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EFFECT OF MAGNETIC TREATMENT ON STRONG CUCUMBER (*Cucumis sativus* L.) TRANSPLANT PRODUCTION

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Cucumber is one of the most popular greenhouse products. Iran produces more than two million tons of this product annually, making it the third largest cucumber producer in the world after China and Turkey. Therefore, attention to maintaining its quality during harvesting is necessary. The present study was conducted to investigate the effects of the intensity and duration of a magnetic field on germination and cucumber transplant growth parameters. Experiments were conducted in a factorial arrangement in a completely randomized design with two treatments including magnetic field intensities in three levels (S1=80, S2=140, S3=240 millitesla), and magnetic field duration in four levels (T1=5, T2=10, T3=15, T4=20 minutes) with three replications. The root length, stem length, leaf area index, root weight, germination percentage, leaf chlorophyll content, and shoot dry weight were measured. The results of the analysis of variance showed that the effect of magnetic field on root length, stem length, leaf area, root weight, germination, and chlorophyll content is statistically significant. There was no significant effect on dry weight. The magnetic field intensity of 140 mT for 5- and 10-minute durations or a high intensity with low duration had more effect on plant growth compared to the blank. It is recommended that other intensities and durations of magnetic fields also be tested.
Keywords: Seed germination, magnetic field intensity, magnetic field duration, chlorophyll content, cocopeat molds

INTRODUCTION

Because of the increasing need for ecological agricultural production combined and plant raw materials for food production, the use of some branches of the industry in new research and making safe decisions to increase agricultural production is necessary (Faqenabi*et al.*, 2009). Arid and semi-arid regions are facing a shortage of water resources, yet there is a lot of agricultural land in these regions. Extending methods that can reduce water consumption in these areas is necessary. One such method is the use of transplanting in agricultural lands for vegetable production. Transplanting is the most reliable method for better plant establishment which benefits from increased land productivity, a reduced growing season, and improved weed control (di Benedetto and Rattin, 2008). Transplanting plays an effective role in reducing the growth period, and decreasing production time on the farm can increase the efficiency of using inputs such as water and thus reduce production costs (Wien, 1997).

Healthy and strong transplants are required for good plant establishment. In recent years, some new methods such as ionization, laser radiation, ultraviolet radiation, magnetic and electrical fields have been used to enhance germination rate and other plant characteristics. The effects of a magnetic field on seed germination and the growth of target plants have been investigated. Studies were performed for the first time by Savostin (1930), who observed increased grain seedlings in wheat under magnetic field conditions. After that, Murphy (1942) reported changes in seed germination caused by the effects of a magnetic field. Physical methods such as magnetic field for stimulating do not change the direction of the physiological processes controlled by the genetic systems of the plant. In other words, physical methods stimulate growth and metabolic processes without genetic manipulation (Radhakrishnan and Ranjithakumari, 2012). Therefore, the application of optimal amounts of physical methods for seeds and plants has no genetic effects on the plant and will not be transmitted to the next generation (Vasilevski, 2000). The results of some studies have indicated that MF has a positive effect on the number of flowers and yield, nutritional reserve, and water absorption of plants. Hence, magnetic therapy with proper intensities at appropriate times can be a kind of harmless environmental technology (Carbonell *et al.*, 2004). Stimulating plants use magnetic fields as a way to replace fertilizers and supplements. Chemical and physical treatments reduce the amount of pesticides in vegetable raw materials and increase the health of the food and the environment (Vasilevski, 2003; Dhawi *et al.*, 2009). It has been reported that a magnetic field also affects the activity of ions and the polarization of bipolar molecules in living cells (Kordas *et al.*, 2009). The cells of the plant have a negative charge that can absorb positive charge ions. Cytochemical studies have shown that root cells exhibit a weak magnetic field to control cells and show a state of calcium saturation in all their organelles and cytoplasm (Dhawi *et al.*, 2009). A magnetic field can increase the release of free radicals and cause stress

