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INFLUENCE OF MAGNETIC FIELD ON GERMINATION, GROWTH AND PRODUCTION OF TOMATO

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ABSTRACT

In the study with tomatoes, there was ivestigated the impact of extremely low frequency electromagnetic fields on seed germination of tomato (*Solanum lycopersicum* L.) after treatment before sowing, as well as the growth of young plants that were exposed to low frequency electromagnetic field before planting in the field when growing transplants under cover. In the experiments conducted in two consecutive years (2012 and 2013), we followed the length of seed germination period of tomato variety „Pavlína“, growth of young plants expressed in plant height and root length, and the fruit size. Magnetization of seeds and young plants was carried out in laboratory conditions, plant growth was evaluated under cover prior to planting, and fruit traits were followed in field conditions where plants were grown on experimental plots (80.0 m^2). The plants were grown in accordance with the standards of an agricultural practice for tomato. At the generative phase, the fruits were collected at regular intervals, and their number and weight were evaluated. Low frequency electromagnetic fields acting at the three inductance levels (20, 40 and 60 mT) and exposure of 20 minutes a day with frequency of 50 Hz, significantly positively influenced the germination, plant growth and fruit size of the studied tomato variety.

Keywords: tomato; electromagnetic field; germination; growth; production

INTRODUCTION

Tomato crop is demanding, requiring thorough approach to the growing technology. It requires a warm location, ample moisture, especially at the time of fruit ripening. Irrigation water should not be applied onto leaves and fruits in order to prevent fruit cracking and spreading of fungal diseases due to wet leaves **(Uher et al., 2009)**.

In the experiment we investigated the effect of low-frequency static magnetic fields on germination, growth and fruits of tomato variety „Pavlína“ which is medium early variety, with determinant growth and robust stature, suitable for the cultivation in southern regions of Slovakia. The fruits are firm, sweet, and suitable for direct consumption and have a shelf life of 2-3 weeks.

Electromagnetic stimulation of seed as well as stimulation of plant growth are among environmentally sound pre-sowing treatment techniques, and should be assigned to the non-invasive, environmentally clean and friendly technologies **(Aguilar et al., 2009, Nimm and Madhu, 2009)**, suitable for organic farming **(Aladjadjiyan, 2010, Bilal et al., 2012)** and for weakening of seed dormancy **(Carbonell et al., 2004, Ratushnyak et al., 2008, Pittman, 1977, and Alikamanoglu and Sen, 2011)**.

The magnetic field affects living systems in interaction of its size and nature of exposure to biological material. It influences cells, tissues, and the other organs and organ systems different ways **(Belyavskaya, 2004, Ottová - Leitmanová, 1993 Toroptsev and Taranov, 1982)**. Studies in cells and organisms of plants confirmed that magnetic fields affected the metabolism of cells **(Belyavskaya et al., 1992, Dardeniz et al., 2006)**. **Sleper et al. (2008)** in their studies found that biological stimulation as influenced by abiotic factors played an important role in optimizing crop in terms of germination. Positive impact on germination and growth of plants mentioned in his study **Aladjadjiyan (2002)** and reported stimulative effect of the energy of magnetic field on the development and morphological characteristics of the plants. According to the same author **(Aladjadjiyan, 2010)** electromagnetic fields have a positive effect on the paramagnetic properties of some atoms in plant cells and pigments in them. In studies of **Rajendra et al., (2005)**, the authors proved that magnetic fields stimulated germination and growth of selected varieties of beans and peas, noting improvement in germination parameters and higher yields. **Masafumi, Takuya and Wataru (1998)** in their study reached better formation of roots of seedlings of maize, compared with the control group as a result of magnetic fields influence. **Fischer et al. (2004)** in their experiment exposed sunflower seedlings to magnetic field, and achieved small yet significant increase in the total green plant weight compared to the control plants. The studies of authors **(Kavi, 1977 and Lebedev et al., 1977)** state that in electromagnetically treated tomato seeds there was confirmed biostimulation effect of those fields in the early stages of germination and growth. **De Souza et al. (2006)** report that electromagnetic tomato seed treatment resulted in a significant increase in leaf area, leaf dry weight, the average weight of the fruits as well as an increase in harvest of tomatoes per unit area. **Martínez et al. (2009)** in their study indicated shortening of seed germination period of magnetically treated of tomato seeds.

