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REGULAR ARTICLE

The effect of magnetic resonance imaging on date palm (*Phoenix dactylifer*a L.) elemental composition

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ABSTRACT

In the last decade work with magnetic fields (MF), has become a common practice in modern life. The ability of a magnetic field to penetrate everything around its source, including living cells, has become a central point of the research. Studies show that MF affects biochemical processes and increases ion uptake, which leads to better plant growth. The goal of this study was to determine if the type of magnetic field, used in magnetic resonance imaging, has the potential to induce useful effects on plant nutrition. Seedling of date palm (*Phoenix dactylifera* L.) established on filter paper for 15 days were exposed to magnetic resonance imaging (MRI) with an intensity of 1500 mT for 0, 1, 5, 10 and 15 min. After treatment, seedlings were grown in soil for 4 weeks. Tissue samples were then analyzed for their elemental composition using inductive couple plasma spectroscopy (ICP). The elements measured were Mg, Ca, Na, P, K, Fe, Mn and Zn. The results showed that increasing exposure, from 1 to 15 min increased the concentration of Ca, Mg, Mn, Fe, Na and Zn, but decreased P concentration compared to the control. Increasing the ion content may improve date palm nutrition suggesting that MRI may have potential as a plant growth enhancer.

Key Words: *date palm; element; inductive couple plasma; magnetic resonance imaging; seedling*.

INTRODUCTION

Biological system display specific magnetic "life" with a characteristic rhythm; thus the magnetic situation, in a biological system, is analogous to a reducing-oxidizing system (Sedlak, 2006). Magnetic fields (MFs) release free radicals (Scaiano et al., 1994), which have an important role in electron transfer and chemical reactions. These free radicals possess non-paired electrons with magnetic moments that can be oriented in an external magnetic field, owing to the interaction between the external magnetic field and the magnetic moment of unpaired electrons (Goodman et al., 1995; Goodman and Blank, 2002). Free radicals, which are known to be enhanced by magnetic treatment, are involved in stimulating protein and enzyme activity (Kurinobu and Okazaki, 1995; Morar et al., 1999). Moreover, MFs induce energy that is distributed among the atoms (Campbell, 1977) and causes accelerated metabolism and consequently better germination (Aladjadjiyan, 2002).

Magnetic field beneficial effects on plants have been discussed for more than a decade (Wojcik, 1995; Aladjadjiyan and Ylieva, 2003; Esitken and Turan 2003). Treatment with a MF creates conditions for molecular transformations and as a result, necessary substances are provided to the cell. This is the core concept of "quantum agriculture" (Aladjadjiyan, 2007). Magnetic fields have a highly stimulating effect on cell multiplication, growth and development (Yokatani et al., 2001). Several studies have shown that MF flux and exposure time positively or negatively affects different features of plants (Aladjadjiyan and Ylieva, 2003; Valiron et al., 2005). Some studies reported that MF had a positive effect on the number of flowers and total yield (Matsuda et al., 1993; Danilov et al., 1994; Samy, 1998; Podlesny et al., 2005), seed germination percentage and nutrient uptake (Esitken and Turan 2003). In addition, application of an MF to irrigation water was shown to increase plant nutrient content (Moon and Chung, 2000). Therefore, MF could be used to substitute or to reduce the need for chemical additives, thus reducing toxins in raw materials and raising the level of food biosafety.

Magnetic resonance imaging (MRI) is a medical tool and a source of magnetic and electromagnetic fields (EMF) (Jin and Jin, 1998). It is thought that any biological effects of the electromagnetic field are only due to the magnetic component (Kangarlu and Robitaille, 2000). An alternating magnetic field (AMF) is generates by MRI. The effect of this type of MF on ionic composition has been studied by Esitken and Turan (2003) in strawberry (*Fragaria* x *ananassa*). However, the effect of MRI on ion accumulation in date palm has never been mentioned in specialty literature. This was the principal motivation for our study with MFs that add to previous studies and is used as an alternative method for improving date palm (*Phoenix dactylifera* L.) productivity.

