, V. A.; Govorun, R. D.; Danilov, V. T. (1992b). Dynamics of RNA and protein synthesis in the cells of the root meristem of the pea, lentil and flax. Biophysics., 37: 649-656.

32. Frey, A. H. (1993). Electromagnetic field interactions with biological systems. FASEB J., 7, 272-281.

33. Goodman, E. M.; Greenabaum, B.; Morrion, T. M. (1995). Effects of electromagnetic fields on molecules and cells. International Review of Cytology, 158: 279-325.

34. Grewal, H. S.; Maheshwari, B. L. (2011). Magnetic treatment of irrigation water and snow pea and chickpea seeds enhances early growth and nutrient contents of seedlings. Bioelectromagnetics, 32, 58-65.

35. Gubbels, G. H. (1982). Seedling growth and yield response of flax, buckwheat, sunflower and field pea after preseeding magnetic treatment. Can. J. Plant Sci., 62: 61-64.

36. Haeder, H. E.; Beringer, H. (1981). Influence of potassium nutrition and water stress on the content of abscisic acid in grains and flag leaves of wheat during grain development. J. Sci. Food Agric., 32: 552–556.

37. Harsharn S. Grewal; Basant, L. (2011). Magnetic treatment of irrigation water and snow pea and chickpea seeds enhances early growth and nutrient contents of seedlings. Bioelectromagnetics, 32: 58-65.

38. Hassan., S.; Parviz, A.; Faezeh, G. (2007). Effects of magnetic field on the antioxidant enzyme activities of suspension–cultured tobacco cells. Bioelectromagnetics, 28: 42–47. Henson IE, Mahalakshmi V, Bidinger FR and Alagars-

39. Hilal, M. H.; Hilal, M. M. (2000). Application of Magnetic Technologies in Desert Agriculture: I-Seed germination and seedling emergence of some crops in a saline calcareous soil. Egypt. J. Soil Sci., 40, (3): 413-423.

40. Hoff, A. J. (1981). Magnetic field effects on photosynthetic reactions. Quarterly Reviews of Biophysics 14 (4), 599-665.

41. Hogland, D. R.; Arnon, I. I. (1950). The water culture method for growing plants without soil. Journal Circular. California Agricultural Experiment Station.Vol. 347 No. 2nd edit pp. 32.

42. Hozayn, M.; Abdul Qados, A. M. S. (2010a). Irrigation with magnetized water enhances growth, chemical constituent and yield of chickpea (Cicer arietinum L.). Agriculture and Biology Journal of North America 1 (4), 671-676.

43. Hozayn, M.; Abdul Qados, A. M. S. (2010b). Magnetic water application for improving wheat (Triticum aestivum L.) crop production. Agriculture and Biology Journal of North America vol.1 (4): 677-682.

44. Hsu, Y. T.; Kao, C. H. (2007). Cadmium-induced oxidative damage in rice leaves in reduced by polyamines. Plant Soil. 291: 27–37.

45. Ijaz, B.; Jatoi, S. A.; Ahmad, D.; Masood, M. S.; Siddiqui, S. (2012). Changes in germination behavior of wheat seeds exposed to magnetic field and magnetically structured water. African Journal of Biotechnology 11 (15), 3575-3582.

46. Johnson; Ulrich (1959). Analytical methods for use in plant analysis. U.S. Dept. Agric. California University. Agriculture, Information, Bulletin, 766.

47. Jones, D. B.; Bolwell, G. P.; Gilliat, G. J. J. (1986). Amplification, by pulsed Electromagnetic fields, of plant growth regulator induced Phenylalanine Ammonia-Lyrase during differentiation in suspension cultured plant cells. Bioelectromagnetics, 5 (1): 1-12.

48. Kuba, M.; Kakimoto, T. (2000). The cytokinin hyposensitive genes of Arabidopsis negatively regulate the cytokinin signalling pathway for cell division and chloroplast development. The Plant J. 23(1): 385-394.

49. Larsen, P.; Harbo, A.; Klungron, S.; Ashen, T. A. (1962). On the bioinductive properties cells: methods and findings. In: Encyclopedia of Plant Physiology, Vol. 2A (Luttge U., Pittman M. G., eds), Springer-Verlag, Berlin. 53-92 pp.

