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Response of Micro-Organism, Trace Elements and Biological Systems to Typical Magetic Field Exposure

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Abstract: Since, the beginning of time, every living organism under the expose of sun rays lived under the inevitable environmental influence of Magnetic Field (MF). The role of the magnetic field and their influence on nutrients modification, microorganism and the biological system is becoming more and more important as new evidence reveals the ability of plants and microorganism to perceive and respond quickly to varying MF by altering their gene expression and phenotype. The literature reviewed has shown a high sensitivity of plants and microorganisms to permanent magnetic fields, in particular, in the intensity range from MF level to very low ones. The external application of electromagnetic fields in plant science and microbiology has shown to influence both the activation of ions and the polarization of dipoles in living cells and the rapid growth of different crops in comparison to control. Literature relived that magnetic field achieves such results by changing the molecular distribution of electronic charge inside each lipid molecule, producing perturbations of collective excitations in the mechanical and electrical properties of the lipid chain which can be treated as a mechanism for intermembrane communication, analogous to a damped harmonic oscillation. Magnetic field strength ranging from (0.0, 20.0, 40.0 and 60.0 mT) encourages nutrient uptake such Ni, Sr, K, Cu, Mg, Fe, Mn, Ca, Zn, Co and V and essential amino acids such as histidine and decreases ion toxicity. However, the results of magnetic field stimulation can be seen after 7th day to 14th day of the treatment.

Key words: Electromagnetic field, magnetic field, trace elemet, biological sytem, mircoorgansism, ions, dipoles, amino acid

INTRODUCTION

Historical background of magnetic field use in agriculture: Before the year 1862, scientists were not aware that magnetism affect the biological activity of the plant. Until the year 1862 when Louis Pasteur observed that magnetism has an effect on plant growth (Kocaman, 2015). However, the study was not accepted by the scientific community as it was classified as pseudoscience (Lower, 2011). In 1930 Savostine conducted the first study on wheat seedling under the influence of magnetic field and he observed 100% increases in the rate of elongation. The 6 years later, Albert Roy Davis theorized that the North and the South poles of a magnet consist of different energies with opposite effects on the plant.

From then on, there is no complete conclusion on how the magnets achieve such a change on the plants but it was predicted that the magnets alter the membrane structure of the plant cells so that the plants absorb more water and nutrients. Krylov and Tarakanova (1960) were among the first to try to find how MF change the behavior of the plant. They proposed an auxin-like effect of the MF on germination. The auxin-like effect was also suggested to explain the ripening of tomato fruits (Boe and Salunkhe, 1963). Whereas Moon and Sook (2000) theorized that MF changes the behavior of the subject by activating the ions and the polarization of dipoles in living cells. At the same time, some researchers still argue about this inclusion as it been believed not to be biologically active, especially, permanent magnetic fields (Belyavskaya, 2004). Nevertheless, the results obtained by Andrei *et al*. (2014), Huang *et al*. (1993), Florez *et al*. (2007), Belov and Bochkarev (1983) have shown the high sensitivity of plants to permanent magnetic fields, in particular, under the intensity range from high MF level to very low ones.

The effect of the magnetic field depends on its strength and intensity, i.e., on the value of magnetic induction squared. Many theoretical investigations were made on the mechanism of how the magnetic field affects the plants. A number of studies have been conducted to prove the viability of magnets on plants development and enhancement but the effects vary due to a number of factors such as strength, frequency, intensity and form of magnets used, the placement of the magnet in relation to the plant or seed, the type of plant used and time exposure also plays a significant role (Andrei *et al*., 2014; Nyakane *et al*., 2019).

