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The Effect of Magnetic Field Intensity and Duration on the Amount of Nutrients Absorbed by Cucumber Transplant

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ABSTRACT
Over many years, the effects of magnetic fields on plant life have been the subject of different research studies. Recently, many authors have reported the effects of magnetic fields on the metabolism and growth of different plant species. In this study, in order to evaluate the effect of intensity and duration of magnetic field on nutrient uptake in cucumber transplant, cucumber seeds were treated with different values of magnetic field intensity and duration. The four levels of magnetic field intensity (0-80-140 and 240mT) and time exposure to the magnetic field were 5, 10, 15 and 20 minutes. After growth of seedlings after 5 leaf foliage, the chemical elements including manganese, zinc, copper, phosphorus, potassium, magnesium and total nitrogen were analyzed. The results showed that the concentration of Mn, Zn, Cu, K, Ca, Mg and N increased, while P and Fe decreased with increasing magnetic field intensity and duration of magnetic field exposure. The results show that iron, zinc, copper, phosphorus and potassium had the highest adsorption at 80 mT and 10 and 15 min, respectively. But phosphorus and potassium at 80mT for 15 and 5 minutes had the most effect on the absorption of these two elements, which increased with increasing magnetic field intensity. Calcium and nitrogen had the highest adsorption at 240 mM and 5 and 20 min, respectively. But the intensity and duration of the magnetic field had no effect on the absorption of magnesium in the transplant of cucumber.

***Key words**:* Cucumber Transplant, Magnetic Field Intensity, Nutrients Absorption

INTRODUCTION

The incorporation of an innovative and environmentally friendly technique in agricultural practice that is capable to enhance plant growth and increase yield is a desirable evolution for sustainable agriculture. Researchers have adopted the use of a magnetic field as a new pre-sowing, environmentally friendly technique. Enhancements on plant characteristics with an economic impact on producer's income could be the future of a modern and organic agriculture. The growing needs in organic agriculture of new methods to replace chemical emergency promoters lead to the development of techniques such as magnetic fields (Bilalis *et al.*, 2012b). In the last decades, studies on the influence of magnetic fields on plants have multiplied and the knowledge that is produced from these researches has accumulated to provide clearer information about the effects of magnetic field on plants. The majority of the researchers use the magnetic field as a pre-sowing technique, as an inexpensive, environmentally friendly technique, which can be applied with relative ease (Vashisth and Nagarajan, 2010). The influence of magnetic field on chemical elements has not been investigated thoroughly. In the early stages of cotton, it was found that the electromagnetic field promoted chemical elements accumulation (Bilalis *et al*., 2013). More specific, chemical analysis showed that the magnetic field has improved elements percentage. Nitrogen, phosphorus, potassium, calcium and magnesium were higher in MF treatments. Strawberry plants that were treated with magnetic field strengths of 0.096, 0.192 and 0.384 Tesla (T) in heated greenhouse conditions, showed that increasing MF strength from control to 0.384 increased the N, K, Ca, Mg, Cu, Fe, Mn, Na and Zn contents, but reduced P and S content (Esitken and Turan, 2004).

Racuciu and *et al.,* (2006) reported that The magnetic exposure to low static magnetic field (50 mT) revealed the stimulatory influence on the plants in their early ontogenetic stages: significant enhancement of the fresh tissue mass, assimilatory pigments level as well the chlorophyll ratio, average nucleic acids level, increase of the average plants length (exception: the dry substance mass accumulation). Magnetic field of 0.15 T strength on maize samples led to an increase of the shoot fresh weight by 72 % compared to the control (Aladjadjiyan, 2002) and EMF treatment by 10 mT intensity of wet treated seeds caused increase in fresh and dry biomass weight of maize (Shabrangi *et al*., 2010). Root growth has been positively influenced by magnetic field pre-sowing treatment in the first 45 days of plant growth. Recently Vashisth and Nagarajan (2010) found that root length and root surface area showed significant increases in sunflower seedlings exposed to static magnetic fields of strength from 0 to 250 mT. Similar results have been recorded by Muraji *et al*. (1998) where in corn seedlings alternating magnetic field of 10 and 20 Hz resulted in 20% greater root growth than control plants. Moreover, root length, and root surface are used as important physiological parameters for evaluation of chemical elements uptake (Wang *et al*., 2006).

According to Esitken and Turan (2004), MF has an effect on plant nutrient Element uptake from growth media. Increase in the MF strength from control to 0.384 T increased concentration of N, K, Ca, Mg, Fe, Mn and Zn of strawberry plant leaves, but at the 0.384

T strength concentration of P and S decreased compared with control. Nutrition value could be enhanced by MF treatment. Sharaf El-Deen. Noticed that MF increased Amino acids, Ca and K content in mushroom (Agaricus bispours). In addition, magnetic field pretreatment of seeds was reported to increased lipid oxidation and ascorbic acid contents in cucumber (Cucumis sativus) (Yao and *et al* 2005). The sugar content in sugar beetroots (Beta vulgaris) and gluten in wheat (Triticum aestivum). The magnetic field may play an important role in cation uptake capacity and has a positive effect on immobile plant nutrient uptake (Esitken and Toran2003). Therefore, MF could be a substitution of chemical additives, which can reduce toxins in raw materials and thus raise food safety. There were few studies linking magnetic field with elements accumulation in plants of strawberry (Fragaria x ananassa) (Esitken and Toran2003). And wheat. Static MF exerts the strong and reproducible effect of reducing apoptosis in several cell systems. This effect is mediated by the MF's ability to increase Ca influxes. Moreover, Mg, K, Fe, Mn, Zn and Na were also affected under SMF and increased significantly while P decreased with raising intensity and time of exposure. Analogues with Esitken and Turan2003. Study which indicated that increasing MF strength from control to 0.384 T increased contents of N, K, Ca, Mg,Fe, Mn, Na and Zn but reduced P and S content the leaves of strawberry. In addition, results may vary according to plant organs, (Wojcik, 1995). Study indicated that MF increased contents of (Mg, Fe and Cu) inbuckwheat (Hruszowska sp.) grain and (P, Ca, K and Zn) in straw.