MATERIALS AND METHODS

PLANT MATERIAL AND EXPOSURE TO MAGNETIC FIELD

Date palm seed (cv. Khalas) was sterilized with 1% sodium hypochlorite for 5 min soaked in water for 24 h at 37°C and then germinated on moist filter paper. Seedlings were placed in 9 cm Petri dishes at 15 d and were subjected to a MF using an MRI device (General Electric, Wisconsin, USA) at King Fahd medical Military Complex (KFMMC). The frequency used for exposure varied from 0.01 to 63,000 Hz, carried alternating current at 220 V with a magnetic flux at 1.5 T (1,500 mT). Samples were treated for 0, 1, 5, 10 and 15 min. After treatment, each seedling was sown in a 20-cm plastic pot containing potting mix (1 soil: 1 peat moss: 1 vermiculite) and kept in a greenhouse under natural light at 30 - 41°C and a relative humidity of approximately 50%.

ANALYZING AND MEASURING ELEMENTS

Elements in the date palm plants were measured using Inductive Couple Plasma-Atomic Emission Spectroscopy (ICP-AES) (Varian-Liberty- ICP-OES series II, USA). Leaves were oven dried at 70ºC for 24 h using a vacuum oven (Duo-Vac oven Lab Line, 3620 Vacuum Oven, Michigan, USA). A microwave assisted digestion system was used to extract elements from leaf samples in a closed microwave system (Zarcinas et al., 1987; Ryan, 2005). The dried samples were digested by weighing 0.25 g of sample into a Teflon® PFA lined microwave digestion vessel and adding 3 ml of 10 M HNO3 (Merck Tracepur) and 1 ml of H2O. Microwave digestion was applied at a power of 600 Watt and a pressure of 350 (Pa) in two stages, first at 120 ºC for 3 min and second at 200 ºC for 10 min. Following digestion, solutions were cooled and transferred to 25 ml volumetric flasks, and diluted to volume with deionized water.

The experiment had 7 replicates, at 5 levels (0, 1, 5, 10 and 15 min). Statistical analysis of the data was based on analysis of variance (ANOVA). Means were separated, where appropriate, using the least significant difference (LSD) at 5%.

RESULTS AND DISCUSSION

The effect of MRI was significantly influenced by exposure time ($P < 0.05$) (Table 1). Macro elements were significantly affected by MRI treatment, the concentration of Ca and Mg increased significantly after 1 min exposure whereas the P concentration decreased significantly at the same dose (Figure 1). The microelements Mn, Fe and Zn also increased significantly with prolonged MRI exposure. A significant ($P < 0.0001$) increase was noticed after 1 min of exposure for Mn, Fe and Zn (Figure 2). The K:Na ratio was also significantly affected by MRI treatment compared with the control, K and Na were highest after 15 min MRI treatment (Figure 3).

Table 1. Analysis of variance of ions accumulation under effect of magnetic resonance imaging in date palm leaves.

Factor	df	MS	F	p
Calcium				
Time	4	4388332	211.72	0.0001
Error	30	20727		
Magnesium				
Time	4	775286	90.70	0.0001
Error	30	8548		
Manganese				
Time	4	1549	129.189	0.0001
Error	30	12		
Phosphorus				
Time	4	854709	40.57	0.0001
Error	30	21066		
Potassium				
Time	4	684272	70.46	0.0001
Error	30	9712		
Sodium				
Time	4	261811	32.51	0.0001
Error	30	8052		
Iron				
Time	4	1065.03	168.67	0.0001
Error	30	6.31		
Zinc				
Time	4	537.04	80.672	0.0001
Error	30	6.66		

In this study, increasing MRI exposure from 0 to 15 min increased date palm Ca content. This is similar to the study of Belyavskaya (2001) who found that MF caused Ca over-saturation in all organelles and the cytoplasm of pea (*Pisum sativum* L.). Magnetic fields exert a strong, and reproducible effect, by reducing apoptosis in several cell systems (Fanelli et al.,

1999) and indirectly cause stress by enhancing the release of free radicals (Parola et al., 2006). This effect is mediated by the MF's ability to increase Ca influx, which participates in many plant growth processes and responses to stress (Trewavas and Malho, 1998).