in a plant, while calcium ions help in some plant growth processes and react to stress, so this is an explanation for increasing calcium in the plant under magnetic field conditions (Dhawi *et al.*, 2009). Alexander and Doijode (1995) pointed out that germination and root length of onion seeds (*Allium cepa*) and rice (*Oryza sativa*) increased when exposed to a weak electromagnetic field for 12 hours. Experiments in Europe on the magnetic behavior of the seeds of pumpkin, tomato, and green cucumber plants showed that the magnetic field caused germination of 96% of seeds in just 3 days; in non-magnetic seeds, germination rate was 73% and germination duration was about 14 days (Rahimian, 2013). On the other hand, tomato seeds showed a greater response to magnetic water than to seed magnetization (Hilal, 2000).
In the case of wheat, 100% germination was observed in the seeds, and germination occurred 6 days after planting; in the case of the field with normal seed, 83% of the seeds germinated and germination was 9 days (Hilal, 2000). Mon and Sook (2000) observed an increase in the germination percentage of tomato seeds (*Licopersicon esculentum* L.) due to the short-term pretreatment of seeds with a direct electric field and a magnetic field. Meiqiang et al. (2005) reported that the different strengths of the magnetite treatment increased the percentage of tomato seed emergence by 28.8%, which may have been caused by the effects of deterioration in pests and diseases. Cakmak (2009) also reported higher growth and germination rates in wheat seeds (*Triticum aestivum* L.) and beans (*Phaseolus vulgaris* L.) with permanent magnetic field treatment. Feizi*et al.* (2012) reported that exposing seeds to a magnetic field with the intensity of 100 mT for 20 minutes had a more stimulating effect; stronger treatments had an inhibitory effect on germination traits. The duration and intensity of the magnetic field differ for each crop. Therefore, this study examined different exposure durations and intensities of magnetic fields in greenhouse conditions on the growth characteristics of cucumber transplants.

MATERIALS AND METHODS

This experiment was conducted in a research greenhouse of Lorestan Agricultural and Natural Resources Research Center, Khorram Abad, Iran, located at latitude 3708014.18 E and longitude 253771.97 N. It is located almost in the center of Lorestan province and at 1140 meters above sea level.
Electromagnetic device design**:** An electromagnetic device was designed according to Naz et al. (2012). This device consisted of two-wire rods 0.6 mm in diameter and a rounding distance of 4000 rounds and was connected to a power supply and placed in order to apply magnetic fields at various intensities. 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, placing the cocopeat molds inside the water, and increasing their volume, cucumber seeds were applied to the culture trays. Pure PS64 cucumber seeds were selected for this study. After the electromagnetic device used in this experiment was designed, a coil was designed around the iron, power supply, and solvent (Fig. 1). The seeds were placed between the coil-coated iron coils and the magnetic fields were applied at different intensities.

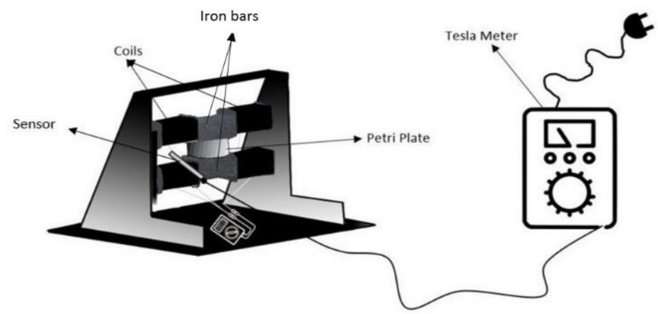

Figure 1. The experimental electromagnet setup (Naz *et al.*, 2012)

Experiment statistical design**:** Experiments were conducted in a factorial arrangement in a completely randomized design with two treatments including magnetic field intensities in three levels (S1=80, S2=140, S3=240 millitesla) and durations in four levels (T1=5, T2=10, T3=15, T4=20 minutes) with three replications.
Plant culture in greenhouse condition: Cucumber seeds were wetted for 24 hours and planted in culture trays on a Cocopeat bed. After seed germination, the plants were nourished with Hoagland nutrient solution. In the five-leaf stage, the plant growth characteristics of root length, stem length, leaf surface area, root weight, stem weight, germination percentage, leaf chlorophyll content, and whole plant dry weight were measured.
Measurement of plant growth characteristics
Stem length**:** This characteristic was determined using a precise ruler.
Leaf surface area**:** To measure the surface area of leaves, a 1-cm grid was used and their outlines were traced. Then the number of square centimeters were counted and the areas of the partial squares was estimated. The area of the stem (petiole) was not included in calculations.
Dry weight of stem and root**:** These traits were measured by precise digitalized balance.
Germination percentage**:** Germination percentage (GP) was calculated using the following formula:
GP = seeds germinated/total seeds x 100
Leaf chlorophyll content**:** Leaf chlorophyll content was measured by chlorophyll meter (SPAD-502).
Statistical analysis: The results of the experiments were analyzed using SPSS 22 software. Mean comparisons of experimental data were performed using the Duncan test at a 5% level of probability. Excel software was also used to draw charts.

