Magnetic Fields Induce Changes in Photosynthetic Pigments Content in Date Palm *(Phoenix dactylifera* L.) Seedlings

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Abstract: Growth, development and plants productivity are usually affected by photosynthetic pigments activity. Magnetic fields are known to induce biochemical changes and could be used as a stimulator for growth related reactions including affecting photosynthetic pigments. The impact of magnetic field strengths on chlorophyll and carotenoids were investigated in this study through the use of date palm (*Phoenix dactylifera* L.) seedlings. To study the effects of magnetic treatments on photosynthetic pigments, date palm seedlings were exposed to magnetic fields in two experiments. In the first experiment, seedlings were treated with static magnetic field at three levels of (10, 50 and 100 mT) and different durations (30, 60, 180, 240 and 360 min). At the second experiment, seedlings were treated with alternating magnetic field at 1.5 T for different durations (1, 5, 10 and 15 min). The photosynthetic pigments (chlorophyll a, chlorophyll b, carotenoids and total pigments) were assayed using spectrophotometric methods. Results indicated that pigments content (chlorophyll a, chlorophyll b, carotenoids and total pigments) was significantly increased under static magnetic field. The highest measurements were recorded at 100 mT, after 360 min of exposure. On the other hand, alternating magnetic field has decreased photosynthetic pigments content after 10 min of treatment with 1.5 T. Low magnetic field doses had a simulative effect on photosynthetic pigments whereas high doses had a negative effect. Chlorophyll a and carotenoids were more affected than chlorophyll b**.** Magnetic fields treatment could be used to enhance plant growth and productivity**.**

Keywords: Date palm, magnetic field, photosynthetic pigments, chlorophyll, carotenoids.

INTRODUCTION

All living processes are highly dependent on energy exchange between cell and environment. Magnetic field (MF) became a part of the environment and source of energy, thereby effects normal metabolisms [1] and has impact on meristem cell division [2]. In addition MF affects water absorption, preservation and ionization [3]. Forces generated by MF may cause magnetophoresis in macromolecules [4]. Metabolic substances as plants photosynthetic pigments could be affected by MF. It has been found that an increase occurs in chemical reactions of plants under MF, which has a positive effect on photochemical activity, respiration ratio and enzyme activity [5-7]. Chlorophyll a is the most important assimilatory pigment involved directly in the conversion of solar energy into chemical energy at the molecular level, thus chlorophyll content is an indicator of plant health and productivity. Similarly, carotenoids play an important role in protecting plants through scavenging reactive oxygen [8], which is known to be increased by MF [9-11]. Previous studies showed that photosynthetic pigments may increase or decrease under MF conditions. Chloroplasts have paramagnetic properties which means that magnetic field of magnetic moments of atoms in them are affected by MF and oriented downwards the field direction [12]. Moreover, MF has an effect over photochemical activity, for example, the rate of CO_2 uptake in radish (*Raphanus sativus* L.) was reduced following exposure to MF [13].

The objective of this study was to evaluate pigments content in date palm (*Phoenix dactylifera* L.) in response to various intensities and durations of magnetic fields, which is to the best of the authors knowledge has never been studied so far. Results could be used in agriculture developments research, and could make magnetic field a growth enhancer.

MATERIALS AND METHODS

Plant Material

Date palm seeds (cv. Khalas) were sterilized with 1% sodium hypochlorite for 5 min. Soaked in water for 24 h, then germinated on moist filter paper at 37°C. Seedlings placed in 9 cm petri dishes at age of 15 days, 7 seedlings per dish, were subjected to either static magnetic field (SMF) or alternating magnetic field (AMF). After treatment, each seedling was planted in 20-cm plastic pots containing potting mix (1 soil: 1 peat moss: 1 vermiculate) and maintained in greenhouse under natural light at temperature of 30 ± 41°C and relative humidity of 50%.