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Subsequently, the effect of magnetic field on plant and the biological system has been researched over a very broad range of values of magnetic induction (Ali *et al*., 2014). The values varied from just over ten microteslas to as much as 10 T, the difference between those extreme values is of the order of one million times (Pietruszewski and Martinez, 2015). Furthermore, it has been theorized that the effect of magnetic field on the plant and biological system takes place in two ways:

- It is influencing the biological processes which are microscopically electrical
- It influences the concentration of metal in the plant (El Taher, 2012)

Because of the life and existence of all cells and living creature, a magnetic field can interact with all living cells to modulate their function due to their electrical origin of the organism (Ali *et al*., 2014). The mechanisms of the magnetic field on various biological systems such as cells and tissue of plants, animals and microorganisms, may be an alternative way in regulating biological activity and removing unfavorable compounds from the bio systems (Najafi *et al*., 2013). The interconnection of the magnetic field with the biological system serves as mediators as well as between the environment and between the organisms (Hunt *et al*., 2009). Biological system and macromolecule are common to the electrical dipole and multipolar moment.

In recent years, researchers have stretched the external use of magnetic field methods in studying environmental pollution by integrating them with other disciplines of science including biological applications such as the biomonitoring of traffic air pollution using magnetic properties of tree leaves Moreno *et al*. (2003) and civil/environmental engineering applications such as studies of building facades to measure erosion rates and monitor urban atmospheric contamination (Monna *et al*., 2008).

List of magnetic fields that are often used in plant science and their merits and demerits

Static magnetic fields: Have a consistent strength and it does not change over time depending on the magnetic device and it can be generated from a piece of iron or other material which has the property of running an electrical current which can be macroscopic currents in wires and is normally described as permanent magnets or DC electromagnets (Tiittanen, 2015). Permanent magnets are normally used to conduct long-term experiments because of its stable of the magnetic field, however, some dives lose the magnetism over time (Kovacs *et al*., 1997). Conducting agricultural experiment using magnetic field does not require expensive equipment or material. Nevertheless, it has been theorized that the small strongest homogeneous field of 20000 G can be achieved if the gap between flat poles is greater or equal to the pole diameter compared with the face diameter of the poles which will decrease the facing pole by 20% of magnetic field from the center of the edge of the pole (Tobia *et al*., 2012; Ertas and Keskin, 2015). However, so far to the best of our knowledge there is no disadvantage of permanent magnets that have been documented which is that their field strength can only be changed by adjusting the gap between the poles (Kovacs *et al*., 1997). Nonetheless, the field direction cannot be inverted to study the effect of polarity or reduced to zero which makes changing pole caps a problem in large magnets.

Oscillating or time-varying magnetic fields are generated through electromagnets such as Alternating Current (AC) and their frequency and waveform differ depending on a periodic form and design of the magnets used (Pulyer and Hrovat, 2002).

Homogeneous fields are normally produced from Helmholtz and flat poles gaps and have a relatively unchanging strength over the space where samples are (Pulyer and Hrovat, 2002).

Heterogeneous fields the design of the gap pole plays a vital role because the gradients depend on the design nature of the magnet (e.g., horseshoe permanent magnets or solenoids) (Roy, 2012).

Magnetic field as a physical field generated from a piece of iron or other material which has the property of running an electrical current which can be macroscopic currents in wires or microscopic current associated with electrons in atomic object (Ertas and Keskin, 2015). A magnetic field is more intense near a concentrated current flow. However with increasing distance from the object, it decreases in intensity more rapidly than does the electric field and it can be measured everywhere in the environment.

The most fundamental benefit of using electromagnets or solenoids is that the tool or a dive is an easy movable and build in tool and the field frequency can be controlled manually and it is easily adjusted by controlling the amount of current delivered to the coils in the magnet depending on the intensity required (Ertas and Keskin, 2015). The magnetic field can also be easily reversed by changing the direction of current and reduced to zero which facilitates changing of the pole caps (Tobia *et al*., 2012). However, one demerit of using larger electromagnets is its implication due to its electrical consumption and which might also require high power supplies and cooling systems to control and to cool down the heat produced by the magnet coils and electromagnetic need proper evaluation especially under hydro experimental trial. This could affect the long-term experiment negatively and might require high capital to maintain the long experiment trial and during the course of the day the temperature in a magnet cooled by tap water can increase by up to 20°C because of the warm tap water affected by environmental day temperature especially, during, Summer days. Concurrently, the electromagnets or solenoids and power supplies incorporate over-temperature sensing devices and feedback protective circuits to guard the equipment against possible cooling-water failure.