RESULTS AND DISCUSSION

The analysis of variance results of the effects of treatments on the measured traits are presented in Table 1.

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

	Df	Mean square	F	Sig.
Stem length	12	1.75	174.81	0.000
Leaf surface area	12	247.92	340.38	0.000
Root weight	12	0.66	5.38	0.000
Stem weight	12	148.92	28.90	0.000
Germination	12	2447.44	30.79	0.000
chlorophyll	12	39.36	28.08	0.000

The analysis of variance results of magnetite cucumber seeds in the pre-culture stage indicate that the effect of the magnetic field on root length, stem length, total length of the stem, leaf area, root weight, plant height, germination, chlorophyll content, and height of the whole plant mean was statistically significant. Nevertheless, there was no significant effects on stem height or dry weight. For many years, the impact of a static magnetic field on the life of a plant has been the subject of studies. Recently, many researchers have reported the effects of a static magnetic field on the metabolism and growth of various plant species (Penuelas *et al.,* 2004). Several experiments have been conducted on the effects of magnetic or water fields exposed to sustained magnetism on plant growth considering the arrival of fruits and vegetables, increased crop production, bacteria, viruses, behavioral traits of animals, birds, aquatic species, and so on. Exposing seeds to a magnetic field for a short time has been shown to accelerate germination and seedlings growth (Carbunell *et al.,* 2000). The root growth of such plants compares with the growth rate of those not grown under the action of the seed. The action of the magnetic field of the seeds accelerates the growth of plants, biosynthesis of proteins, and development of roots (Chao *et al.,* 1967; Phirke, 1998). Scientific reports by many researchers have shown that exposure to magnetic fields increases the growth of non-standard seeds and increases their quality. Also, the strong impact of such exposure on accelerating the early stages of plant growth after emergence is very evident (Aladjadjiyan, 1998 and 2002). Wheat growth in the static magnetic field (Martinez, 2002) is stimulated by various irradiation protocols.

Stem length**:** The variations in stem length in different magnetic field intensities and exposure times are shown in Figures 5 and 6. In this experiment, exposure to a magnetic field with the intensity of 140 mT for 10 minutes had the greatest effect on increasing stem length. However, with increasing intensity and duration of the magnetic field, stem length decreased, as shown in figures 2 and 3.

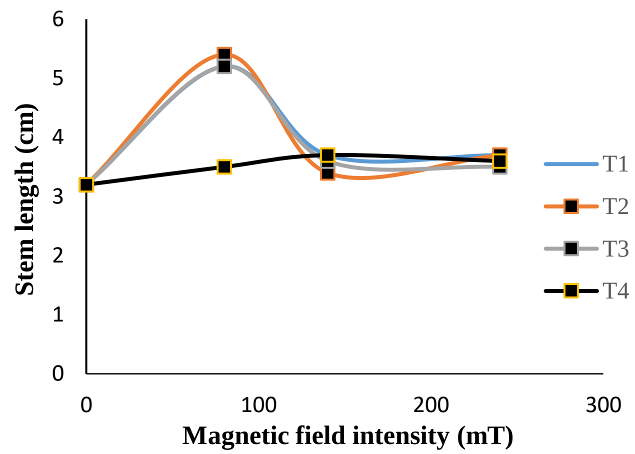

Figure 2. Changes in stem length at constant times and intensity of different magnetic fields