The SMF was applied using an electromagnetic circuit constructed by Dr. Essam Hassan, Electrical Engineering Department, King Fahd University of Petroleum and Minerals (KFUPM), Saudi Arabia. Inductions of SMF used at

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three levels (10, 50 and 100 mT), and exposure duration at 6 levels (0, 30, 60, 180, 240 and 360 min). The magnetic circuit consisted of two coils; each coil consist of 480 turns per coil wound on carbon steel and loaded by variable currents to achieve variable magnetic field intensities. The pole pieces cross section is made with 10 cm internal diameter to enable placing the 9 cm petri dish horizontally. The experiment was setup as a 3×6 factorial design with two main factors, SMF intensity at three levels (10, 50 and 100 mT) and exposure duration at 6 levels (0, 30, 60, 180, 240 and 360 min) with 7 replications for each treatment. A total of 126 seedlings were used in this experiment.

The AMF was applied using magnetic resonance imaging (MRI) device (General Electric, USA). The frequency used for exposure has variation from 0.01 to 63000 Hz, carried alternating current at 220 V with magnetic flux at 1.5 T (1500 mT). Samples were treated for 0, 1, 5, 10 and 15 min. This experiment involved a single factor at 5 levels (0, 1, 5, 10 and 15 min) with 7 replications for each treatment. A total of 35 seedlings were used for this experiment. All chemical analysis was conducted 7 times.

Estimation of Photosynthetic Pigments

Photosynthetic pigments were extracted according to Arnon method [14]. Date palm leaf samples (0.5 g) were ground using mortar and pestle in 5 ml of 80% acetone, then filtered through No. 2 Whatman filter paper. The developed color was measured at three-wave lengths 470, 646 and 663 nm, using UV/ VIS spectrophotometer Model V-530, Jasco, International Co Ltd, Tokyo, Japan). The amounts of pigments were calculated according to Lichtenthaler and Wellburn [15] simultaneous equations:

$$\text{Chlorophyll a } (\mu g/ml) = 12.21\ A_{663} - 281\ A_{646}$$

$$\text{Chlorophyll b } (\mu g/ml) = 20.13\ A_{646} - 5.03\ A_{663}$$

$$\text{Carotenoids } (\mu g/ml) = \frac{1000\ A_{470} - 3.27[\text{Chl a}] - 104\ [\text{Chl b}]}{227}$$

Total pigments = chlorophyll a + chlorophyll b + carotenoids

$$\text{Pigments yield } (\mu g/g \text{ fresh weight}) = \frac{\text{volume used}}{\text{weight used}} \times 100$$

Total pigments = chlorophyll a + chlorophyll b + carotenoids

Statistical Analysis

The statistical analysis of the data was performed using analysis of variance (ANOVA) and the means were separated using the least significant difference (LSD) at 5%.

RESULTS

The current study shows that photosynthetic pigments are significantly affected by the SMF two factors (the intensity and the exposure duration) as indicated by the significant two-way interaction based on ANOVA (Table **1**) (at $p<0.05$). Chlorophyll a, chlorophyll b, carotenoids and total pigments concentration increased significantly as SMF intensity increased (Fig. **1A-C**); however, the significant increased for photosynthetic pigments at low dose treatment at 10 mT started after 180 min of SMF exposure; whereas at 50 mT; short exposure for 30 min was sufficient to increase photosynthetic pigments significantly; the highest values for photosynthetic pigments observed at 100 mT; prolonged exposure time increased the pigments level significantly.