However, the study cannot only conclude on the magnetic use without considering the efficiency of magnetic. Nonetheless, the analysis and evolution of magnetic efficiency was found complex towards the measurements of the efficiency, in regard to which magnetic parameters should be measured. One of the reasons was the magnetic size and field strength.

Nonetheless, the primary objective of this study is to inspire fundamental research leading to a better understanding and a more widespread acceptance of magnetically modified biological treatment processes as a viable additional tool for plant stimulation and biological system in all living organisms. Emphasis is placed on providing a balanced review of potentially pertinent studies.

In the following review, the effects of magnetism on plant and biological system as well as trace elements are been reviewed and discussed on the key results. Since, magnetic field on living systems, particularly the effect on the growth of plants have been the object throughout the globe. These modulations inappropriate conditions can have useful outcomes such as treatment or inducing the desirable characteristics of different compounds.

The key purpose of this review is to evaluate the viability of low Magnetic Fields Frequency (MF), Electromagnetic Fields (EMF), Electric Fields (EF) on plants, biological systems and trace elements. And finally, these studies provide a basis for collaboration among researchers and farmers. Research works are reviewed and summarized which provides the source researcher, a summary of the research focus, electromagnetic field technology covered and comment on the key results of the work reviewed.

Effects on microorganism: The study conducted by Moreno *et al*. (2003) on bacterium Bacillus mucilaginous under magnetic intensity of ~0.26 showed three-time overall increase of dry whey and the rapid growth of bacterium as compared to control. A low frequency of electromagnetic field was used to determine its effect on the growth of *Escherichia coli*. The study observed that the growth of *Escherichia coli* could be stimulated or inhibited by exposure to an oscillating of 100 mT and extremely low frequency of 6.5 h. The exposed cells had 100 times greater viability than unexposed cells, whereas the viability varied with duration of exposure (Jensen *et al*., 2004). In another set of experiment, permanent magnetic field was used to improve the cultivation of Cyanobacterium spirulina platensis for production of nutraceuticals. The study showed a significantly higher specific growth rate of $0.22d^{-1}$ in S. *platensis* exposed to 10 mT magnetic fields when compared to $0.14d^{-1}$ for untreated culture. However, the growth of *Spirulina platensis* was maximum when it was cultured phototrophically at lower light intensities but did not show improvement under heterotrophic conditions (Monna *et al*., 2008). *Spirulina platensis* exposed to 10 mT magnetic field showed rapid growth on of $0.22d^{-1}$ when compared to $0.14d^{-1}$ of untreated culture. However, the growth of *Spirulina platensis* was maximum when it was cultured phototrophically at lower light intensities but did not show improvement under heterotrophic conditions (Hirano *et al*., 1998). Another study conducted by Kordyum *et al*. (2005) on substrate utilization and exposure of the thermotolerant yeast strain, *Kluyveromyces marxianus* IMB3 to electric-field stimulation. The study showed enhanced utilization of cellobiose and conversion of substrate into ethanol by thermotolerant yeast, *Kluyveromyces marxianus*. As a result, ethanol yield increased by nearly 40% over the control. In this regard, the study concluded that electric field stimulation may be used to improve the substrate utilization efficiency in microbial processes. However, the stimulation effect of magnetic field of 0, 1 mT flux density could be seen more quickly, between the 7th and 14th day of treatment, than the effect of magnetic field of 0,025 mT flux density Genkov *et al*. (1974). Furthermore, using bio electromagnetic for stimulation of microbes particularly with microalgae provides a new extended domain of disciplines and methodologies for harvesting, cultivation and processing of biomass for production of biofuels, bioenergy and added value bio-products. However, lots of research is needed to further explore and understand the viability of magnetic devices, especially, for commercial purposes (Li *et al*., 2007).

