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Article

Effects of Different Magnetic Field Strengths and Duration on Seed Germination and Bacterial Growth

Vedat Atli [1] and Mehmet Emre Erez [2,*]

1 Van Yüzüncü Yıl University, Science Faculty, Molecular Biology and Genetics, 65100 Van, Turkey; vedatatli322@gmail.com, https://orcid.org/0009-0006-1651-2168
2 Van Yüzüncü Yıl University, Science Faculty, Molecular Biology and Genetics, 65100 Van, Turkey; emreeerez@hotmail.com, https://orcid.org/0000-0002-4944-365X
* Corresponding author: emreeerez@hotmail.com

Abstract: A magnetic field (MF) is an unavoidable environmental component for all organism. MF is constantly interacting with living systems and is known to influence a wide range of biological activities. Effects on organism are related to the strength and direction of the Earth's magnetic (geomagnetic) field variation. We aimed to investigate the effects of different magnetic field strength and also duration on seed germination (wheat and tomato) and bacteria growth (*Bacillus* and *Staphylococus*). The study was carried out in the presence of the magnetic resonance (MR) device. As a result of the measurements made in the MRI room, the organisms were subjected to a magnetic field of 0.2 and 1 Tesla. The seeds were exposed to the magnetic field for 4 days and the effects of each day were evaluated separately. The effect of the magnetic field varied interestingly with respect to the strength and especially by exposure time. The bacteria were exposed to two different magnetic fields continuously for 4 days. At the end of the application, morphological changes and zone diameters were determined. Seeds responded according to their genus and the magnetic field strength they were exposed to. Tomatoes were the most affected seeds in high magnetic field application, while wheat seeds were the least affected group. In bacterial growth, high tesla application increased the growth and pigment production of pigment bacteria, it was significantly reduced the growth of *Staphylococcus* bacteria. The findings have the unexpected implications that the germination can be effected associated with strength and exposure method. The effects and results of the magnetic field differ according to the species of organism used and even the variety and cultivars. A single paragraph of about 250 words maximum. For research articles, abstracts should give a pertinent overview of the work.

Keywords: Bacterial growth, Germination, Magnetic field, Magnetic resonance device, Magnetic responses.

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1. Introduction

Living organism have to be in constant interaction with their environment throughout their lives. They try to adapt to the all changes (Climatic, ecologic and technologic) that occur in their habitats. In conductive materials found in nature, a significant force occurs as a result of the movement of electrons. This force is called the magnetic field. The magnetic field is a phenomenon that cannot be seen with the eye, but is known to have effects on living organism. Many organism (migratory birds, insects, protists, magnetotactic bacteria, magnetosomes) have magnetic sensing mechanisms (Galland and Pazur, 2005; Lohman and Johsen, 2000). With the rapid development of technology and health sector, many studies are carried out on the effect of magnetic field. Interactions between Magnetic field and organism is become more popular as method cause to growth and development of organism.

The reduction of surface tension in magnetized waters has been the subject of research by researchers. Since the magnetic field causes polarization by displacing water atoms, it changes the physicochemical properties of water (Cai et al., 2009). With the physicochemical change, it is expressed that the surface tension of the water decreases and the viscosity increases. Magnetized water changed the pH of the soil and the environment and affected the uptake of some minerals (Ca, Mg, P, N). The changes that occur, by affecting the growth and development of organisms; It has been suggested that it causes changes in yield and quality (Bellaloui et al., 2012; Furlan et al., 2012).

It is known that the magnetic field changes the membrane structures of plants and ensures that more water and nutrients are taken. In studies, MA is effective in increasing enzyme activity and water uptake of seeds (Emanuel et al., 2023). In other studies, it has been revealed that MF applied to the seed before sowing increases the performance after germination (Vashisth and Nagarajan, 2008).

Sensitivity occurs in living species according to the wavelength and frequency of the magnetic field. The biological effects of the north and south poles of the magnetic field on living things can be different (Yano et al., 2004). The south

pole of the magnet can increase plant and bacterial growth, while the north pole can cause inhibition. Accordingly, magnetism can be used to slow the formation of bacterial infections or tumors.
Tomography devices, mobile phones, base station, high voltage lines penetrate into the interior of cells and tissues when their frequencies are low and their energy is high. This situation triggers the uncontrolled opening and closing of cell membrane channels, and the change in the biochemical structure of the cell. Thus, abnormalities may begin to appear, especially as a result of the increase in electromagnetic field (Çerezci et al., 20012).
In this context, two different magnetic fields strength (0,2 and 1 Tesla) were applied to different organisms in the study. The effects of magnetic field on the germination of two seeds (wheat and tomato) and the development of two bacteria (*Bacillus* sp. and *Staphylococcus* sp.) were examined.