Table 1. Analysis of Variance of Photosynthetic Pigments Influenced by Two Types of Magnetic Fields

Factor	df	MS	F	P*
Static Magnetic Field				
Carotenoids				
Intensity	2	17.038	82.064	0.0001
Time	5	5.982	28.812	0.0001
Intensity X Time	10	0.987	4.753	0.0001
Error	108	0.208		
Chlorophyll b				
Intensity	2	24.756	86.141	0.0001
Time	5	9.817	34.160	0.0001
Intensity X Time	10	1.494	5.197	0.0001
Error	108	0.287		
Chlorophyll a				
intensity	2	244.843	370.81	0.0001
Time	5	74.452	112.76	0.0001
Intensity X Time	10	11.242	17.02	0.0001
Error	108	0.66		
Total pigments				
Intensity	2	612.29	486.63	0.0001
Time	5	200.83	159.61	0.0001
Intensity X Time	10	29.95	23.81	0.0001
Error	108	1.62		
Alternating Magnetic Field				
Carotenoids				
Time	4	3.065	12.12	0.0001
Error	30	0.2526		
Chlorophyll b				
Time	4	1.6030	6.7435	0.0005
Error	30	0.2377		
Chlorophyll a				
Time	4	10.791	16.239	0.0001
Error	30	0.665		
Total pigments				
Time	4	39.058	29.526	0.0001
Error	30	1.324		

* Data are the results obtained of each treatment replicated 7 times; $p < 0.05$ considered significant.

The effect of AMF was significantly influenced by exposure time at $p<0.05$ (Table **1**). The highest level of photosynthetic pigments noticed at 1 min of AMF treatment, followed by a significant decreased at 5-15 min of AMF exposure