The aim of the current study was to evaluate the positive effect of magnetic field pre-sowing treatment in a wide range of plant measurements, from the early stages of growth till yield. Moreover, the study objective was to indicate that this innovative technique could increase the yield of cucumber transplant, through enhanced absorption of nutrients. The positive effect of the magnetic field using Simple pre-sowing treatment in characteristics with the economic impact on producer's income, such as yield, could be the future of a modern, organic and sustainable agriculture.

MATERIALS AND METHODS

This experiment was conducted in a research greenhouse of Lorestan Agricultural and Natural Resources Research Center, Khorramabad, located at 48 degrees and 21 minutes east longitude and 33 degrees and 29 minutes north latitude, is located almost in the center of Lorestan province and was carried at 1140 meters above sea level.

Electromagnetic device design

Electromagnetic device was designed according to Naz *et al.* (2012). This device consisted of two-wire rods with a diameter of 0.6 mm and a rounding distance of 4000 rounds which is connected to a power supply and placed in order to apply the intensity of the various magnetic fields. The sensor bars should be placed adjacent to the location of the seed samples and applied to the intensity of the corresponding magnetic field. Then, after seeding the kidneys and placing the cocopeat molds inside the water and increasing the volume of cucumber seeds were applied to the culture trays. The seeds of the cucumber plant were selected as the pure PS64 and after the design of the electromagnetic device used in this experiment, a coil was designed around the iron, power supply and solvent (Fig1). In order to apply the magnetic field on the seeds, they were placed between the coil-coated iron coils at different intensities of the magnetic field.

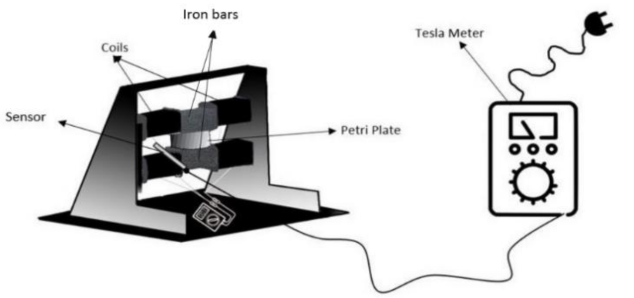

Figure 1.The experimental electromagnet setup (Naz *et al*., 2012)

Experiment statistical design

The experiment was conducted in a factorial arrangement in completely randomized design with two treatments including magnetic field intensities in three levels (S_1=80, S_2=140, S_3=240 militesla), and magnetic field duration in four levels (T_1=5, T_2=10, T_3=15, T_4=20 minutes) with three replications.

Plant culture in greenhouse condition

Cucumber seeds were wetted for 24 hours and planted in culture tray with coco peat bed. After seed germination, plant was nourished with Hoagland nutrient solution. In five-leaf stage, nutrient content of plant including manganese, iron, zinc, copper, phosphorus, potassium, calcium, magnesium and nitrogen were measured.

Nutrient uptake determination

Plant nutrient uptake was determined in plant extractant using analytical devices including spectrophotometer for phosphorous, flame photometer for potassium, Kejeldal method for nitrogen and atomic absorption for determining micronutriens (Fe, Zn, Cu, Mn) and Ca and Mg.

Statistical analysis

The results of the experiments were analyzed using SPSS 22 software. Mean comparisons of experimental data were performed using Duncan test at 5% level of probability. Excel software was also used to draw charts

RESULTS AND DISCUSSION

According to the results of the analysis of variance table (Table 1) the measured parameters on the cucumber transplant show that the effect of magnetic field on the uptake of manganese, iron, zinc, copper, phosphorus, potassium, calcium and nitrogen was significant, But the absorption of magnesium was not significant.

Table 1. Analysis of variance (ANOVA) calculated for measured parameter

	Sum of Squares	df	Mean Square	F	Sig.
Mn	14681.516	3	4893.839	1.008E3	.000
Fe	572533.676	3	190844.559	15.490	.000
Zn	8455.766	3	2818.589	542.254	.000
Cu	339.563	3	113.188	52.240	.000
P	.058	3	.019	34.231	.000
K	.734	3	.245	135.127	.000
Ca	1518703.816	3	506234.605	2.781E3	.000
Mg	2.951E7	3	9838048.003	1.038	.389
N	21.640	3	7.213	3.984E3	.000

Manganese (Mn)

According to Figures 2 and 3, the effect of different magnetic field intensities on the absorption of Mn shows that the intensity of 240 mT for 10 minutes shows the best effect on Mn absorption. Faten Dhawi *al* (2009) reported that the ions accumulation was affected by the magnetic field in date palm plants. The magnetic field may play an important role in cations uptake capacity and has a positive effect on immobile plant nutrient uptake which raises the products nutrition value of date palm. The function of manganese in the plant is closely associated with the function of iron, copper and zinc as enzyme catalysts. Manganese is needed for photosynthesis, respiration, nitrate assimilation and the production of the plant hormone auxin. Without manganese, hydrogen peroxide accumulates in the cells and damages them. Like iron, manganese is immobile within the plant accumulating mostly in the lower leaves. Deficiencies are more likely in calcareous or alkaline soils, or over-limed soils; availability is high in acidic soils.