Effects on biological system: The study MF pretreatment was conducted to determine time exposure on physiological factors of *Phaseolus vulgaris*. The result of this study showed that, in contrast to magnetic field by B = 1.8 mili-Tesla for 30 and 60 min can be to some garden to decrease the biosynthesis of chlorophyll, carotenoid, phenolic and flavonoid compounds. However, it was assumed that the accumulation of chlorophyll content in the treated plants decreased the absorption of light energy and photosynthetic activity which may lead to a higher generation of ROS and would explain the decreased levels of phenolic compounds and antioxidant activity (Mihaela *et al*., 2009). Hirano *et al*. (1998) also used permanent magnetic field to evaluate physiological response of a cyanobacterium Anabaena doliolum. The result of the study showed that the effect of magnetic field was significant on a 2 h exposure with N+S poles where one culture was exposed to only N pole which was then mixed with another culture exposed to S pole only. Treated cultures recorded 150, 110, 38, 34 and 20% increase in phycocyanin, chlorophyll a, carbohydrates, carotenoid and protein content, respectively and 55% increase in optical density over the control. Abou *et al*. studied the effectiveness of static magnetic field on two sources, the urine samples of patients with urinary tract infections and the reference strain under various exposure times and intensities. The results showed that magnetic time exposure increases the permeability of ion channels in the cytoplasmic membrane, formation of free radicals and active oxygen, disintegration of the cell wall, extrusion of the cytoplasmic contents, retraction of the cytoplasmic membrane. However, the electric field mainly generated by ions flowing to the membrane from the external environment, can change the molecular distribution of electronic charge inside each lipid molecule, producing perturbations of collective excitations in the mechanical and electrical properties of the lipid chain which can be treated as a mechanism for inter membrane communication, analogous to damped harmonic oscillations (Aguilara *et al*., 2015).

Nonetheless, Ursache *et al*. (2009) studied the effect of electromagnetic fields and electromagnetic irradiation with 1 mT intensity on seed germination and seedling growth of Satureja bachtiarica. The results showed a significant increase in the treated samples whereas morphological comparison of the treated and control samples showed a significant decrease in the mean shoot length, leaf area, fresh and dry weight. in the same manner, another study was carried out by Erygin *et al*. (1988) on seed improvement of three varieties of sugar beet growth using low frequent magnetic field acting independently and in combination with other method of seed improvement. The study showed that low frequent magnetic field, influenced the chlorophyll content. Even though, the best results were obtained in the combination of magnetic field and conditioning. MF treatment also had a positive influence on content of nitrogen in plants through the better uptake of nitrogen from the soil. By treating seed with magnetic fields, it is possible to improve short cycle varieties, adapted to rainy season zones (Vishki *et al*., 2013). On the other hand, the exposure of seeds to physical energy treatments through static magnetic field of strength below 250 mT for one hour could be a suitable, cheap and easy seed invigoration method for improving germination and seedling vigor indices of poor-quality seed. Seed enhancing energy treatments not only increase the growth and vigor parameters of seedlings but also play a significant role in enhancing biochemical properties of seeds (Ramirez *et al*., 2016).

The study was carried out to evaluate the effects of both a 60 Hz sinusoidal MF and a 60 Hz pulse MF on the early growth of the plants. The results showed that sinusoidal and pulsed MFs affect the plant growth in different ways (with respect to different kinds of plant). However, the 60 Hz sinusoidal has an apparent enhancing effect on growth but with the occurrence of some morbid state phenomena. Nevertheless, the pulsed MF harms plant growth rather than enhancing growth as the sinusoidal MF does (Aguilar *et al*., 2009). The combination of high frequency of Radiofrequency (RF) and Microwave (MU) electromagnetic waves of non-thermal power density upon the assimilatory pigments in the vegetal tissues was conducted by (Shahin *et al*., 2016). Their results reviled that plant exposure to RF and MW electromagnetic waves of low power density has elicited detectable responses. However, a direct measurement of the levels of chlorophylls and carotenes showed stimulatory effect on the biosynthesis processes from vegetal green tissues when the exposure duration was relatively short couple of hours.