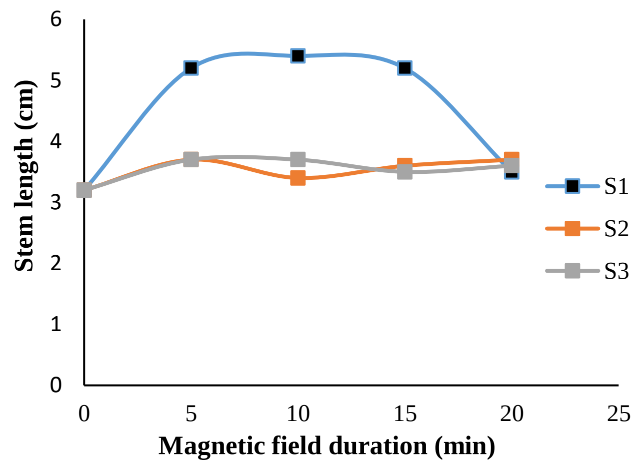

Figure 3. Changes in stem length with time in constant magnetic field

Harichand *et al*. (2002) reported that exposing seeds to a magnetic field increased stem length, seed weight per spike, and wheat yield. Celestino (2000) reported that exposure to a magnetic field (10 mT; 40 h) increased plant height and seed weight of wheat crop. The vegetative growth of Vicia Fabia seedlings was enhanced by magnetic fields (100 mT); this result was confirmed by the increased mitotic index and elevated 3H-thymidine elevation (Rajendra, 2005). Alajajian (2002) observed that a magnetic field stimulates the germination of maize and increases the vegetative energy, length and weight of the germ. Florez *et al.* (2005) and Martinez *et al*. (2002) also observed elongation of wheat seedlings under magnetic field conditions.

The comparison of mean stem lengths in different treatments showed that S1T2 treatments were significantly different from other treatments, and the other treatments were significantly different from the control. The treatment of exposure to a magnetic field with the intensity of 80 mT for

10 minutes was significantly different from the control and other treatments, as shown in Figure 4.

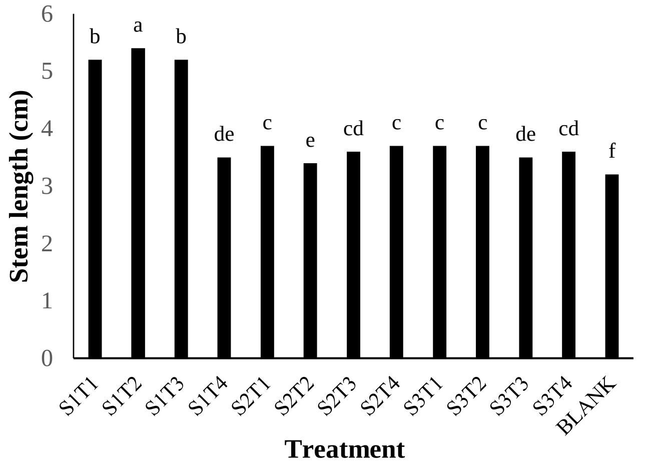

Figure 4. Comparison of the effects of different treatments of duration and intensity of the magnetic field on the stem length

Leaf area index: Leaf area index in a constant magnetic field intensity showed an increasing trend over time (Fig. 5). All treatments of magnetic field intensity and duration were significantly different compared to the control. S1T3 had a significant difference compared to the control and other treatments. Naz *et al.* (2012) reported that the plant height and leaf area index of okra under exposure to a magnetic field increased significantly compared to the control. They further stated that the increase in plant height could be due to the effect of magnetism on ion activation and dipole polarization in living cells. The increased leaf area in comparison with the control may be due to increased values of photosynthesis.