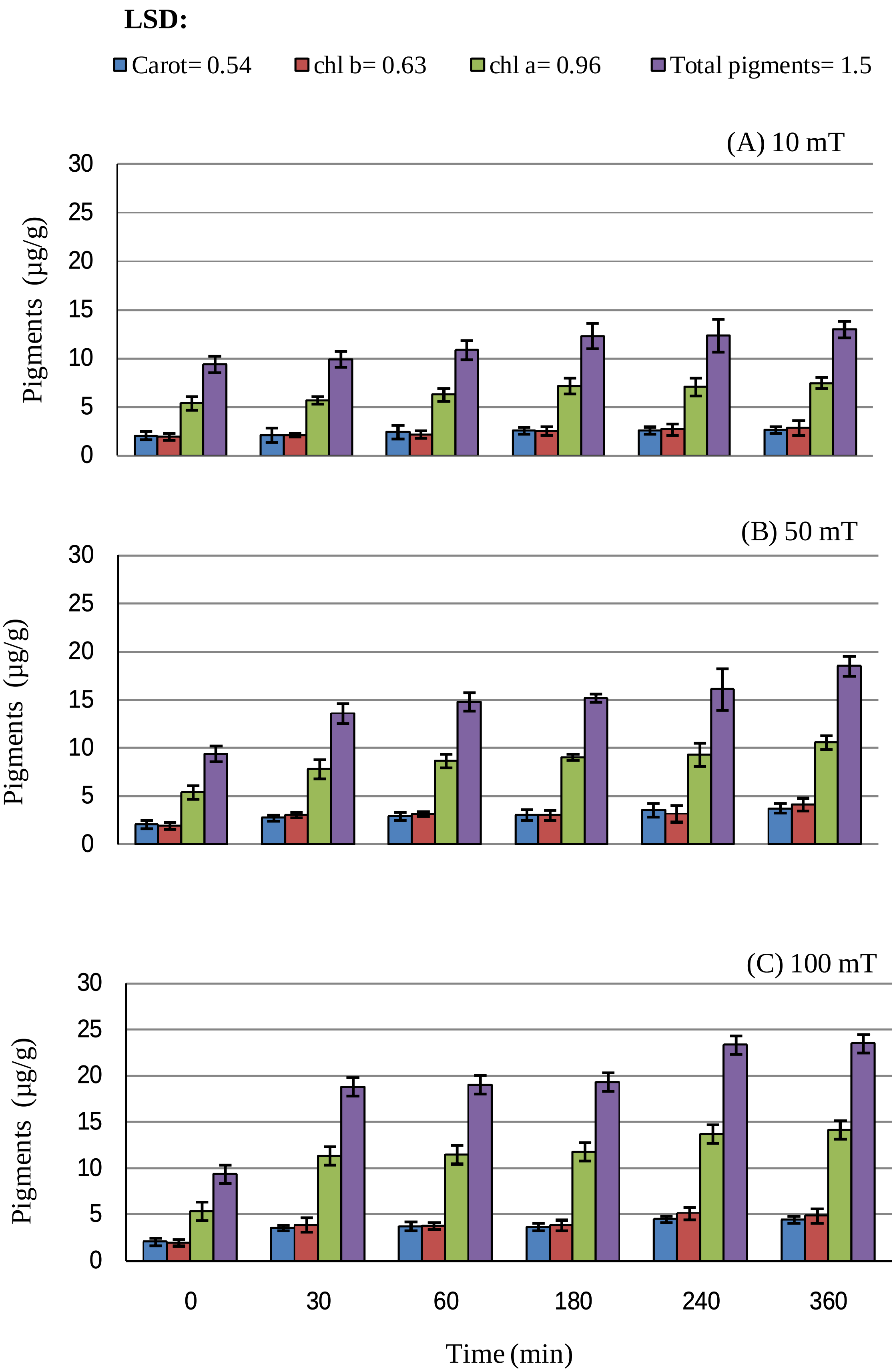

Fig. (1). Photosynthetic pigments content affected by static magnetic field. The relationship between static magnetic field and pigments content for different exposure (**A**: 10 mT, **B**: 50 mT, **C**: 100 mT) and durations (30, 60, 180, 180, 240 and 360 min). Means ± SD, *n* = 7.

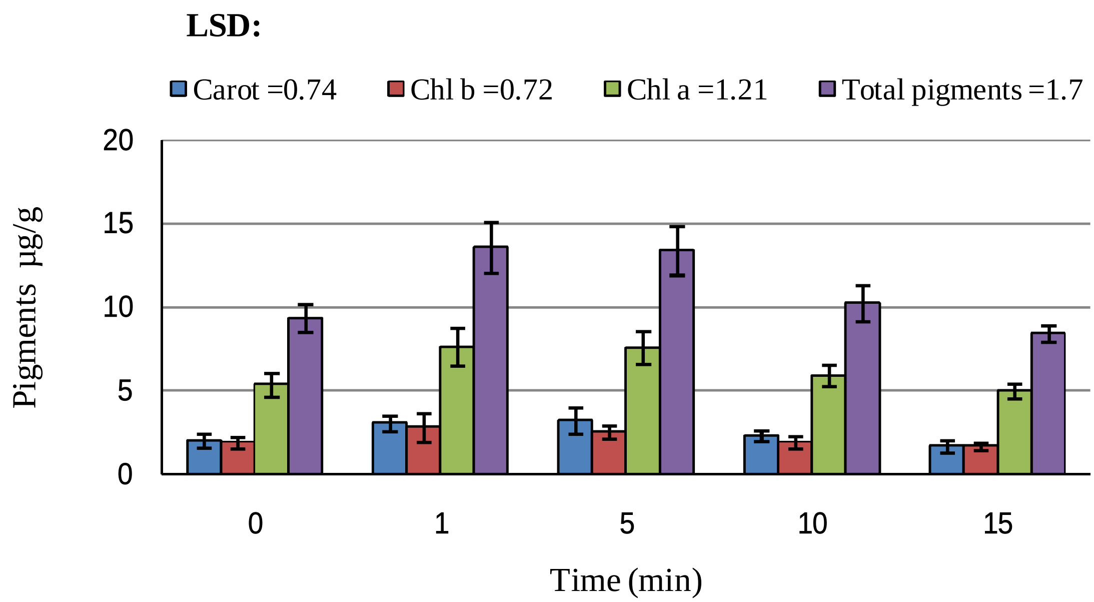

Fig. (2). Photosynthetic pigments content affected by alternating magnetic field. The relationship between alternating magnetic field and pigments content for different durations 1, 5, 10 and 15 min. Means ± SD, $n = 7$.

(Fig. **2**). In contradiction to SMF results, increasing exposure time has a negative impact on pigments level under AMF treatments.