Effects on agro-morphological traits: The preliminary research of magnetic nano particles stimulation on spinach plants was conducted to improve the iron content in spinach plants. The results of this study showed a significant response of spinach yield and high iron content compared to the products on the market with 9.897 mg/100 g and 3.3 mg/100 g, respectively (Herranz *et al*., 2013). Pretreatment of *Lens culinaris* L., seed that contains significantly Fe^{2+} of ferromagnetic element) was evaluated under different magnetic field intensities of 0.06 and 0.36 Tesla (T) for different periods of time 5, 10 and 20 min. The results obtained in this study showed a huge improvement of the first stages of growth in higher plants. In general, the seedlings from seeds magnetically pretreated grew taller and heavier than untreated controls. Furthermore, seedlings showed greatly improved root characteristics. It is therefore, suggested that this technique may be profitably exploited as lentil is generally, grown without irrigation and enhanced root growth will be useful in extracting moisture from deeper layers (Ruzic and Jerman, 2006). However, another study was conducted on the assimilatory pigments and nucleic acid levels in young plants of *Zea mays*, provided by germinated seeds in magnetic fluid and electromagnetic field presence, grown in the presence of water based magnetic fluid in culture medium. The results obtained on this study shows that LM-EMF experimental samples had twice higher level than in the control samples, due to regeneration reactions of the plant metabolism processes against the putative local heating of the vegetal tissue produced by the electromagnetic field energy absorbed by the magnetic nanoparticles internalized in vegetal tissue. However, For the LM-EMF samples, the assimilatory pigments contents were found decreased for increased volume fraction of magnetic fluid solution with 20% in the case of chlorophyll a, an inhibitory effect being evidenced (Yulianto *et al*., 2016). Nonetheless, another study of stationary magnetic field (130 mT) on the mitotic activity was carried out to analyze selected biochemical parameters of lupin *Lupinus angustifolius* L. The data presented on this study showed that 130 mT MFS enhances the growth and development of aboveground parts which is manifested by an increase in the length and weight of the shoots and an increase in the photosynthetic pigment content. The study concluded that, MFS is beneficial for the improvement of growth and productivity of economically important (Najafi *et al*., 2013). Furthermore, low to higher magnetic field was carried to compere seed response to different intensities. The study showed that by applying electromagnetic fields was evident in improvement of germination rates, growth of coleoptiles and thus, the decrease in the time of dormancy (Dobreva *et al*., 2010). However, continuous Static Magnetic Field (SMF) on growth and concentration of phytohormones and chlorophylls in maize and sunflower plants SMF in two directions, parallel to gravity force (field-down) and anti-parallel (field-up) showed the negative effect of SMF in both directions on dry weight of maize plants whereas a prominent increase in roots of sunflowers was detected. However, the field-up direction caused a significant increase in IAA and t-Z contents (Rochalska, 2005).