The aim of the study was to determine the effects of low frequency electromagnetic fields on germination, growth and fruits of tomato variety „Pavlína“.

MATERIAL AND METHODOLOGY

The experiment with tomato variety “Pavlína” was carried out in years 2012 and 2013. Part of the experiment was conducted in laboratory conditions - magnetization of tomato seeds and the magnetization of the young plants until the date of planting in open. Seeds and young plants were exposed to an electromagnetic field (EMF) at the level of induction of 20 mT (variant 1), 40 mT (option 2), or 60 mT (variant 3), with the same frequency (50 Hz) and the exposure time for 20 minutes a day. Magnetization of plants was performed every day within 48 days. Seeds and young plants in the control variant (variant 4) were not exposed to EMF.

The electromagnetic induction coil used in the experiment was made based on own project, taking into account the requirements of the experiment. An induction coil with an internal diameter 2R = 55 cm (Fig. 1) created a magnetic field defined according to **Horak and Krupka** (1976) relationship for the solenoid.

Description electromagnetic inductor

Electromagnetic inductor (coil), which we used in the experiment is composed of:
- Supply network driver,
- Voltage transducer,
- Meter of magnetic induction,
- Leading wires to the induction coil,
- Cylindrical induction coil.

The seeds of tomato were sown on March 10 into trays with universal substrate, and were regularly irrigated afterwards. 2 grams of seed produced in previous year was used for sowing in each of experimental years. After germination and froming of first pair of true leaves young plants were transplanted and grown under cover until May 15. Growing space with young plants after germination was ventilated to maintain a temperature of 15 °C, after transplanting day were increased to approximately 25 °C during night hours 15 °C.

Tomato plants were planted in field conditions for experimental fields on May 15, into light, soil rich in humus, at spacing 0.5 x 0.5 m. Surface irrigation was used according to need (soil moisture level).

In the first phase of the experiment the period of germination and growth of young plants (above-ground and underground part) were monitored, after planting in open field production of fruit was assessed (quantity and weight of ripe fruit). Results of the experiment were evaluated statistically by analysis of variance.

RESULTS AND DISCUSSION

The time required for germination of seeds in the experimental years is given in Table 1a and Table 1b.

As to the time needed for seed germination the shortest period was recorded in the second experimental variant (40 mT) - by 3 days (50%) shorter time compared to untreated seed. The longest period of germination was found in the control variant (0 mT) - 6 days (P <0.001).

Data on growth of young plants under cover in the experimental years are shown in Table 2a and Table 2b. Electromagnetic field had a significant impact on the growth characteristics of both aboveground part and roots of the experimental plants. The strongest growth was recorded in the second experimental variant in which aboveground part reached 0.45 m in average (55.2% compared to the control variant), and root length reached 0.36 m (71.4%).

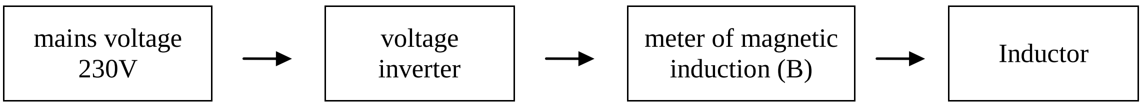

Figure 1 Block diagram of the electromagnetic inductor device

Table 1a Period of seed germination in experimental variants (year 2012)

Variant	EV1	EV2	EV3	CV
Induction level (B)	20 mT	40 mT	60 mT	0 mT
Germination period (days), compared to CV	4,0 66.6% *	3,0 50.0% ***	4,0 66.6% **	6 ***; **; *

Table 1b Period of seed germination in experimental variants (year 2013)

Variant	EV1	EV2	EV3	CV
Induction level (B)	20 mT	40 mT	60 mT	0 mT
Germination period (days), compared to CV	3,5 41,6% *	3,0 50,0% ***	3,0 50.0% **	6 ***; **; *

EV1 - the first experimental variant; EV2 - the second experimental variant; EV3 - the third experimental variant; CV - control variant, *** P <0,001; **P <0,1; *P <0,5

Table 2a Growth of plants in experimental variants prior to planting to field conditions (year 2012)