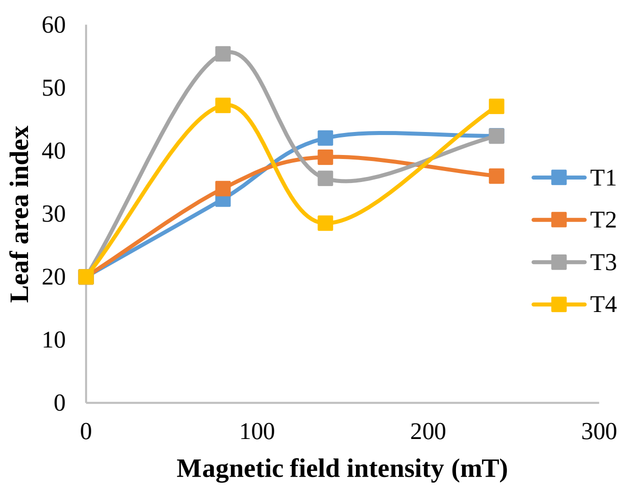

Figure 5. Leaf surface changes with increasing magnetic field intensity at fixed times

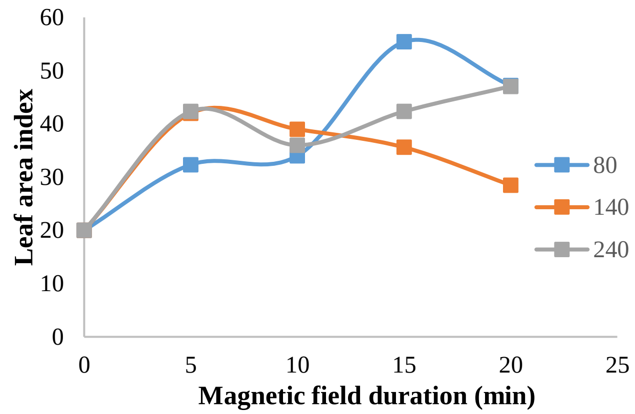

Figure 6. Leaf surface changes with increasing time in fixed magnetic field

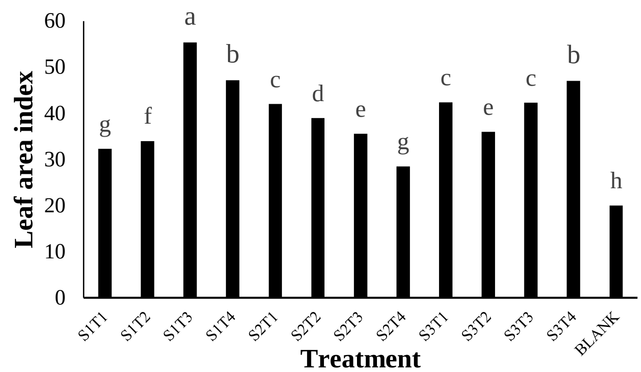

Figure 7. Comparison of the effect of different treatments of intensity and duration of magnetic field on leaf area index

Root weight: The comparison of root weight in different treatments showed that S3T3 had a significant difference compared to the control and other treatments. Treated lentil seedlings grew better than seeds that were not treated, and their root and biomass growth was significantly different as well (Ahmad, 2009).

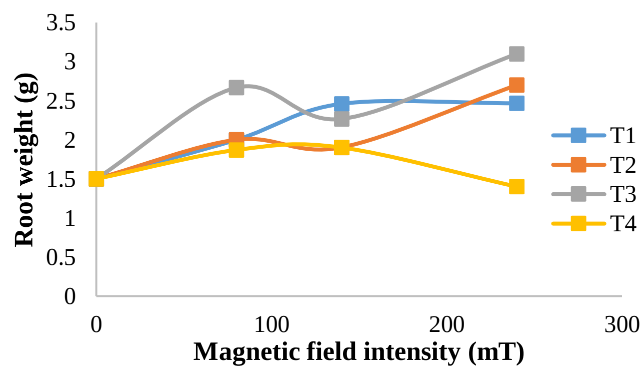

Figure 8. Root weight changes with increasing magnetic field intensity at fixed times