DISCUSSION

The MF could increase an inner energy which is distributed among the atoms causing accelerated metabolism [12]. The humidity which allows ions to mobilize is one of the factors that make the absorbed MF energy to be effective [16]. Increasing ions mobility and ions uptake improved under MF which leads to a better photo stimulation and growth [16]. Moreover, MF has the ability to change water properties, thus magnetized water increased rice chlorophyll content [17]. The condition of humidity was available in seedlings in the present study. Static magnetic fields at the range of 10-100 mT and exposures for 30-630 min have increased photosynthetic pigments significantly. Similar to Racuciu *et al.* study who reported that long MF exposure has the ability to increase assimilatory pigments [18]. This fact was confirmed by several studies for different plants; where MF treatment increased the chlorophyll content in sugar beet (*Beta vulgaris* L.) leaves [19] and content of chlorophyll a, b and carotenoids in potato (*Solanum tuberosum* L.) [20]. Additionally, studies by Atak *et al*. [21, 22] involving MF impact on soybean (*Glycine max* L.) confirmed that MF significantly increased chlorophyll a, chlorophyll b and total chlorophyll contents. The SMF intensities used in the present study were relatively low.

Alternating magnetic field intensity was high enough to cause photo-pigments inhibition at prolonged durations. Whereas, MF short exposure is accompanied with increases in chlorophyll a, chlorophyll b and total chlorophyll contents [23]. Similarly, longer exposure decreased the level of photosynthetic pigments in *Zea mays* L. [24] and *Robinia pseudoacacia* L. seedlings [18]. Photosynthetic pigments decreased could be due to the effect of MF on the reduction in plastids inside the cells [3]. The reduction of pigments explained by Commoner *et al*. [25], that chemical with unpaired electrons posses a magnetic moment which plays an important role in electron transfer and kinetics of chemical reactions. The electrons with magnetic moments can be oriented in the external MF. As a result of the interaction between the external MF and the magnetic moment of unpaired electrons, the energy is absorbed. Chloroplasts have magnetic moments and could be affected by the absorbed energy at a high dose of MF which can disturb the pigments synthesis. Other possible explanations for the decline in pigments content are that carotenoids may be consumed in radical scavenging reactions [8], or free radicals inhibited the synthesis through affecting photosynthesis enzymes. In conclusion, MF could be used as a stimulator for growth related reactions. Photosynthetic pigments content have shown a significant increase in response to magnetic fields at low dose. Short exposure to alternating magnetic field had a positive impact, whereas long exposure had a negative effect on pigments content similar to MF effect on proline [26]. Using magnetic field treatment could be a promising technique for agricultural improvements but extensive research is required, using different levels of magnetic field doses to determine the optimum dose.

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REFERENCES

[1] Aladjadjiyan A. The use of physical methods for plant growing stimulation in Bulgaria. J Cent 2007; 8: 369-80.

[2] Belyavskaya NA, Fomicheva VM, Govorun RD, Danilov VI. Structural-functional organisation of the meristem cells of pea, lentil and flax roots in conditions of screening the geomagnetic field. Biophysics 1992; 37: 657-66.

[3] Taia W, Al-Zahrani H, Kotbi A. The effect of static magnetic forces on water contents and photosynthetic pigments in sweet basil *Ocimum basilicum* L. (*Lamiaceae*). Saudi J Bio Sci 2007; 14: 103-7.

[4] Paul A, Robert F, Meisel M. High magnetic field induced changes of gene expression in arabidopsis. BioMag Res Technol 2006; 4: 7.

[5] Phirke PS, Patil NN, Umbarkar SP, Dudhe YH. The application of magnetic treatment to seeds: methods and responses. Seed Sci Technol 1996; 24: 365-73.

[6] Martinez E, Carbonell MV, Amaya JM. A static magnetic field of 125 mT stimulates the initial growth stages of barley *(Hordeum vulgare* L.). Electro Magnetobiol 2000; 19: 271-7.