2. Materials and Methods

2.1. Determination of magnetic field strength

In order to determine the effect of the magnetic field on different organisms, the magnetic field strength in the MR (Magnetic resonance) device in the Radiology Unit of the Van Regional Training and Research Hospital was measured with the help of the HT-20 digital Tesla meter. In the MR room with varying magnetic field intensities, (0.2 and 1-Tesla fields) were detected. A magnetic field was applied to bacteria and plant seeds at this location. For the control group (0 Tesla), the location where the magnetic field strength was not found in the same environment was selected.

2.2. Application of magnetic field to seeds

10 uniform and mature seeds of commercial wheat and tomato were selected. Sterilized seeds used in this study were left in petri dishes with a double layer of sterile blotting paper. 6 ml of distilled water was added to all seeds. Then the seeds were exposed to 0.2 and 1 Tesla magnetic fields in MR room. Ambient temperature (20 °C) detected. The seeds were exposed to the Magnetic field for 4 days. In order to determine the effect of exposure time as well as the magnetic field strength in the seed samples, the condition of the seeds was evaluated every day. Measurements were taken from the seed samples on the 1st, 2nd, 3rd and 4th days of the seeds. Thus, the change and relationship between the strength of the magnetic field and the exposure times were also determined. In this study, magnetic field applied seeds were taken with the control group at the end of the application period (1.^{st,} 2.nd, 3.rd and 4.th day) and all measurements were taken together at the end of the 4th day (Fig. 1).

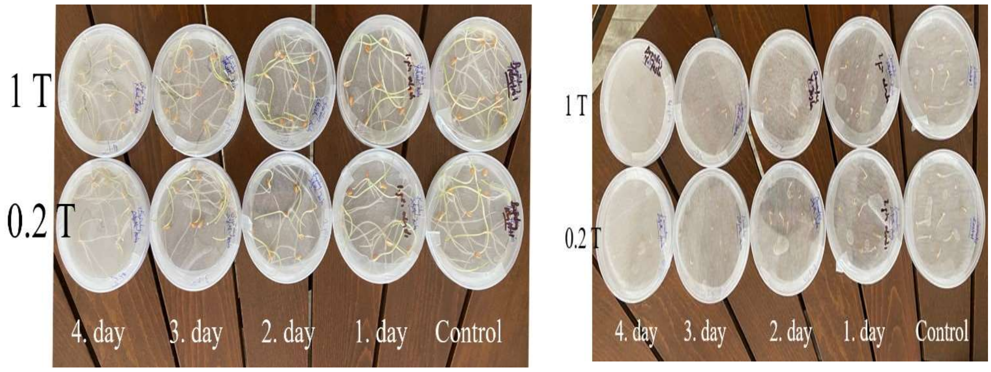

Figure 1. Application protocol and general view of magnetic fields exposed seeds.

2.3. Application of magnetic field to Bacteria

Bacteria samples (Bacillus sp. (Pigmet produece bacteria) and *Staphylococcus* sp.) to be used in this study were planted on Müller Hilton-agar in petri dishes. Three different magnetic fields (control, 0.2 and 1 Tesla) were applied to the bacteria in three replications in each group. After the petri dishes were left at the specified points for both bacterial species, the ambient temperatures (22±2 °C) were controlled and incubated for four days. Samples of bacteria exposed to magnetic field were exposed to magnetic field for four days. Colonies were measured at the end of the period. Metal shit of the same diameter was used for bacterial transfers to petri dishes and three replicates were used for measurements.

2.4. Measurement of test results

As stated before, plant seeds to which two different magnetic fields were applied for 4 days were removed from the petri dishes at the end of the application periods and measured one by one. Seeds that emerged were considered as germinated. Seedling lengths were measured with a ruler. For the bacterial study, the growth zones of *Staphylococcus* and pigment bacteria (*Bacillus*) were exposed to two different magnetic fields for 4 days. Zone diameters were measured.

3. Results

3.1. Effect of MR on germination percentage

Variable magnetic field affects the biological functions of organisms by changing the functions of hormone and enzyme activity in the organism, affecting nutrient entry and exit by affecting membrane permeability, or affecting DNA synthesis (Strasak et al., 2002). In germination physiology, all physiological events occur depending on DNA and enzyme activity.