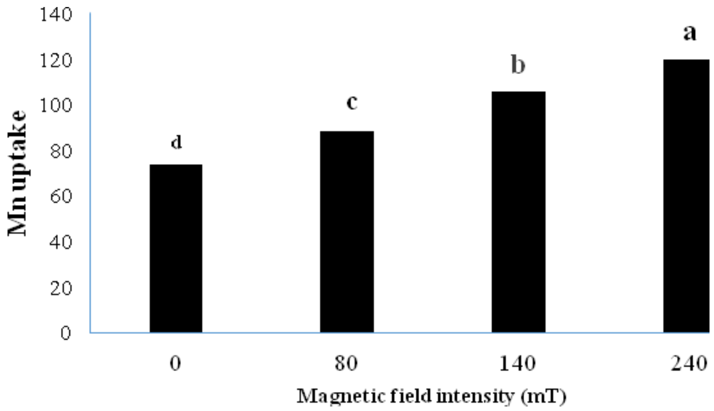

Figure2: Effect of various magnetic field intensity on plant Mn uptake

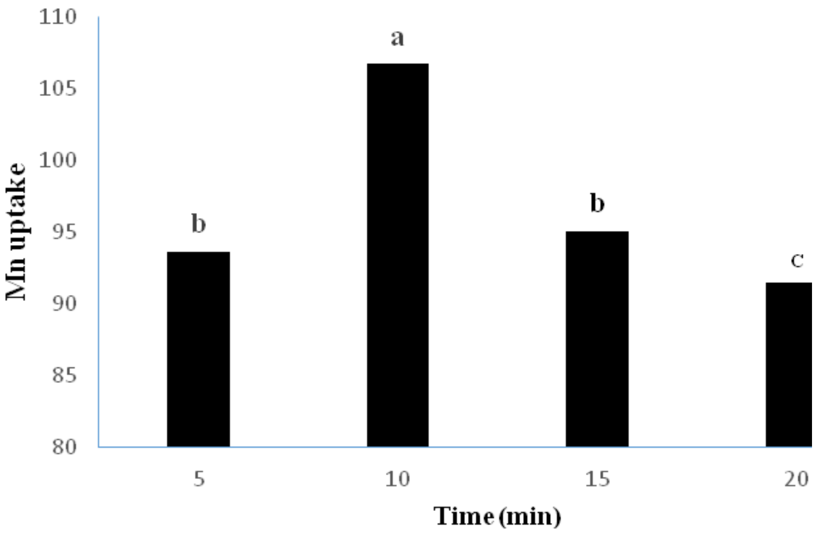

Figure 3. Effect of different time exposure of magnetic field on Mn uptake

Iron (Fe)

The effect of different magnet field intensities on iron absorption, according to the diagrams 4and 5 shows that the control treatment is more significant than the other magnetic field treatments. And with increasing field intensity, iron absorption decreases. Iron is needed to produce chlorophyll and to activate several enzymes, especially those involved in Photosynthesis and respiration. Iron is immobile in the plant. Deficiencies of iron are more likely in alkaline or calcareous soils, and can be induced by over liming, poor drainage, or high concentrations of metallic ions in the soil or nutrient solution. Iron availability decreases at pH above 7. Manganese toxicity can induce an iron deficiency. Iron deficiency causes a uniform pale green chlorosis of the newest cucumber leaves; all other leaves remain dark green. Initially, the veins remain green, which gives a net-like pattern. If the deficiency is severe, the minor veins also fade, and the leaves may eventually burn, especially ifexposed to strong sunlight. The optimal course of action for long-term improvement is to address any chemical or physical issues in the soil. Proper drainage and soil aeration promote the availability of iron. While foliar sprays of iron sulfate (150 g/100 L) can be used to alleviate symptoms, they are not a permanent solution as symptoms may return once the sprays are stopped. For crops grown in soilless media, a nutrient solution with 2-3 ppm Fe should be used. Iron chelates are typically preferred in hydroponic solutions as they are less likely to precipitate under alkaline conditions. It is not recommended to rely on leaf analysis to diagnose iron deficiency due to surface contamination with soil, the immobility of iron within the plant, or the presence of physiologically inactive iron within tissues. Bronzing of leaves with tiny brown spots is a sign of iron toxicity.

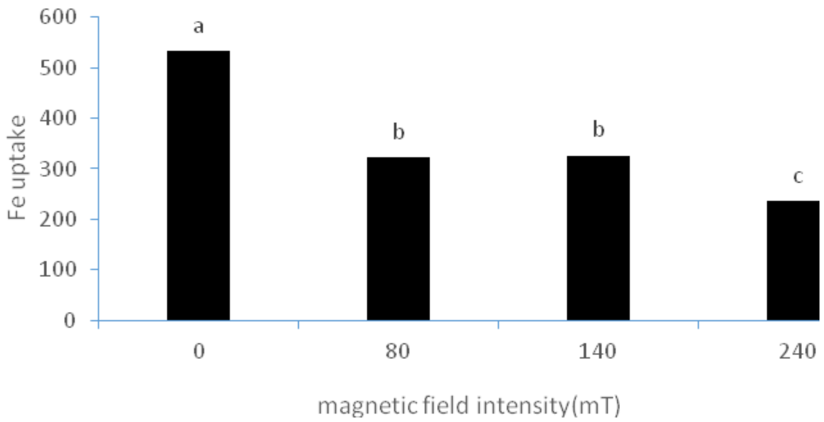

Figure 4. Effect of various magnetic field intensity on plant Fe uptake

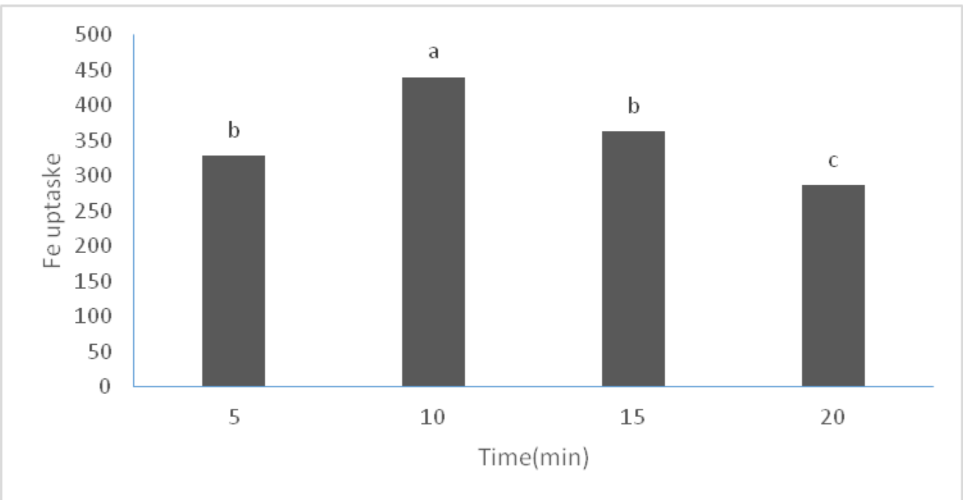

Figure 5. Effect of different time exposure of magnetic field on Fe uptake

Zinc (Zn)