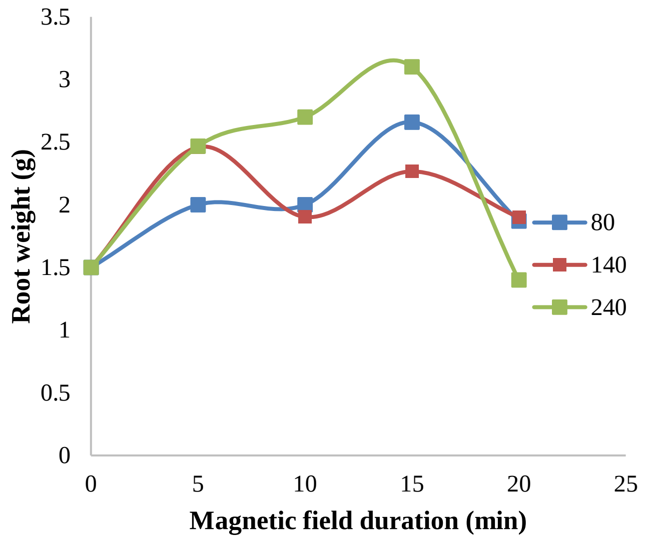

Figure 9. Root weight changes with increasing time in constant magnetic field

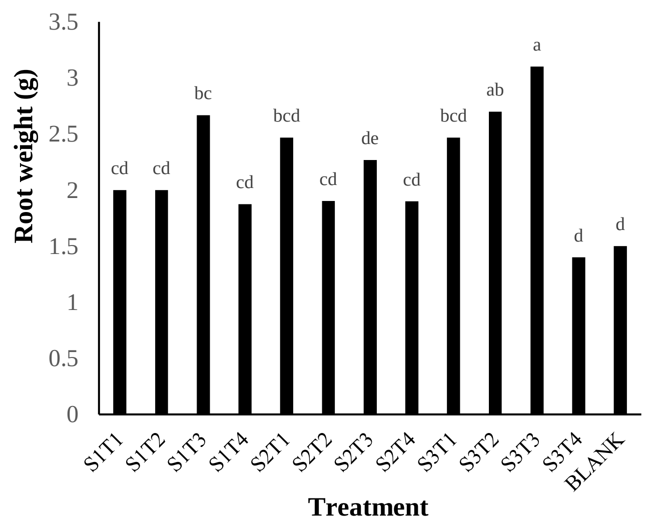

Figure 10. Comparison of the effect of different treatments of intensity and duration of magnetic field on root weight

***Germination percentage*:** Changes in seed germination under a constant magnetic field and constant time are shown in Figures 15 and 16. As can be seen, S1T3 and S2T2 treatments had higher germination rates compared to the others. After three days of planting seeds treated with a magnetic field, almost 100% germination was achieved compared to the control (Figure 11). The higher the intensity of the magnetic field was (240 mT for 20 minutes), the lower was the germination percentage.

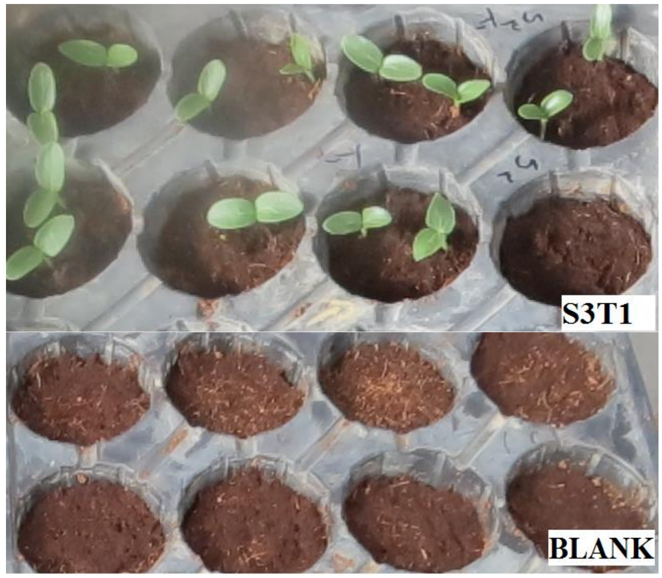

Figure 11. The effect of magnetic field on seed germination after three days

Pourakbar and Hatami (2012) reported that a magnetic field has a significant effect on germination percentage, root length, and stem length of *Satureiahortensis* L. seeds. Feizi *et al.* (2012) and Tahir and Karim (2010) reported similar results from the effect of a magnetic field. Florez *et al.* (2007) and Racuciu *et al.* (2008) also observed increased germination rate, fresh weight of stem, and total plant height of corn seedlings in magnetization field treatment.