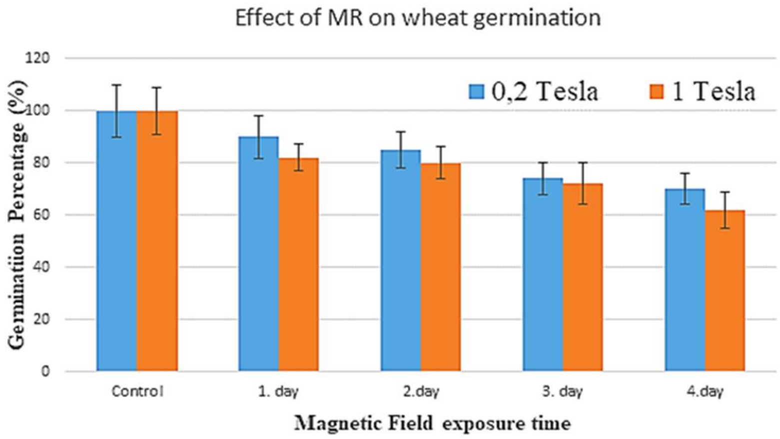

Figure 2. Germination percentage of wheat seed exposed to different magnetic field strength and duration.

In studies on magnetic field, it is generally stated that low Tesla applications increase germination, but long-term and high magnetic field applications reduce the germination rate. The most remarkable results in the germination experiment detected on tomato seeds. 1 tesla application reduced the germination rate to 60% on the 2nd day, 40% on the 3rd day and 30% on the 4th day. A similar situation was also identified in the 0.2 tesla application (Fig. 3). The decrease in germination may cause the magnetic field to negatively affect the Ca+ ions signaling the mitotic cycle (Vashisth et al., 2013).

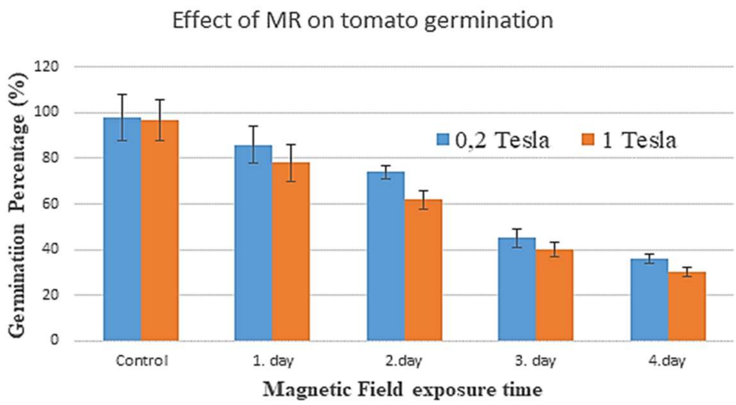

Figure 3. Germination percentage of tomato seed exposed to different magnetic field strength and duration.

3.2. Effect of MR on root elongation

Various and different results regarding the magnetic field application obtained with the MRI device were detected in root lengths. It was noticed that the 1 tesla application, which caused a higher inhibition in the germination percentage results, caused the root to elongate more than the 0.2 tesla application. It was determined that the application of 0.2 tesla prevented the development of more than 1 tesla of roots on all days (Fig. 4).

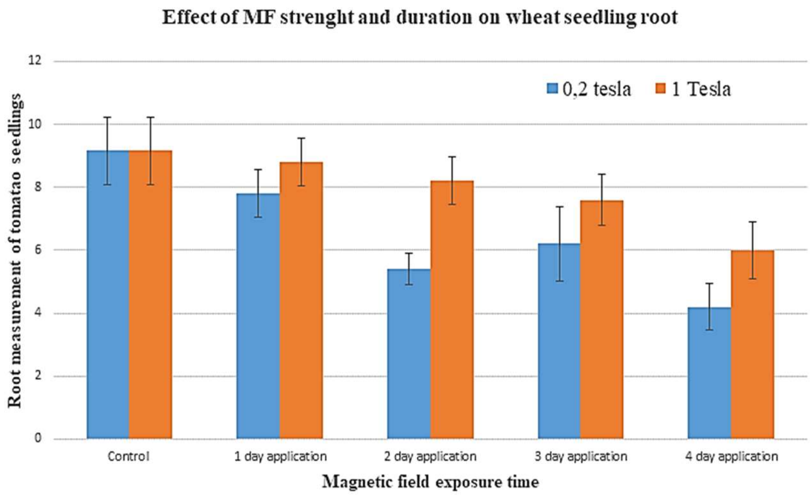

Figure 4. Root measurement of wheat seedlings exposed to different magnetic field strenght and duration.