[7] Carbonell MV, Martinez E, Amaya JM. Stimulation of germination in rice (*Oryza sativa* L.) by a static magnetic field. Electro Magnetobiol 2000; 19:121-8.

[8] Strzalka K, Kostecka-Guga A, Latowski D. Carotenoids and environmental stress in plants: significance of carotenoid-mediated modulation of membrane physical properties. Russ J Plant Physiol 2003; 50: 168-73.

[9] Scaiano JC, Cozens FL, McLean J. Model of the rationalization of magnetic field effects *in vivo*. Application of radical-pair mechanism to biological systems. Photochem Photobiol 1994; 59: 585-9.

[10] Sahebjamei H, Abdolmaleki P, Ghanati F. Effects of magnetic field on the antioxidant enzyme activities of suspension-cultured tobacco cells. Bioelectromagnetics 2007; 28: 42- 7.

[11] Abdolmaleki P, Ghanati F, Sahebjamei H, Sabet Sarvestani A. Peroxidase activity, lignification and promotion of cell death in tobacco cells exposed to static magnetic field. Enviromentalist 2007; 27: 435-40.

[12] Campbell GS. An introduction to environmental biophysics. Springer-Verlag, NY, USA, 1977.

[13] Yano A, Ohashi Y, Hirasaki T, Fujiwara K. Effects of a 60 Hz magnetic field on photosynthetic CO_2 uptake and early growth of radish seedlings. Bioelectromagnetics 2004; 25: 572-81.

[14] Arnon ID. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in Beta vulgaris. Plant Physiol 1949; 24: 1-15.

[15] Lichtenthaler HK, Wellburn AR. Determinations of total carotenoids and chlorophylls a and b of leaf extracts in different solvents. Biochem Soc Trans 1983; 11: 591 -2.

[16] Pietruszewski S. Influence of pre-sowing magnetic biostimulation on germination and yield of wheat. Int Agrophys 1999; 13: 241-4.

[17] Tian WX, Kuang YL, Mei ZP. Effect of magnetic water on seed germination, seedling growth and grain yield of rice. J Jilin Agric Univ 1989; 11: 11-6.

[18] Racuciu M, Creanga DE, Galugaru CH. The influence of extremely low frequency magnetic field on tree seedlings. Rom J Phys 2008; 35: 337-42.

[19] Rochalska M. Influence of frequent magnetic field on chlorophyll content in leaves of sugar beet plants. Nukleonika 2005; 50: 25-8.

[20] Rakosy-Tican L, Aurori CM, Morariu VV. Influence of near null magnetic field on *in vitro* growth of potato and wild Solanum species. Bioelectromagnetics 2005; 7: 548-57.

[21] Atak C, Emiroglu O, Alikamanoglu S, Rzakoulieva A. Stimulation of regeneration by magnetic field in soybean (*Glycine max* L. Merrill) tissue cultures. J Cell Mol Biol 2003; 2: 113-9.

[22] Atak C, Celik O, Olgun A, Alikamanolu S, Rzakoulieva A. Effect of magnetic field on peroxidase activities of soybean tissue culture. Biotechnology 2007; 21: 166-71.

[23] Atak C, Danilov V, Yurttafl B, Yalçin S, Mutlu D, Rzakoulieva A. Effect of magnetic field on *Paulownia* seeds. Com JINR Dubna 2000; 1-14.

[24] Racuciu M, Creanga DE, Amoraritei C. Biochemical changes induced by low frequency magnetic field exposure of vegetal organisms. Rom J Phys 2007; 52: 601-6.

[25] Commoner B, Heise JJ, Townsend J. Light-induced paramagnetism in chloroplasts. Proc Natl Acad Sci USA 1956; 42: 710-14.

[26] Dhawi F, Al-Khayri JM. Proline accumulation in response to magnetic fields in date palm *(Phoenix dactylifera* L.). Open Agri J 2008; 2*:* 80-8.

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