Stange et al. (2002) emphasized that 50-60 Hz and 10-100 mT magnetic fields cause changes in the permeability of the plasma membrane of Vicia faba L. tip cells and alter ion movement across the membrane. Esitken and Turan (2003) reported that MF increased ion uptake, consequently MF could increase osmotic pressure. The Na:K ratio which balances osmotic pressure in the plant is also affected by MRI treatment. The content of K and Na is increased. It is suggested that electrophoretic segregation of charged components in the outer leaflet of the cell membrane is responsible for enhanced adsorption and stimulation of macromolecule uptake (Antov et al., 2005), which balance osmotic pressure by the K and Na pump.

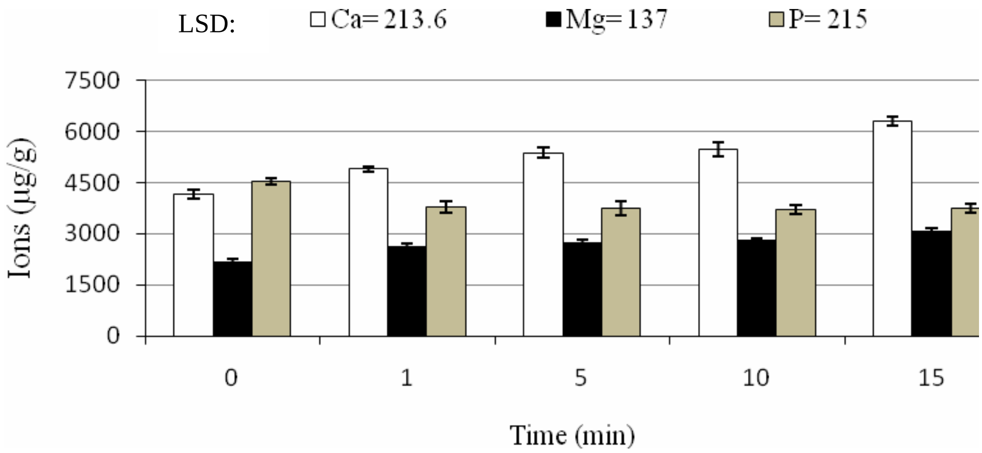

Figure 1. The effect of magnetic resonance imaging for 0, 1, 5, 10 and 15 min on Ca, Mg and P level in date palm leaves. Mean ± SD, n = 7.

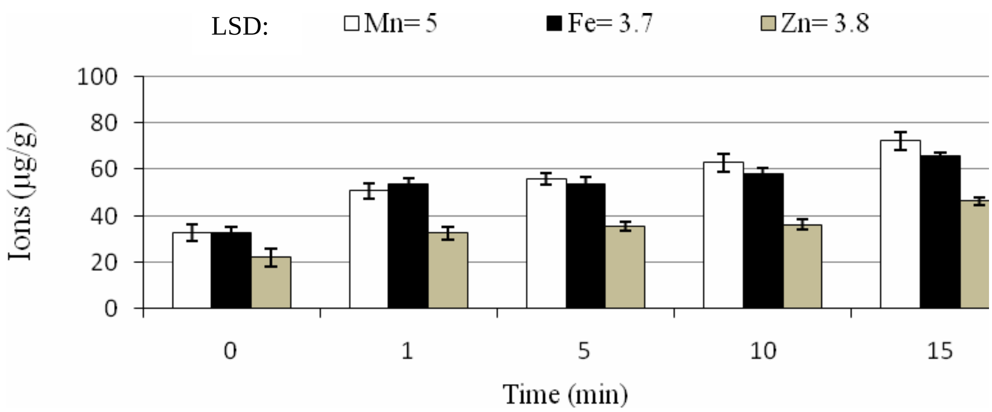

Figure 2. The effect of magnetic resonance imaging for 0, 1, 5, 10 and 15 min on Mn, Fe and Zn level in date palm leaves. Mean ± SD, n = 7.