Concerning the effect of different magnetic field intensities on zinc absorption, it is shown that 80mT for 15 minutes shows the best effect on zinc absorption. Zinc contributes to the formation of chlorophyll and the production of the auxins plant hormones. It is an integral part of several plant enzymes. Zinc deficiency appears as a distortion and interveinal chlorosis (yellowing) of older plant leaves, and retards plant development as a consequence of low auxin levels in the tissue. In soils zinc becomes less available as the soil pH rises and in the presence of calcium carbonate. A heavy application of phosphorus can induce zinc deficiency due to the precipitation of the zinc in the form of zinc-phosphates. Uptake of zinc is hindered by over-optimal copper, iron, manganese, magnesium, and calcium. The normal zinc content of soils usually falls in the range of 10-300 ppm Zn. Hydroponically grown cucumbers develop zinc deficiency when plants have too low zinc in the nutrient solution. Normal zinc levels in hydroponic solutions runs at 0.1-0.5 ppm. The symptoms of deficiency are not well defined, but usually a slight interveinal mottle develops on the lower leaves, this symptom spreads up the plant. The upper internodes remain short. Small leaf size most characterizes zinc deficiency; in severe cases, short internodes cause the top of the plant to grow bushy. Overall growth is restricted and the leaves become yellow-green to yellow except for the veins, which remain dark green and well defined. Symptoms of deficiency appear when the concentration drops below 15-20 ppm Zn

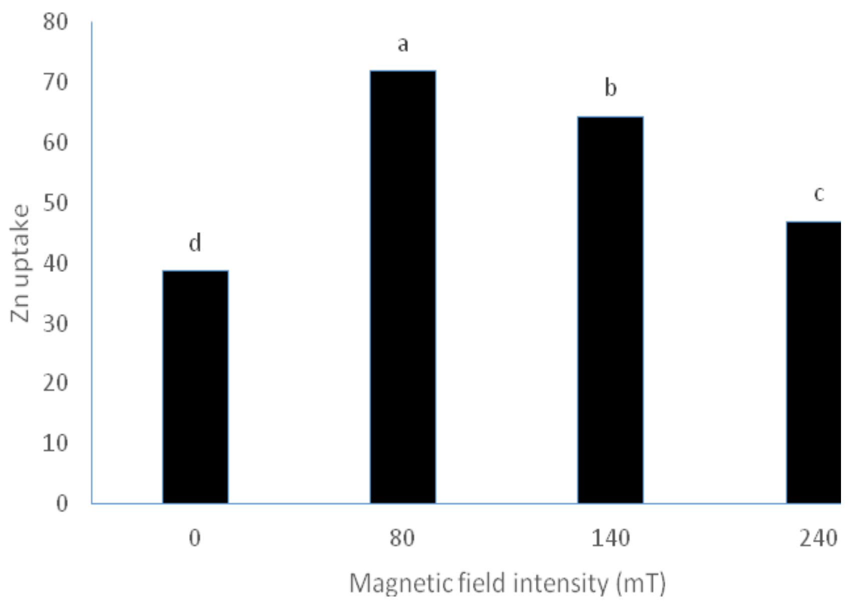

Figure 6. Effect of various magnetic field intensity on plant Zn uptake

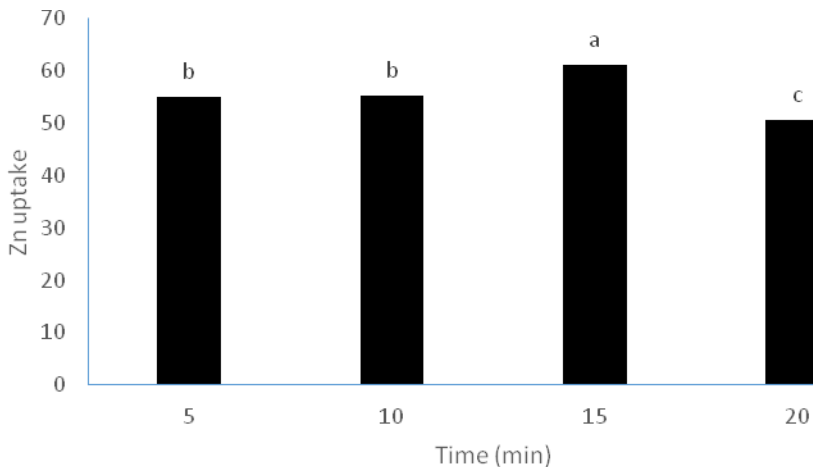

Figure 7. Effect of different time exposure of magnetic field on Zn uptake

Cupper (Cu)

Concerning the effect of different magnetic field intensities on the absorption of copper element, as with zinc, it shows that 80mT for 15 minutes shows the best effect on copper absorption. Several enzymes with diverse properties and functions depend on copper, including those involved in photosynthesis and respiration. Although copper is mobile in plants well supplied with the element, it is much less mobile in deficient plants. Therefore, copper concentration in young developing tissue is likely related to plant status. However, soil analysis is a more useful guide to copper deficiency than tissue analysis.

