THEEFFECTS OF EXTREMELY LOW FREQUENCY MAGNETIC FIELDS ON TOMATO SEEDS GERMINATION

EFECTELE CÂMPURILOR MAGNETICE DE FRECVENȚE FOARTE JOASĂ ASUPRA GERMINĂRII SEMINȚELOR DE TOMATE

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***Abstract**. In this paper were investigated the effects of magnetic fields on the germination of tomato seeds, Korall cultivar. The experiments were performed under laboratory-controlled conditions to eliminate the influence of variations in environmental factors. The tomato seeds, during the whole germination period, were exposed to a magnetic field generated by electrical conductors crossed by different electric currents. Three types of extremely low frequency magnetic fields were used for treatments (0 Hz - 13 μT; 0 Hz - 20 μT and 50 Hz - 20μT). The results obtained are useful for the development of a smart system for stimulating the germination of tomato seeds.*
Keywords: germination of tomato seeds, magnetic field exposure, extremely low frequency magnetic field, Korall cultivar tomatoes

***Rezumat**. În această lucrare s-au urmărit efectele câmpurilor magnetice asupra germinării semințelor de tomate, soiul Korall. Experimentele s-au desfăşurat în condiții controlate de laborator pentru a elimina influența variațiilor factorilor de mediu. Semințele de tomate, pe toată durata de germinare, au fost expuse în câmp magnetic generat de conductori electrici străbătuți de diferiți curenți electrici. Pentru tratamente s-au folosit trei tipuri de câmpuri magnetice de frecvență foarte joasă (0 Hz - 13 μT; 0 Hz-20 μT şi 50 Hz -20μT). Rezultatele obținute sunt utile pentru dezvoltarea unui sistem inteligent de stimulare a germinării semințelor de tomate.*
Cuvinte cheie: germinarea semințelor de tomate, expunere în câmp magnetic,câmp magnetic de frecvență foarte joasă, tomate soiul Korall

INTRODUCTION

Although there have been made numerous studies on the effect of electromagnetic radiation, most of itcentered mainly on humans and animals. Studies on plants are not very numerous and do not have conclusive results, focusing on the main sources of exposure, namely: radiation from high voltage lines or from the Earth's magnetic field. Both the negative and positive effects of exposure to different fields are studied. Low frequency magnetic fields present an

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advantage in the field of biotechnology because they are much less toxic and easier to control unlike ionizing radiation.A representative example is given by NMR analyzes on a set of samples of some *Lemnoideae* species exposed to very weak fields that show an increased alanine production (Monselise *et al*, 2003). In another paper, the effect of 50 Hz magnetic field (magnetic induction of 10 mT) on mitotic activity in maize root was analyzed, where a small percentage of chromosomal abberations could be observed in the root of *Zea Mays* (Răcuciu, 2011). In 2010, a study was conducted on *Brassica Napus* exposed to electromagnetic fields, some anomalies being noticed such as slow development and the appearance of micronuclei that were totally different in terms of genotype (Shabrangi *et al*, 2010).

In conclusion, the exposure of plants to magnetic fields can cause different effects at the cellular or organ level, effects that may be related to the system that controls plant's metabolism and the intracellular balance of calcium ions (Belyavskaya, 2004).

The main objective of this study is to determine the effects of extremely low frequency magnetic fields (ELF-MF) on the germination of tomato seeds (*Solanum lycopersicum*, Korall cultivar).

MATERIALS AND METHOD

The experiment was conducted on tomato seeds, cv.Korall, during thegrowth stage 0 (germination, sprouting, bud development: 001-009 onBBCH scale) and growth stage 1 (leaf development:100-102a onBBCH scale) (Acosta-Quezada *et al*, 2016;Meier, 2018). The following parameters were determined: the percentage of germinated seeds, the germination capacity, the germination rate, the germination velocity, the root length and the stem length at the end of the germination process.The seeds used in the experiment were of *Solanum lycopersicum* 'Korall' tomatoes, ZkiVetomag - Hungary.