50. Lowry, O. H.; Rosebrough, N. J.; Farr, A.; Randail, R. T. (1951). Protein measurement with Folin Phenol Reagent. Journal of Biological Chemistry, 193 : 265 – 275.

51. Macheix, J. J.; Quessada, M. P. (1984). Caractérisation d’une peroxydase impliquée spécifiquement dans la lignification, en relation avec l’incompatibilité au greffage chez l’abricotier. Physiologie Végétale, 22: 533–540.

52. Mackinney, G. (1941): Absorption of light by chlorophyll solutions. Journal of Biological Chemistry. 140 : 315 – 322.
53. Madhava Rao, K. V.; Sresty, T. V. (2000). Antioxidative parameters in the seedlings of pigeon pea (Cajanus cajan L. Millspaugh) in response to Zn and Ni stresses. Plant Sci., 157: 113–128.

54. Maheshwari, B.L.; Grewal, H.S. (2009). Magnetic treatment of irrigation water: Its effects on vegetable crop yield and water productivity. Agricultural Water Management 96, 1229-1236.

55. Malik, C. P.; Singh, M. B. (1980). Plant Enzymology and Histoe-nyzymology. Kalyani Publishers. New Delhi. Marinkovic B., Ilin Z., Marinkovic J., Culibrk M.; Jacimovic electromagnetic field. Biophysics in agriculture production. University of Novi Sad, Tomograf.

56. Marinkovic, B.; Ilin, Z.; Marinkovic, J.; Culibrk, M.; Jacimovic, G. (2002). Potato yield in function variable electromagnetic field. Biophysics in agriculture production. University of Novi Sad, Tomograf.

57. Martinez, E.; Carbonell, M. V.; Amaya, J. M. (2000). A static magnetic field of barley (Hordeum vugare L.). Electro and Magnetobiol., 19: 271-277.

58. Metzner, H., Rau, H.; Senger, H. (1965). Untersuchun-gen zur synchronisier-barkeit einzelner pigment angel-mutanten von chlorella. Planta J., 65 : 186 – 194.

59. Mihaela, R.; Dorina, C.; Carmen, A. (2007). Biochemical changes induced by low frequency magnetic field exposure of vegetal organisms. Rom. J. Phys., 52(5–7): 645–651.

60. Mihaela, R.; Simona, M.; Dorina, E. C. (2009). The response of plant tissues to magnetic fluid and electromagnetic exposure. Romanian J. Biophys., 19(1): 73–82.

61. Miller, R. O. (1998). Nitric-perchloric acid wet digestion in an open vessel, Handbook of Reference Methods for Plant Analysis, Kalra, Y.P., Ed., Boca Raton: CRC, pp 57–61.

62. Mohamed, Y.; Capesius, I. (1980). Wirking von Gibberellinsaure und Fd Ud auf die Menge und die Zusammensetzung der DNA wahrend des streichungswachstum von Pisum sativum. Z. Pflanzen Physiol., 98: 15–23.

63. Morejon, L. P.; Castro, J. C.; Velazquez, L. G.; Govea, A. P. (2007). Simulation of pinus tropicalis M. seeds by magnetically treated water. Int Agrophys., 21: 173–177.

64. Mostafazadeh-Fard, B.; Khoshravesh, M.; Mousavi, S.; Kiani, A.(2011). Effects of magnetized water and irrigation water salinity on soil moisture distribution in trickle irrigation. Journal of Irrigation and Drainage Engineering 137 (6), 398-402.

65. Moussa, H. R. (2001). Physiological and biochemical studies on the herbicide (Dual) by using radiolabelled technique. PhD thesis, Ain Shams University, Egypt.

66. Moussa, H. R. (2011). The impact of magnetic water application for improving common bean (Phaseolus vulgaris L.) production. New York Science Journal 4 (6), 15-20.

67. Naguib, M. I. (1963). Colorimetric estimation of plant polysaccharides. Zucker, 16: 15 – 18.

68. Naguib, M. I. (1964). Effect of seven on the carbohydrate and nitrogen metabolism during germination of cotton seeds. Indian Journal of Experimental Biology, 2: 149-152.