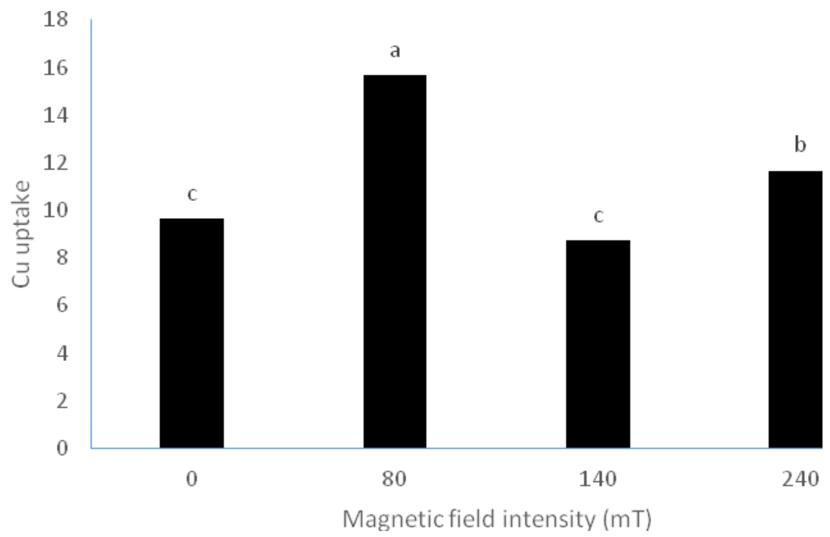

Figure 8. Effect of various magnetic field intensity on plant Cu uptake

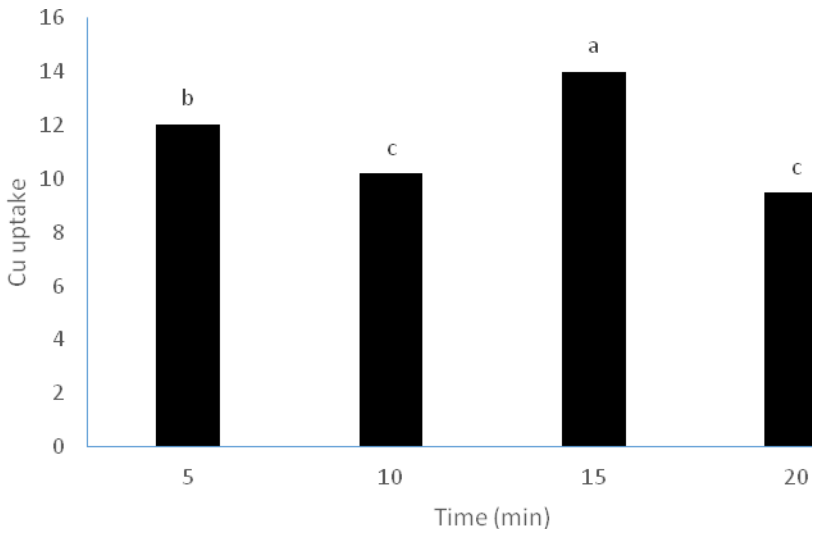

Figure 9. Effect of different time exposure of magnetic field on Cu uptake

Phosphorus (P)

Regarding the effect of different magnetic field intensities on the absorption of phosphorus, it shows that with increasing intensity from 80 mT to 140 mT and 240 mT, the amount of phosphorus absorption is decreased, so that the best intensity and duration of exposure is shown in Figures 10and 11. Seeding to absorb the phosphorus element is 80 mT for15 minutes. Faten Dhawi and *at al*. (2009) Seedlings of date palm (Phoenix dactylifera L.) were treated with varying doses of the static magnetic field (SMF) in order to evaluate the effect on elements uptake. The SMF source is a magnetic circuit set to produce three levels of magnetic field intensities (10, 50 and 100 mT). Seedlings were exposed to these magnetic fields for different periods: 0, 30, 60, 180, 240 and 360 min. Leaf samples were subjected to chemical analysis for elements (Mg, Ca, Na, P, K, Fe, Mn and Zn) using inductively coupled plasma (ICP) spectroscopy. The results revealed that concentrations of Ca, Mg, Mn, Fe, Na, K, and Zn increased, while P concentration decreased with raising SMF intensities and durations of exposure. The static magnetic field has a potential to enhance growth due to the positive effect on the plant major elements such as Ca and Mg, but negative electrical charges on the plants inhibited the uptake of anions such as P. Increasing ions may elevate the nutrition value of date palm plants. Phosphorus plays a crucial role in the normal growth and development of roots and reproductive organs such as flowers, fruit, and seeds. It is essential for strong early plant growth and the development of a robust root system, particularly during the establishment of seeded or transplanted cucumbers. Phosphorus is necessary for cellular division and the formation of molecules involved in energy transformation, such as ADP and ATP. Plants require phosphorus at all stages of growth, but the demand is highest during crop establishment and early plant growth. When phosphorus is limited, it is translocated from older to younger tissues, like leaves, roots, and growing points. For crops like cucumbers, which continuously produce new vegetative and fruiting tissues, a consistent supply of phosphorus (and other nutrients) is necessary to maintain high-quality fruit production over an extended period. In soil-grown crops, phosphorus availability is usually optimal when the soil pH falls between 6.0 and 6.5. In acidic soils (pH < 6.0), phosphorus is associated (or "tied up" or "fixed") with iron and aluminum compounds that are not readily available to most plants. In soils where pH is greater than 6.5, phosphorus is primarily associated with calcium and magnesium. As pH increases, calcium- and magnesium-phosphate compounds become less available to plants.