The study consisted of four experimentsfrom which in threeof them the tomato seeds wereexposed,during the whole germination process, toELF-MF of different intensity. In each experiment were used 150 seeds, placed in five Petri dishes, which were kept in special laboratory spaceswhere optimal germination conditions were ensured (temperature of 19^{o}C - night / 26^{o}C - day; dark - day length; permanent moisture). The variants for the involved experiments were:

I. MF1 – seeds exposed to a magnetic field (B = 13 μT) created by a conductor crossed by a direct electric current, with the following characteristics: ν = 0 Hz, I = 0.2 A, U = 8 V.

II. MF2 – seeds exposed to a magnetic field (B = 20 μT) created by a conductor crossed by a direct electric current, with the following characteristics:ν = 0 Hz, I = 0.3 A, U = 16.2 V.

III. MF3 – seeds exposed to a magnetic field (B = 20 μT) created by a conductor crossed by an alternanting electric current, with the following characteristics: ν = 50 Hz, I = 0.2 A, U = 12.9 V.

IV. Control – the samplesfor whichno magnetic field was applied to the seeds.

To perform the magnetic field exposure, the electrical circuit was made as seen in figure 1, consisting of an electric current source, thin copper wires of the same section, ammeter, voltmeter and high-power electrical resistors. The electrical resistances had the role of dissipating the thermal energy generated by the Joule effect. To avoid the influence in the germination process, these resistors were placed outside the germination space. The wires through which the electric current passed were positioned under the Petri dishes to ensure a uniform magnetic field throughout the germination area. For both safety and equal distribution, wooden boards were used as support.

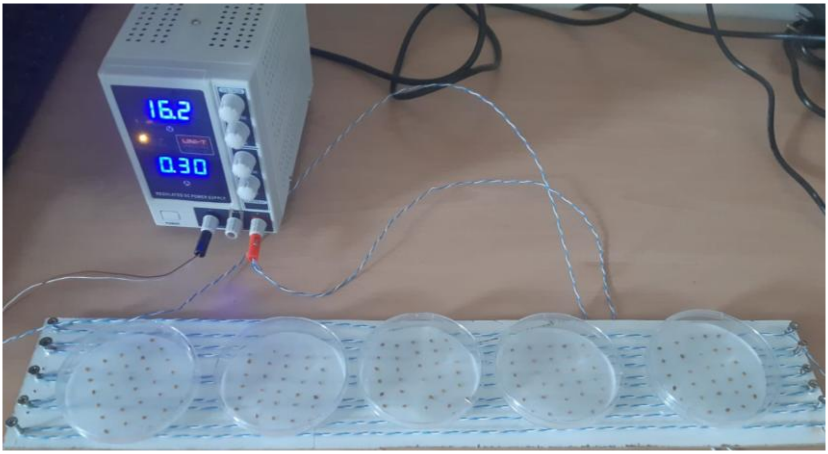

Fig. 1 The electrical circuit used for the exposure of tomato seeds under magnetic field

RESULTS AND DISCUIONS

The low frequency electromagnetic radiation (0-60 Hz) can have different effects on plants and this matter must be investigated further. If these effects are positive, it can be used to stimulate the growth and development of plants. For example, if it is found thatthe growth is accelerated, then wire installations can be used to expose plants to a magnetic field, using optimal values, in addition to the natural one. If the results show that radiation exposure increases the percentage of seed germination, this may increase the yield of a small greenhouse crop. On the other hand, if radiation exposure causes negative effects, a set of protection methods is required.

In agriculture and gardening, the germination rate represents the number of germinated seeds of plants over a certain period. It is a measure used by farmers or scientists and is usually expressed as a percentage. For instance, a germination rate of 85% indicates that approximately 85 out of 100 seeds are likely to germinate under appropriate conditions during the given germination period. The germination rate of the seeds is determined by the genetic composition of the seeds, by the morphological features and, also, by the environmental factors. The germination rate is very important in order to calculate the necessary number of seeds for a fixed area, knowing the number of plants desired to grow on that area. An acceptable germination rate for tomatoes to consider that a seed is of quality is over 80%, while a rate below 50% is unacceptable.