69. Namba, K.; Sasao, A.; Shibusawa, S. (1995). Effect of magnetic field on germination and plant growth. Acta Horticulture, 399: 143-147.

70. Nasher, S. H. (2008). The Effect of magnetic water on growth of chickpea seeds. Eng. & Tech. 26(9):4 pages.

71. Nelson, N. (1944) A photometric adaptation for somagi method for determination of glucose. Journal of Biological Chemistry, 153-275.

72. Oldacay, S.; Erdem, G. (2002). Evaluation of chlorophyll contents and peroxides activities in I (Helianthus annuus L.) genotypes exposed to radiation and magnetic field. J. of Appl. Sci., 2 (10): 934-937.

73. Otsuka, I.; Ozeki, S. (2006). Does magnetic treatment of water change its properties?. J. Phys. Chem., 110: 1509–1512.

74. Özalpan, A.; Atak, C.; Yurttas, B.; Alikamanoglu, S.; Canbolat, Y.; Borucu H.; Danilov V.; Rzakoulieva A. (1999). Effect of magnetic field on soybean yield (Glycine max L. Merrill). Turkish Association of Biophysics, XI National Biophysics Congress, Abstract Book, pp: 60.

75. Özge, Ç.; Çimen, A.; Aitekin, R. (2008). Stimulation of rapid regeneration by a magnetic field in Paulownia node cultures. J. Cent. Eur. Agric., 9(2): 297–304.

76. Pietruszewski, S. T. (1999 a). Effect of alternating magnetic field on germination, growth and yield of plant seeds. Int. Agrophysics, 5 (11): 209-215.

77. Pietruszewski, S. T. (1999 b). Influence of pre-sowing magnetic biostimulation on germination and yield of wheat. Int. Agrophysics, 13, 241-244.
79. Pietruszweski, S. (1993). Effects of magnetic seed treatment on yields of wheat," Seed Sci. Technol., 21, 621-626.
80. Pintilie, M.; Oprica, L.; Surleac, M.; Dragut Ivan, C.; Creanga, D. E.; Artenie, V. E. (2006). Enzyme activity in plants treated with magnetic liquid. Rom. J. Phys., 51(1–2): 239–244.
81. Pittman, U. J. (1972). Biomagnetic responses in potatoes. Can J Plant Sci., 52: 727-733.
82. Reina, F. G.; Pascual, L. A.; Fundora, I. A. (2001). Influence of a stationary magnetic field on water relations in lettuce seeds. Part II: Experimental Results. Bioelectromagnetics, 22: 596–602.
83. Richards, L. A. (1954). Diagnosis and Improvement of Saline and Alkali Soil, (ed.) U.S. Salinity Laboratory. U. S. Dept. Agric. Hand Book 60.
84. Ruzic, R.; Jerman, I.; Gogala, N. (1998). Water stress reveals effects of ELF magnetic fields on the growth of seedlings. Electro- and Magnetobiology, 17: 17-30.
85. Sadeghipour, O.; Aghaei, P. (2013). Improving the growth of cowpea (Vigna unguiculata, L. Walp.) by magnetized water. Journal of Bio. & Env. Sci. vol. 3 (1): 37-43.
86. Sekine, T. Sasakawa, Morita, S., Kimara, T. and Kuratomi, K. (1972). Cf. Laboratory Manual for Physiological studies of Rice Eds. S. Yashida, D. Foeno, J. N. Cook and K. A. Gomez, Publ. by International Rice Research Institute Manila.
87. Shabrangi, A.; Majd, A. (2009). Effect of magnetic fields on growth and antioxidant systems in agricultural plants, PERS Proceedings, Beijing, China, March, 23-27.
88. Shindy, W.; Orrin, S. (1975). Identification of plant hormones from cotton ovules, Plant Physiol., 55: 550–554.
89. Slattery, R. O. (1957). The influence of progressive increases in total soil moisture stress on transpiration, growth and internal water relationships of plants. Aust. J. Biot. Sa. Vol. 10: pp 320-336.
90. Snedecor, G. W.; Cochran, W. B. (1967) Statistical Methods. 6 Ed. Iowa State University Press.
91. Takac, A.; Gvozdenovic, G.; Marinkovic, B. (2002). Effect of resonant impulse electromagnetic stimulation on yield of tomato and pepper. Biophysics in agriculture production, University of Novi Sad, Tampograff.
92. Tian, W.X.; Kuang, Y.L.; Me, Z.P. (1991). Effect of magnetic water on seed germination, seedling growth and grain yield of rice. Field Crop Abstracts. 044-07228.
93. Turker, M.; Temirci, C.; Battal, P.; Erez, M. E. (2007). The effects of an artificial and static magnetic field on plant growth, chlorophyll and phytohormone levels in maize and sunflower plants. Phyton Ann. Rei. Botanicae, 46: 271–284.
94. Vakharia, D. N.; Davariya, R. L.; Parameswaran, M. (1991). Influence of magnetic treatment on groundnut yield and attributes. Indian J. Plant Physiol. XXXIV: 131-136.
95. Vashisth, A.; Nagarajan, S. (2008). Exposure of seeds to static magnetic field enhances germination and early growth characteristics in chickpea (Cicer arietinum L.). Bioelectromagnetics, 29: 571–578.
96. Weatherly, P. E. (1950): Studies in the water relation of cotton plants. I- The field measurement of water deficits in leaves. New Phytol. Vol. 49. Pp:81-97.
97. Weatherly, P. E.; Barr, C. (1962): Examination of the relative turgidity technique for estimating water deficits in leaves. Aust. J. Biol. Sci. Vol.15(3).pp:413-418.
98. Ya, P. L.; Tunekazu, T. (1966): An improved colorimetric determination of amino acids with the use of ninhydrin. Anal. Biochem., 14 : 71 – 77.
99. Yurttas, B.; Atak, C.; Gökdoan, G.; Canbolat, Y.; Danilov, V.; Rzakoulieva A. (1999). Detection of the positive effect of magnetic field on sunflower plants (Helianthus annuus L.). Turkish Association of Biophysics, XI National Biophysics Congress, Abstract Book, pp: 59.