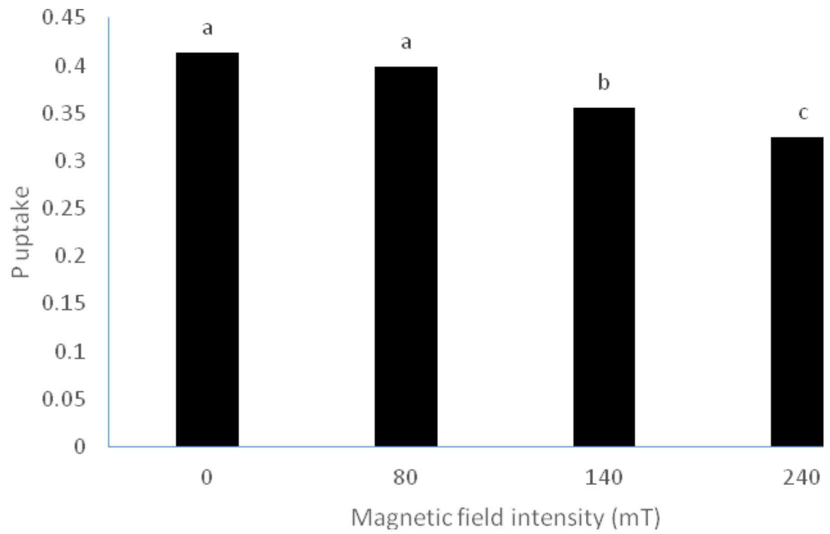

Figure10. Effect of various magnetic field intensity on plant P uptake

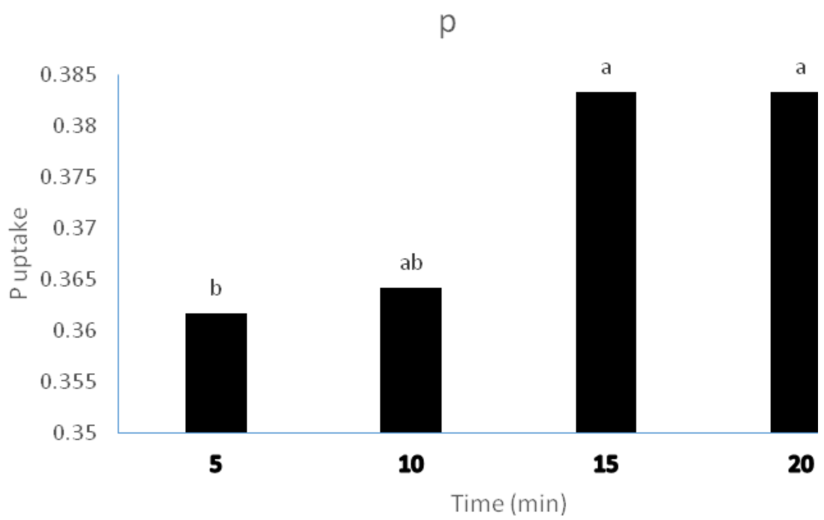

Figure 11. Effect of different time exposure of magnetic field on P uptake

Potassium (K)

According to the diagrams12 and 13, the effect of different magnetic field intensities on potassium uptake shows that the control treatment is more significant than other magnetic field treatments. And as the intensity of the field increases, the amount of potassium absorbed decreases. According to Gang *et al* (2012) and Mahouachi (2007), concentrations of potassium in jojoba and banana plants were also reduced, respectively, under drought conditions. Similar results were found by Restrepo-Diaz *et al*. (2008) in the leaves of water-stressed olive plants, regardless of nutritional status. Moreover, Al-Khazen *et al*. (2011) showed that water stress also reduced potassium but, adding MWT resulted in almost double the amount of potassium compared to non-MWT water under the same water stress. According to our results, Potassium absorption decreased with increasing intensity and duration of exposure. It therefore appears that potassium levels are reduced under water stress conditions but that MWT offsets this effect, perhaps as a result of its beneficial impact on nutrient uptake, as described below It is known that potassium is characterized by high mobility in plants at all levels (within individual cells and tissues as well as in long-distance transport via the xylem and phloem). Potassium is the most abundant cation in the cytoplasm. Importantly, its salts are known to be a major contributor to the osmotic potential of cells and tissues (Marshner, 1995).

Potassium is a crucial nutrient that plays a vital role in numerous physiological processes in all plants, including the activation of at least 60 different enzymes involved in plant growth and metabolism (Marschner, 2012), the regulation of the water balance of the plant through the root osmotic gradient and the functioning of stomata guard cells (Marschner, 2012), the activation of several enzymes and control of ATP formation as part of photosynthesis (Marschner, 2012), the enhancement of the translocation of nutrients through the xylem system and of organic compounds, mainly carbohydrates, in the phloem system from source to sink (Marschner, 2012), involvement in any major step of protein synthesis (Marschner, 2012), reduction of plant susceptibility to plant disease and abiotic stresses (Marschner, 2012), and counteracting salinity (Marschner, 2012). Adequate potassium levels enhance the production and phloem transportation of carbohydrates within the plant and play a crucial role in enhancing plant resistance to low temperatures, salinity, drought, and diseases (Marschner, 2012). Ample amounts of potassium should therefore be supplied to the crop to ensure abundant K levels in all major organs. Severe potassium deficiency will retard the transportation of sugars within the plant, leading to starch accumulation in the lower leaves. Cucumbers are unique among most crops in their high potassium requirements, with the cucumber plant being one of the only crops requiring more potassium than nitrogen (Figure 3.11) (Marschner, 2012). Moreover, an increase in cultivation intensity requires a higher K/N ratio (Marschner, 2012).

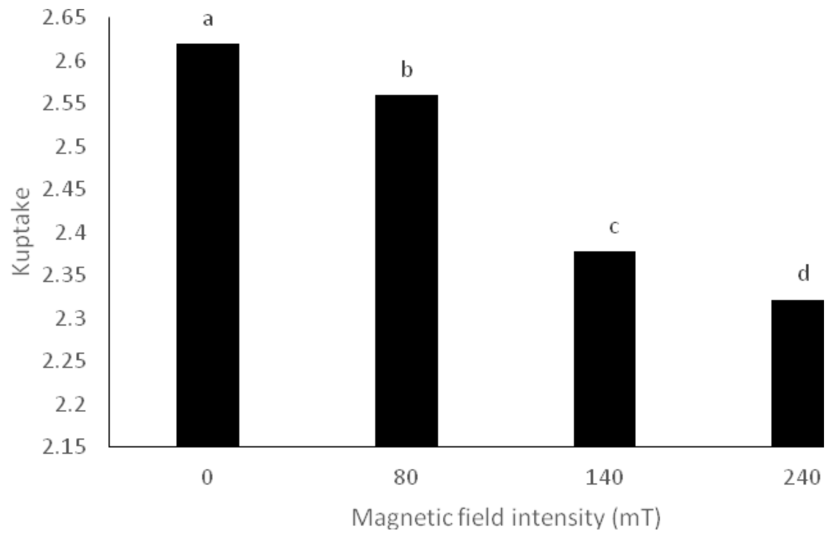

Figure12. Effect of various magnetic field intensity on plant K uptake

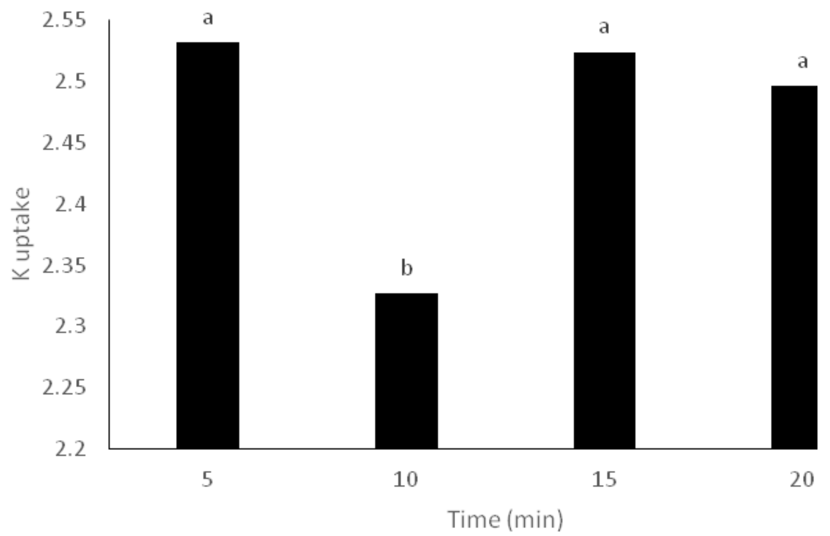

Figure 13. Effect of different time exposure of magnetic field on K uptake

Calcium (Ca)