The germination capacity is another parameter that can be taken into account when determining the quality of plant seeds and represents the ability of a plant to complete the germination process.

The germination velocity is the time required for the seed to form its root.

The average germination rate for all experiments was 90.5%.At the end of the experiment, the germination rate for each variant (fig. 2) was of 90.67% (MF1), 86.67% (MF2), 89.33% (MF3) and 93.33% (control). As can be observed, the highest variation (3.9%) from the average value was obtained for the experiment involving direct current (I = 0.3 A), followed by control samples. The germination rates closest to the average were obtained in the case of the alternating and direct current with I = 0.2 A.The difference between the set of samples exposed to the more intense magnetic field (MF2) and the control sample is of 7.18%. Even if it seems to be small, nevertheless, it can be considered a change from a statistical point of view and presents importance for crops cultivated on larger areas.

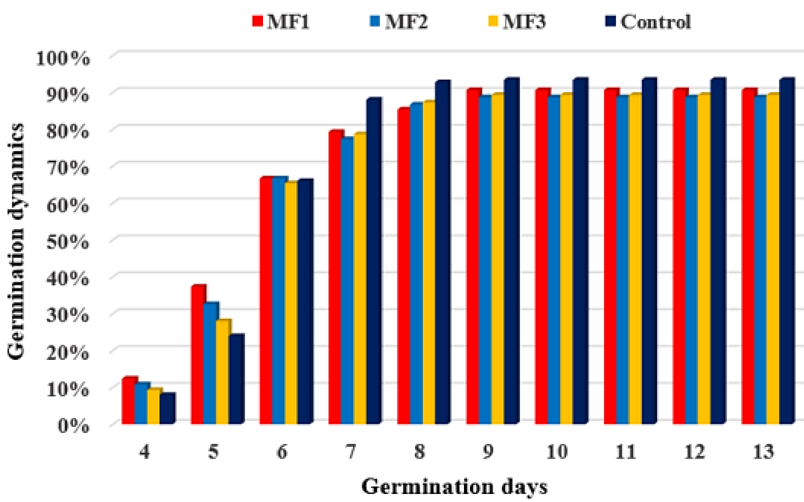

Fig. 2 The germination dynamics of tomato seeds exposed to different magnetic fields

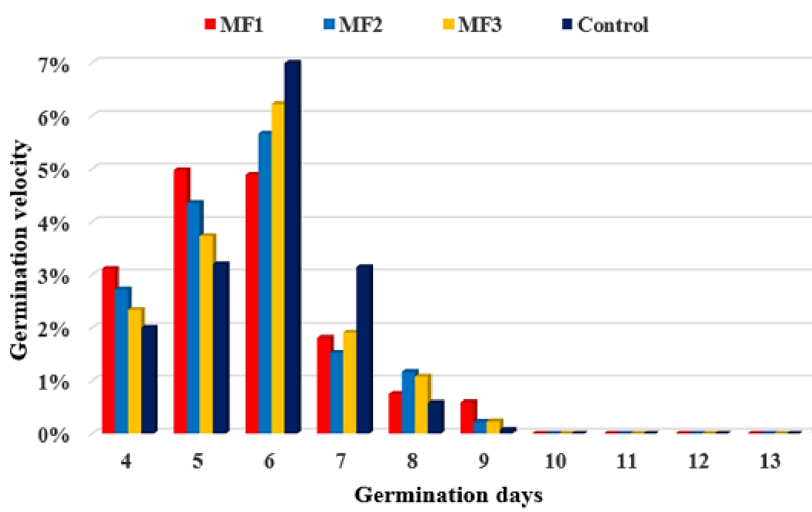

Fig. 3 The germination velocity of tomato seeds exposed to different magnetic fields

The germination dynamics was calculated as the cumulative number of seeds germinated each day and expressed in percentage.