1/16/2015
Improved agronomical practices for faba bean crops, such as crop establishment and plant density, fertilization and irrigation regime, weed, pest and disease management, harvesting time, and harv... The global production of faba bean grain in 2014 was 4.1 million tons, which is approximately 21% greater than in 1994 (FAO, 2017). The fresh and dry seeds of faba bean are used for human consumption; they are highly nutritious because they have a high protein content (up to 35% in dry seeds), and are a good source of many nutrients, such as K, Ca, Mg, Fe, and Zn (Lizarazo et al., 2015; Longobardi et al., 2015; Neme et al., 2015). Waterlogging, e.g., during flowering, limits faba bean growth and yield (Pampana et al., 2016). El Sayed HESA (2014) Impact of magnetic water irrigation for improve the growth, chemical composition and yield production of broad bean (Vicia faba L.) plant. Am J Exp Agric 4(4):476â€“496 CrossRef Google Scholar. Ghanati F, Payez A (2015) Iron biofortification and activation of antioxidant system of wheat by static magnetic field. Hozayn M, Qados AMSA (2010) Irrigation with magnetized water enhances growth, chemical constituent and yield of chickpea (Cicer arietinum L.). Agric Biol J Am 1(4):671â€“676 Google Scholar. Hozayn M, El Monem AAA, Abdelraouf RE, Abdallah MM (2013) Do magnetic affect water use efficiency, quality and yield of sugar beet (Beta vulgaris L.) plant under arid region condition? J Agron 12(1):1â€“10 CrossRef Google Scholar. Faba bean (Vicia faba L) is a widely cultivated legume grain, known for its great potential for yield and high protein contents (i.e., 25â€“40%) (Matthews and Marcellos, 2003). The capability of faba bean to grow under limited irrigation (Khalafallah et al., 2008; Al-Suhaibani, 2009; Alderfasi and Alghamdi, 2010) and moderate salinity (Khalafallah et al., 2008; Abdelhamid et al., 2010) has made it one of the most preferred crops for agricultural production in arid and semiarid lands. However, many studies have indicated that the nitrogen nutritional status of faba bean possessed positive impacts on its ...