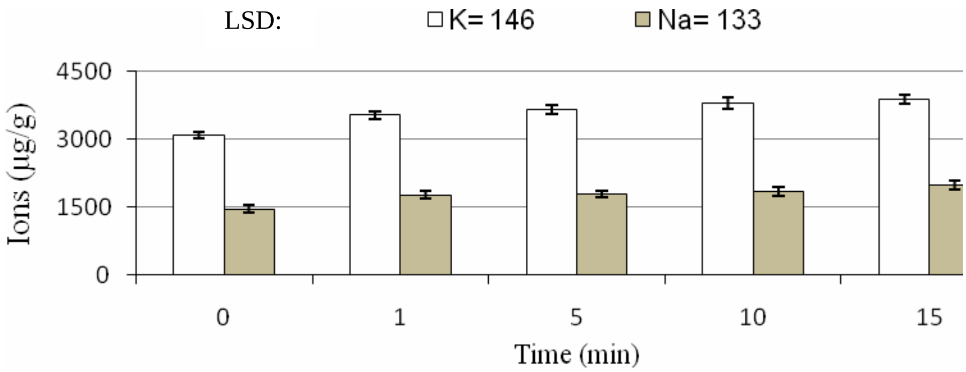

Figure 3. The effect of magnetic resonance imaging for 0, 1, 5, 10 and 15 min on the K:Na ratio in date palm leaves. Mean ± SD, n = 7.

Additionally, microelements such as Mn, Fe and Zn were increased. As found by Esitken and Turan (2003) in strawberry leaves (*Fragaria* x *ananassa*), where increased MF strength increased the content of N, K, Ca, Mg, Cu, Fe, Mn, Na and Zn but reduced P. Further, the change in ion content under MF may differ in organs of the same plant. Wojcik (1995) reported that MF increased the content of Mg, Fe and Cu in buckwheat (*Fagopyrum esculentum*) grain and the P, Ca, K and Zn content of straw; which indicate that MF effect could differ in the same plant parts. David et al., (1993) suggested that the effect of MF on plants may be species-specific for example the trunks of trembling aspen (*Populus tremuloides* Michx) and red maple (*Acer rubrum* L.) trees grew wider and the trunk of red pine (*Pinus resinosa* Aiton) grew taller when affected by a naval communications antenna electromagnetic field. Nonetheless, the growth of other species was not affected. The effect of magnetic field depended on many factors such as plant species, intensity and duration of exposure. Indicating that MF could affect perennial species and annuals; depending on many factors.

CONCLUSIONS

In this work elemental composition of date palm was significantly affected by MF treatment. The content of N, K, Ca, Mg, Fe, Mn and Zn were significantly increased while P was significantly decreased. Although the study did not cover ion accumulation in long term of a perennial plant (date palm), the growth of date palm proceeded with an increase in fresh weight of shoots and roots; indicating that the accumulation of ions had a positive effects on growth and productivity. Observations suggested that MF, induced by MRI, may play an important role in cation uptake capacity and has a positive effect on uptake of immobile plant nutrients. Magnetic fields induced by MRI could be a promising technique for agricultural improvements but extensive further research is required to determine the effect using a wider range of species and MF doses. The MRI used in the current study was a local hospital device and could be generated by designing an electromagnetic circuit in laboratory, produce an alternating magnetic field with the same specifications. This would reduce the expense and increase the range of exposure to study different levels of magnetic fields.

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