Effect of magnetic field on germination and root development is so different with each other. Determined results can be the reason of physiologic and biochemical pathyway difference on germination and root development. In a study, in order to determine the effect of magnetic field treatment on seed germination, they chose 3-day-old seedlings with the same primary root length as starting materials. It's possible that the magnetic field intensity required to promote root growth is greater than that required for seed germination (Jin et al., 2019). In our study when the effect of the magnetic field on the root length of tomato seedlings was examined, one-day application of 0.2 tesla significantly increased root development. However, on the following days (2^{nd}, 3^{rd} and 4^{th}), especially the application of 0.2 tesla reduced root development and decreased the measurment values more than 1 tesla application, similar to wheat seedlings. Magnetic field application caused a sudden and significant decrease on days 3 and 4. (Fig. 5)

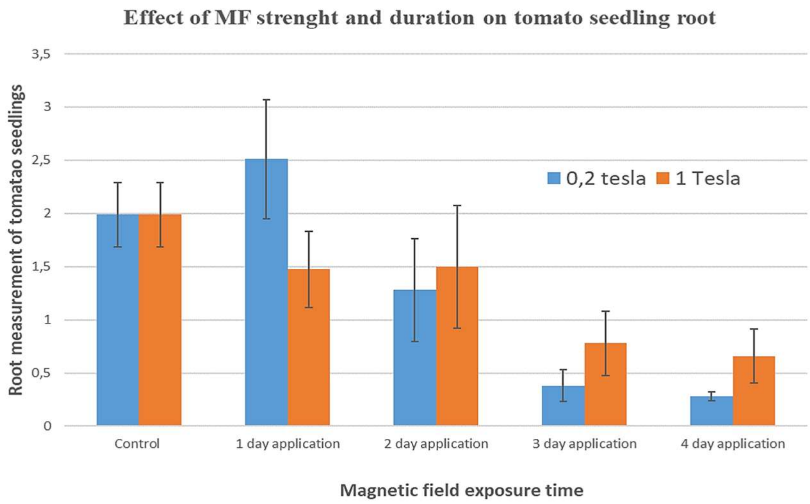

Figure 5. Root measurement of tomato seedlings exposed to different magnetic field strenght and duration.

The magnetic field dosage affects root biomass, stem girth, and leaf size. Furthermore, root growth is more responsive to magnetic fields than shoot growth. MF regulates the natural propensity of Fe and Co atoms and uses their energies to maintain the translocation of microelements in root meristems, hence influencing root development through nutrient intake and movement (Sarraf et al., 2020).

3.3. Effect of MR on bacterial growth

Bacterial growth of the applied magnetic field caused different responses. While magnetic field application to pigment bacteria reduced pigment formation, it caused the bacterial zone diameter to increase. It was determined that the 0.2 tesla application zone diameter was larger than the control and 1 Tesla application (Fig. 6). Because nutrient absorption happens through the membrane, the cell membrane of bacteria plays an important role in understanding the cellular growth mechanism. Depending on the strength and direction of the magnetic field, the magnetic field influences the ionic motion of fluids and has a significant impact on the terminal velocities of bacteria in liquid media (Justo et al., 2006).

a b

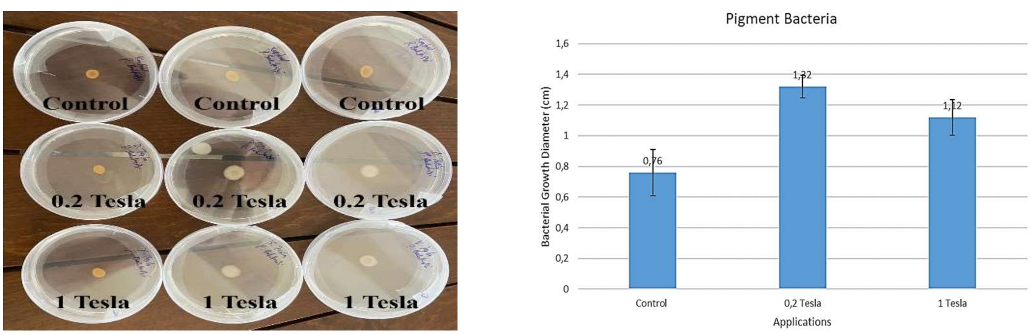

Figure 6. Magnetic field applied pigment bacteria (a), bacterial zone diameters at the end of the period (b).