According to the diagrams14 and 15, the effect of different magnetic field intensities on calcium absorption shows that a 240 mT intensity for 5 minutes results in the best absorption of calcium. The graph shows that as the magnetic field intensity increases, the amount of calcium absorption is increased. Calcium takes a key role in the structure and functioning of cell membranes and the strength of cell walls. Calcium also reduces plant susceptibility to diseases. Most calcium-related disorders of crops are caused by unfavorable growing conditions and not by inadequate supply of calcium to the roots. Rapidly growing crops in hot windy conditions are most at risk. Deficiencies can also develop when cucumbers grow quickly under continuously humid conditions, as in a greenhouse. Other contributing factors are waterlogging, soil salinity, high potassium or ammonium supply, and root diseases. Calcium moves in the plant's transpiration stream and is deposited mainly in the older leaves. Deficiencies are found in the youngest leaves and growing points, which have low rates of transpiration. Emerging leaves appear scorched and distorted and may cup downwards because the leaf margins have failed to expand fully (Figure 3.20). Mature and older leaves are generally unaffected. With a severe deficiency, flowers can abort, and the growing point may die. Fruits from calcium-deficient plants are smaller and tasteless, and may fail to develop normally at the blossomed.

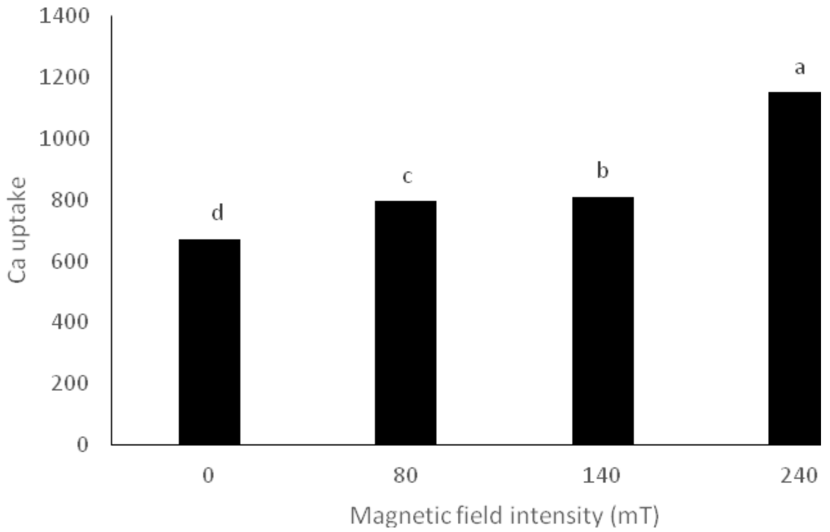

Figure14. Effect of various magnetic field intensity on plant Ca uptake

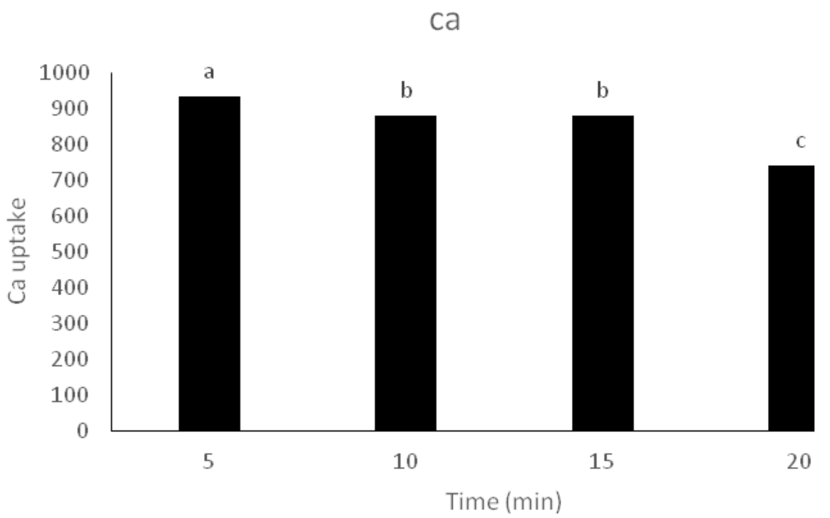

Figure 15. Effect of different time exposure of magnetic field on Ca uptake

Magnesium (Mg)

According to Figures 16and 17, the effect of different magnetic field intensities on magnesium uptake shows that the magnetic field is ineffective on magnesium uptake. The graph shows that the magnetic field intensity and duration of exposure to the seeds had no effect on magnesium uptake. Magnesium is a center constituent of the chlorophyll molecule, so its key role in the photosynthesis process is crystal-clear. Magnesium deficient soils may be found in coarse-textured soils in humid regions, and especially on light, sandy, acidic soils in higher rainfall areas. Magnesium deficiency can be also induced by high rates of potassium, ammonium or calcium (heavy liming) fertilizers. Symptoms are more likely to show during cold weather or on heavy wet soils, when roots are less active.