Effects on trace element: Tomato plants was used to investigate iron uptake mechanisms, plant metabolic response to iron-deficiency stress, uptake of trace elements through time and the effect of fly ash amendments in trace element uptake. The results obtained in this study shows that plants increased their uptake of Cd, Co and Mo as the fly ash content of soil was increased. Static MF was carried out to evaluate the effect of different intensity on the uptake of carbon and light energy utilization on the cyanobacterium *S. platensis*. The study showed significant levels of micro and trace elements (Ni, Sr, Cu, Mg, Fe, Mn, Ca, Co and V) and essential amino acids such as histidine improved at 250 mT magnetic field treatments. Also, chlorophyll a content of the magnetically treated sample was higher than the control, suggesting better light harvesting for photosynthesis. However, there was slight decrease in lipid synthesis (Justo *et al*., 2006). The effect of different magnetic field strengths (0.0, 20.0, 40.0 and 60.0 m T), at different time intervals ranging from 0-300 min on some properties of irrigation water the pH, Electric Conductivity (EC) and Total Dissolved Salts (TDS) was investigated and analyzed. The results showed a positive effect of magnetic treatment on growth parameters, yield, increasing germination, absorption of the nutrients (N, P, K, Fe, Mn, Zn and Cu) and decreasing ion toxicity. Furthermore, the investigation of two irrigation treatments (control and water stress) under magnetic band M, using silver nano particles N, M+N and M+N+50% F) was determined on performance of *Trachyspermum ammi*. The study concluded that magnetic field exposure, probably encourages nutrient uptake efficiency could be applied to reduce fertilizer requirement. On the other hand, the cultivation of plants under low MF could be an alternative way of WUE improving (Mihaela *et al*., 2007). However, magnetic bio-stimulation on tomato plants *Lycopersicon esculentum* (Mill) cv. under NPK fertilizer levels showed that the treatment of magnetic field of 100 gausses for 15 min improved vegetative growth, increased total phosphorus content of tomato leaves and total yield while reduced pH value in soil extraction (Jensen *et al*., 2004).

RESULTS AND DISCUSSION

After surveying various methods used to improve the quantitative and qualitative attributes of agronomic and botanical production in conservatory or field conditions, it is therefore, concluded that the biological effects of MF or EMF treatments depend on the strength and exposure period. The interaction of magnetic field and exposure time indicated that a certain combination of magnetic field and duration are highly effective in biological and stimulation of certain characteristics.

The response of living organisms under the exposure of MF or ELM is becoming more and more important as new evidence reveals the ability of the subjected organism to perceive and respond quickly to varying MF by altering their gene expression and phenotype. To mention few, Yulianto *et al*. (2016) documented that spinach products which are stimulated with magnetic nanoparticles on planting medium have high iron content than similar products on the market. Iron content on the spinach plants products were stimulated with magnetic nanoparticles and spinach plants in the market are 9.897 and 3.3 mg/100 g, respectively. Furthermore, a stimulatory effect on nucleic acids biosynthesis was obtained in the LM-EMF experimental samples a twice higher level than in the control samples, due to regeneration reactions of the plant metabolism processes against the putative local heating of the vegetal tissue produced by the electromagnetic field energy absorbed by the magnetic nanoparticles internalized in vegetal tissue (Sapkota, 2012; Justo *et al*., 2006). However, Aguilara *et al*. (2015) observed a significant reduction of dry weight of maize plants under SMF whereas a significant increase in roots of sunflowers was detected.

The application of MF on chemical composition and availability of nutrients in the soil as well as the increments of total yield, the mechanism of action of magnetic field treatment in the plant is optimistic. The study indicates that using magnetic susceptibility-based monitoring technique can provide valuable information on the migration behavior of the metal pollutants and the potential depth of soil contamination. Nonetheless, using magnetic measurements, in conjunction with chemical analytical techniques to study metal migration, can give valuable information that may help determine the focus of remediation efforts at high priority locations (Li *et al*., 2007). Hence, MF exposure possibly encouraged nutrient uptake efficiency and could also be applied to reduce fertilizer requirement. On the other hand, the cultivation of plants under low MF could be an alternative way of trace element (Shahin *et al*., 2016). This finds support from the study conducted by Sapkota (2012) who stated that the levels of micro and trace elements (Ni, Sr, Cu, Mg, Fe, Mn, Ca, Co and V) and essential amino acids such as histidine were significantly enhanced under MF exposure of 250 mT. Also, chlorophyll a content of the magnetically treated sample was above the control tested samples, suggesting better light-harvesting for photosynthesis. However, there was a slight decrease in lipid synthesis.