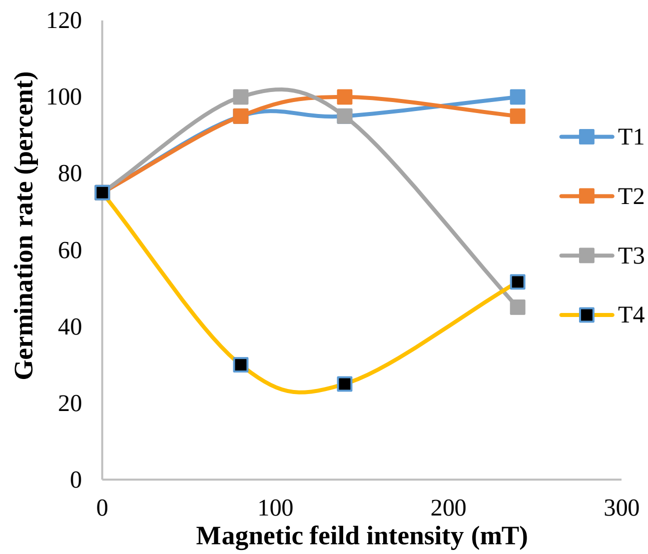

Figure 12. Germination changes with increasing magnetic field intensity at constant times

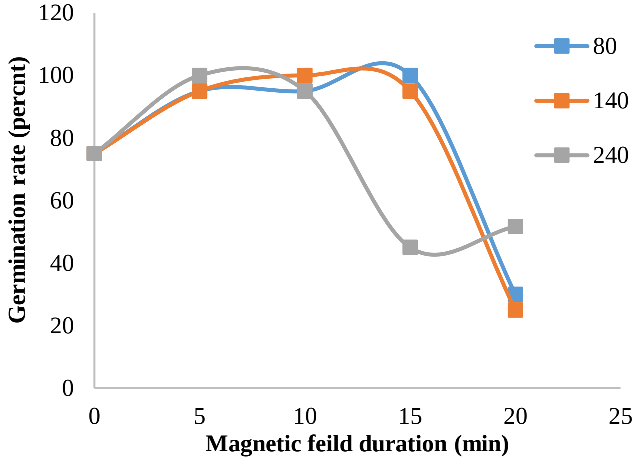

Figure 13. The variation of seed germination rate with increasing time in constant magnetic field intensity

The comparison of mean germination percentages of seeds in different treatments (Fig. 14) showed that all treatments other than S1T4, S2T4, S3T3, and S3T4 had significant differences with the control.

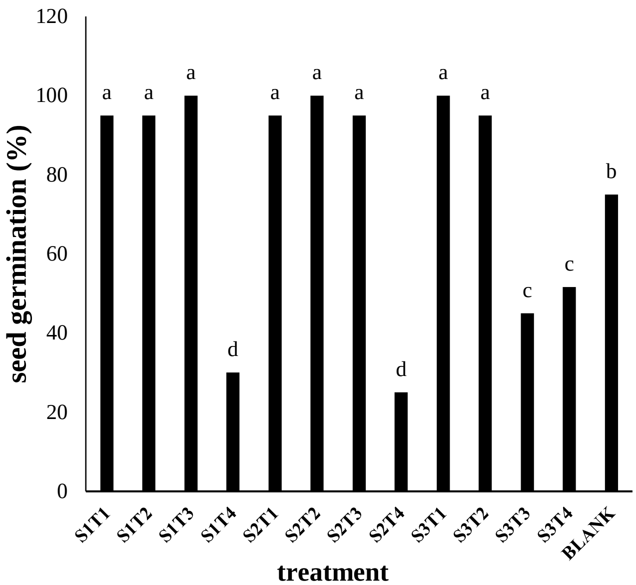

Figure 14. Comparison of the effect of different treatments of intensity and duration of magnetic field on seed germination

Chlorophyll: As can be seen from Figures 18 and 19, the S1T1 treatment had a good effect on chlorophyll content compared to the others. Racuciu (2008) reported that long-time magnetic field exposure increased chlorophyll content. Atak (2007) also concluded that magnetic field significantly increased chlorophyll a and b and total chlorophyll content.