The germination velocity was calculated as the percentage of seeds germinated every day (fig. 3). Although the values of this parameter are quite similar for different samples, it should be noted that for MF1 the seeds had a superior germination velocity in the first days as compared to the other samples. It is interesting that although for MF1 was obtained the lowest maximum of the germination velocities, it did not reach the lowest minimum, the profile being more constant.

In figure 4 is presented the length of roots and stems of tomato plant in leaf development stage, as well as the total plant length for each variant.

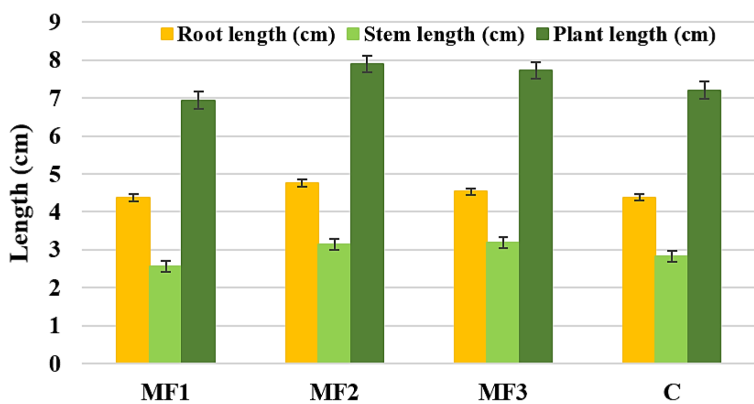

Fig. 4 The length of roots and stems of tomato plant in leaf development stage (102a onBBCH scale)

To better summarize the data, table 1 presents the percentages for different parameters of all the variants. The length was calculated in comparison with the control values.

Table 1.

The percentage of germinated seeds and length difference, in percentage, between treated and control samples

Sample	Germinated seeds (%)	Root length difference (%)	Stem length difference (%)	Plant length difference (%)
MF1	90.67%	-0.04%	-9.40%	-3.72%
MF2	88.67%	8.62%	10.85%	9.49%
MF3	89.33%	3.57%	12.91%	7.24%
Control	93.33%	-	-	-

There are no notable differences, in terms of average root length as compared with the control experiment, for MF1 and MF3. But a seminificative result was obtained for MF2 in which high amperage direct current was used.

Regarding the average length of the stem, MF3 in which was used alternating current (I = 0.2A) has the highest value, while MF1 with low intensity direct current (I = 0.2A) has the lowest values of the average length of the stem.

In terms of the effect on the total average length, the MF2 seeds had the highest stimulating effects. The seeds that were treated using MF3 alternating current also benefited from a positive stimulant effect as compared to the control. The MF1 seeds are the only ones that showed a negative stimulating effect, the average total length of the plants being below the total average length of the control.

CONCLUSION

1. The germination rate was affected in each experiment, regardless of the current intensity or the type of current used to create the magnetic field. The lowest germination rate was in the case of seeds exposed to direct current radiation of 0.3A, with a germination rate of 4.7% lower than in the case of the control, followed by seeds exposed to radiation produced by alternating current (4% lower than in the case of the control). The least affected were the seeds exposed to a radiation created by the direct current of 0.2 A. Thus, it is advisable to limit the exposure before germination.

2. Different types of current and intensities affect different parts or growth stage of the plant.The alternating current helps the development of the stem, while the direct current helps the development of the root. Hence, if a faster development of plant roots is targeted, then an exposure to magnetic fieldcreated by direct current of 0.3 A should be used.

3.Even though the changes between the seeds exposed to ELF-MF and the control ones are not considerable high, they may be of importance for large area crops.Moreover, this study indicatesthe types of magnetic fields suitable at certain stages of development and for certain parts of the plant.

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