In Staphylococcus bacteria, high Tesla (1 Tesla) application reduced the bacterial zone diameter compared to the control. It was determined that applying low tesla (0.2 Tesla) caused the zone diameter to decrease further (Fig.7).

a b

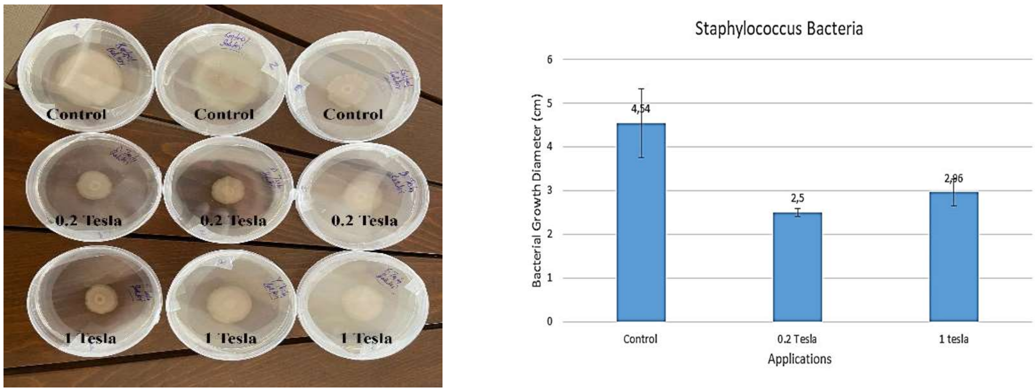

Figure 7. Magnetic field applied Staphylococcus bacteria (a), bacterial zone diameters at the end of the period (b).

The lag phase is experienced by most of the oscillatory magnetic field instances; this can be explained by the fact that it takes longer for bacteria to adapt to the oscillating magnetic field environment (Masood et al., 2020). Many components need to be taken into consideration when determining differences in magnetic field applications on bacteria. such as the type of bacteria, adaptation process or medium. As expected, the growth rate appears to be slower for the agar samples as compared to the bacteria grown in liquid nutrient broth. Justification of this behavior is related to the mobility of nutrients in the liquid broth as compared to the jelly-like agar (Saleem et al., 2021).

4. Discussion

When the effect of magnetic field obtained by magnetic resonance device on germination of wheat seeds was examined, it was determined that high and low tesla applications could not fall below 80% until the 3rd day. However, it was observed that especially 1 Tesla application on the 3rd and 4th days affected the germination rate and caused germination inhibitions. However, it was observed that the application of 0.2 tesla caused more inhibition than 1 Tesla (Fig. 2). In the study, no significant change was observed until the 3rd and 4th day. The effects of the magnetic field do not directly affect the germination of the wheat plant. The effect manifests arises when the effect of the magnetic field is high in strength and duration. A study with wheat seeds found that the intensity of the MF had a favorable influence on germination, although the exposure period did not differ significantly from the control seeds (Hussain et al., 2020). Various MF intensities appear to have varied impacts on plants, such as increased enzyme activities and/or photosynthetic pigment content; increased cell division; and water that is more efficient and nutrient uptake (Sarraf et al., 2020).

All magnetic field treatments significantly increase root growth but not leaf or hypocotyl growth. As a result, in reaction to magnetic field stimulation, the root is the most sensitive organ in the seedling. Magnetic field treatments stimulate root meristem cell division but have little effect on cell size in the mature zone.

Magnetic field pretreatment has a favorable influence on cucumber seedling growth and development. The magnetic flux concentrations, frequencies, and pretreatment of plant material all influence seed germination and plant growth. In our study high strength of magnetic field and long exposure significantly affected root development (Yinan et al., 2005)

Magnetic field-induced modification in cellular dynamics and ion transport in electrolytes has been found to alter the growth rate of different bacterial species differently. However, this effect may vary depending on the nature and behavior of the bacteria or the composition and temperature of the growth medium and should not be misinterpreted as a magnetic field effect (Masood, 2017).

4. Conclusion

The importance of MF reactions is growing as new research indicates organism's ability to recognize and respond to varied magnetic field by altering their metabolism, gene expression, and phenotype. All organism have to be exposed to magnetic fields throughout their lives. However, the effects, mechanisms and pathways of the magnetic field on organisms are not yet fully understood. Magnetic fields could be used as a new technique but for this, cellular and molecular based studies are needed.

Conflicts of Interests

Authors declare that there is no conflict of interests

Financial Disclosure

Author declare no financial support.

Statement contribution of the authors

This study's experimentation, analysis and writing, etc. all steps were made by the authors.

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