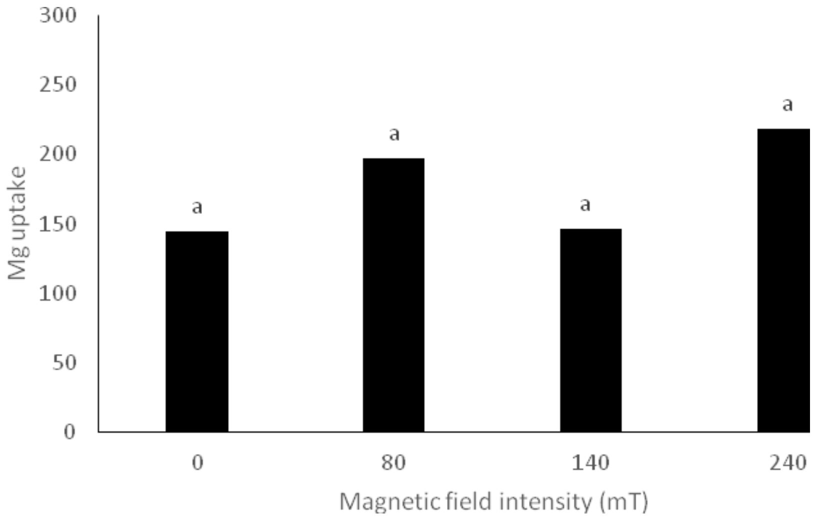

Figure16. Effect of various magnetic field intensity on plant Mg uptake

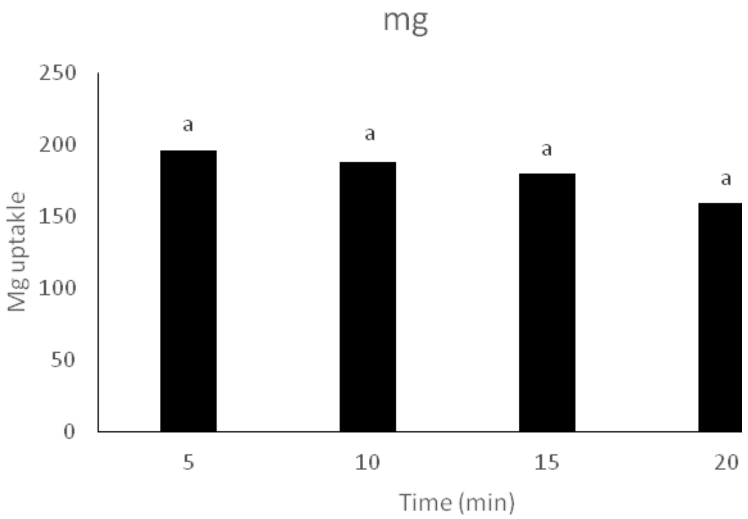

Figure 17.Effect of different time exposure of magnetic field on Mg uptake

Nitrogen (N)

According to Figures 18 and19, the effect of different magnetic field intensities on nitrogen uptake increased with increasing magnetic field intensity. So that 240 mT for 15 minutes is more significant than other magnetic field treatments. And with increasing field intensity, nitrogen uptake increases. Nikolaos katsenios and *at al* show that Total Nitrogen content has been found to increase by the use of magnetic field treatment. The highest values of nitrogen percentage were measured in MF-30 treatment. In both magnetic field treatments, nitrogen percentage was statistically significantly higher than control. Most plants need nitrogen in large amounts. It is generally considered to drive plant growth. Nitrogen plays an essential role in the composition in all proteins in all plants. Since it is a major structural and functional factor for every plant, crop yields are highly dependent on N availability to the plant. Nitrogen is required in the production of chlorophyll (the green pigment in leaves), which is responsible for converting sunlight to usable plant energy. Therefore, shortage of nitrogen reduces the plant's capacity to trap energy through photosynthesis. It is important that when reaching the flowering stage, the plant will be well developed vegetative; or it will have a low yielding potential.

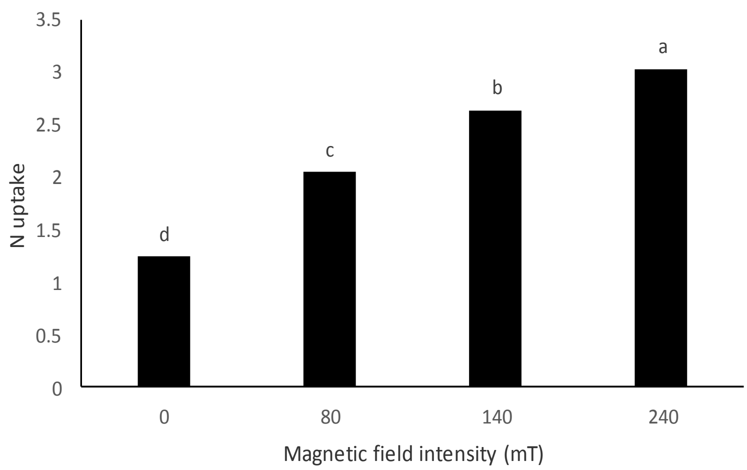

Figure18. Effect of various magnetic field intensity on plant N uptake

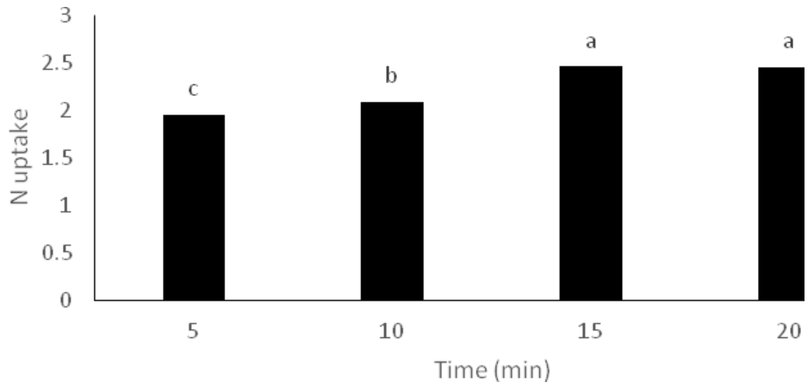

Figure 19. Effect of different time exposure of magnetic field onN uptake

CONCLUSION

The exposure of plants to magnetic field is one of the potentials, safe and affordable physical application for enhancing the crop productivity and to improve the quantitative and qualitative attributes of agronomic and botanical production in greenhouse or field conditions. Our results showed that pre-sowing magnetic field treatment has significant effect on plant nutrient uptake and productivity. It is recommended that other aspect of plant growth such as enzyme determination carry out in field and greenhouse conditions.

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