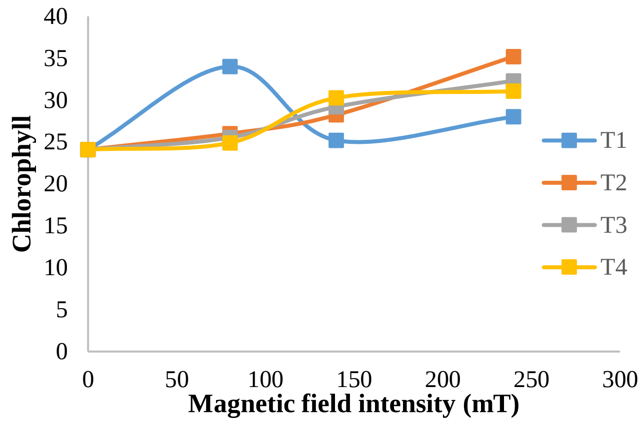

Figure 15. Chlorophyll changes with increasing magnetic field intensity at constant times

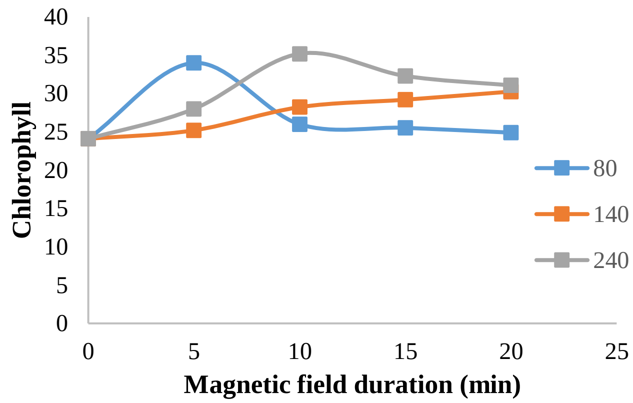

Figure 16. The variation of Chlorophyll content with increasing time in constant magnetic field intensity

A comparison of chlorophyll contents in different treatments is shown in Figure 17.

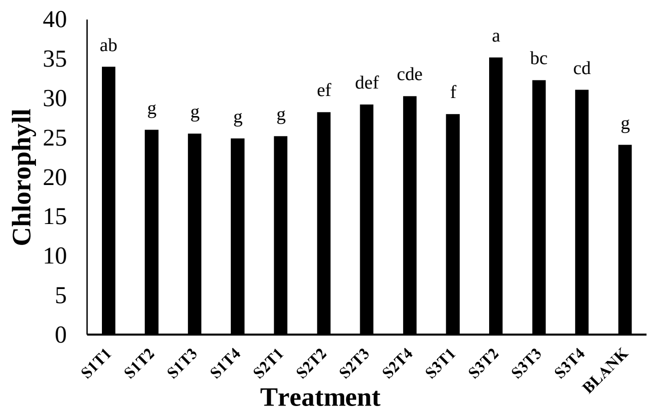

Figure 17. Comparison of the effect of different treatments of intensity and duration of magnetic field on Chlorophyll content

Racuciu*et al.* (2008) reported a 4.2% increase in chlorophyll in a 50-mT treatment compared to the control. Similar results were also reported by Dhawi and Al-Khayri (2008). As a result, the magnetic field can be used as a growth stimulus.

***Conclusion*:** According to the results, the use of a magnetic field to stimulate early seedling growth from cucumber seeds is possible. The magnetic field caused a significant decrease in seedling germination time of cucumber; in other words, the germination rate significantly increased. When the seeds were exposed to the magnetic field, the best time was found to be 15 minutes. It seems that low to moderate periods had more effect on the seeds. Germination decreased with increasing severity and exposure time of the seeds. By increasing the intensity of the magnetic field up to 140 mT, the rate of germination showed an increasing trend, but it fell sharply at a field intensity of 240 mT and decreased to even lower than the control treatment. Therefore, the magnetic field can be used as a non-invasive and non-destructive growth factor for the plant. Stimulating seedling growth of cucumber seeds through magnetic field treatments may have a significant positive effect on the more advanced stages of plant growth, which will be further published in the next section of this study and the next article.

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