The application of bioelectromagnetic for stimulation of microbes particularly focusing on the microalgae has also caught the interest of many researchers in the science community. Therefore, it is of paramount importance to exploit its commercial potential for biotechnology and biofuel applications because its influence is it is still absolute (Yulianto *et al*., 2016). However, EMF stimulation may also be used to improve the substrate utilization efficiency in microbial processes. Cells when subjected to electric field pulses of 0.25 kV for 10 msec in the presence of the enzyme cellobiose which showed the enhanced utilization of cellobiose and conversion of substrate into ethanol by a thermotolerant yeast, *Kluyveromyces marxianus*. As a result, ethanol was significantly improved by 40% over the control (Monna *et al*., 2008). Nonetheless, the stimulation effect of magnetic field of 0.1 mT flux density could be seen more quickly, between the 7 and 14th day of treatment, than the effect of magnetic field of 0,025 mT flux density. Hence, ergosterol content slightly increased in the first week of treatment. According to their examination, morphological changes were observable on the conidia of Aspergillus puniceus and *Alternaria* alternate whereas the pigmentation of the colony of *Aspergillus* niger changed, the cultures remained white (Ruzic *et al*., 1997). In addition, a significantly higher specific growth rate of 0.22^{d-1} in *S. platensis* exposed to 10 mT magnetic field when compared to $0.14d^{-1}$ for untreated culture. The growth of *S. platensis* was maximum when it was cultured phototrophically at lower light intensities but did not show improvement under heterotrophic conditions (Vishki *et al*., 2013). A magnetically treated liquid medium consisting of ferromagnetic salts showed the rapid growth of the bacterium over control in 3 h. Similarly, magnetically treated dry whey medium yielded three times higher cell count than the untreated medium. However, there was an overall increased response from the exposed dry whey illustrating how the culture medium composition may influence the effect of the MF. In the same manner, the study observed that the growth of *Escherichia coli* could be stimulated or inhibited by exposure to an oscillating 100 mT extremely low-frequency ELF for 6.5 h. Exposed cells had 100 times greater viability than unexposed cells, however, the viability varied with duration of exposure (Justo *et al*., 2006).

The application of MFT device improves the overall biological system indirectly and directly by adjusting biological features of the object. This finds support in study conducted by Mihaela *et al*. (2009) who attributed that the electric field, mainly generated by ions flowing to the membrane from the external environment, can change the molecular distribution of electronic charge inside each lipid molecule, producing perturbations of collective excitations in the mechanical and electrical properties of the lipid chain which can be treated as a mechanism for intermembrane communication, analogous to a damped harmonic oscillation. However, using sinusoidal and pulsed MFs affect the plant growth in different ways (with respect to different kinds of the plant). The 60 Hz sinusoidal has an apparent enhancing effect on growth but with the occurrence of some morbid state phenomena. Nevertheless, the pulsed MF harms plant growth rather than enhancing growth as the sinusoidal MF does.

CONCLUSION

The primary objective of this study was to understand the merits and demerits of MF and ELF particularly focusing on the agronomic attributes. Emphasis is placed on providing a balanced review of potentially pertinent studies. Exposing living organism to MF or ELM is ethically safe and affordable physical applications to improve the quantitative and qualitative attributes of agronomic and botanical production in greenhouse or field conditions. However, there is still a need for further research, since, the variety of magnetic devices tested makes it difficult to apply under field condition, especially, if not focusing on treating water to enhance chemical properties but rather focusing on the plant development and crop stand. However, the inconsistency and contradictory outcomes from the studies appear to indicate that the effects of magnetic fields on plants may be species-specific and/or is dependent on the characteristics of field exposure such as intensity and duration. A review of work done in the electro/magnetic field for improving the physiological activity of plants in recent years indicates a promising potential of such research characteristics in the future.

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