Variant	EV1	EV2	EV3	CV
Induction level (B)	20 mT	40 mT	60 mT	0 mT
Aboveground part (m)	0.34 21,4%	0.44 57,1% ***	0.37 32,1% **	0.28 ***; **
Underground part root (m), relative increase compared to CV	0,20 0.0%	0,37 85.0% ***	0,27 13.5% **	0.20 ***; **

Table 2b Growth of plants in experimental variants prior to planting to field conditions (year 2013)

Variant	EV1	EV2	EV3	CV
Induction level (B)	20 mT	40 mT	60 mT	0 mT
Aboveground part (m)	0,30 0.0%	0,46 53.3% ***	0,39 30.0% **	0,30 ***; **
Underground part root (m), relative increase compared to CV	0,24 9.0%	0,35 59.0% ***	0,31 40.9% **	0.22 ***; **

EV1 - the first experimental variant; EV2 - the second experimental variant; EV3 - the third experimental variant; CV - control variant, *** P <0,001; **P <0,1; *P <0,5

The weakest growth was recorded in the control variant e.g. 0.29 m (aboveground part) and 0.21 m (roots). These differences were significant at P <0.001.

Average weight of tomato fruits harvested at the time of maturity reached in the experimental variants in individual years are shown in Table 3.

The highest mean weight of ripe fruit was observed in the second experimental variant (159 g), which was by 11.2% higher compared with the lowest mean fruit weight achieved in the control variant (143 g), and the difference was significant (P <0.01). In the all experimental variants, the mean fruit weight was higher than that recorded in control variant.

Treatment of seeds of tomato variety „Pavlína“, as well as the young plants with electromagnetic fields at different induction levels (20, 40 and 60 mT), single exposure 20 minutes a day by planting in the eperimental field in open significantly effected seed germination and subsequent growth of young plants, as well as the size of the fruits. The magnetically treated tomato seeds showed shortened germination period, and also faster growth of seedlings was recorded, greater length above ground (stem) and underground (root) systems, and earlier fruit setting up to 14 days compared to tomatoes in the control variant. Plants exposed to EMF produced larger fruit - mean weight of tomatoes in the second experimental variant wa by 17 grams higher than that in the control variant (0 mT). Fruits of the tomatoes ripened evenly, which may have major economic importance.

In all experimental variants (EV1, EV2 and EV3) we observed a positive effect of magnetic fields on all monitored parameters of the experiment, compared to plants and fruits in the control variant.

References on the biological effects of magnetic fields

Table 3a Mean fruit weight in experimental variants (year 2012)

Variant	EV1	EV2	EV3	CV
Induction level (B)	20 mT	40 mT	60 mT	0 mT
Mean fruit weight (g), relative Increase compared to CV	147 4,2%	157 11,3% **	150 6,3%	141 **

Table 3b Mean fruit weight in experimental variants (year 2013)

Variant	EV1	EV2	EV3	CV
Induction level (B)	20 mT	40 mT	60 mT	0 mT
Mean fruit weight (g), relative Increase compared to CV	147 1,4%	161 11,0% **	152 4,8%	145 **

EV1 - the first experimental variant; EV2 - the second experimental variant; EV3 - the third experimental variant; CV - control variant, **P <0,1 have shown that the magnetic field can cause or change number of phenomena, such as the increase in the expression of calcium channels **(Belyavskaya, 2004)**.

Studies carried out by the authors **Aksyonov et al. (2001)** confirmed that the 15 minute treatment of seeds of wheat by the magnetic field of induction of 30 mT caused amplification of root growth by nearly 25%, while the length of the stems of the plants was higher by 40% compared to the control plants. **Alexander et Doijode (1995)** report that the use of the magnetic field within the seed treatment before germination improved root growth and viability of rice and onions. Similar results reported **Murphy (1994) and Phirke et al. (1996)**.

Authors **Bachárová and Valšíková (2013)**, in the experiments found a beneficial effect of magnetic radiation on tomato seed germination at frequencies of 20 mT and 40 mT.

Garcia et al. (2001) in experiments with magnetically treated lettuce seeds have found their earlier germination compared with untreated seeds, which could be due to increasing the amount of water absorbed. Even **Hoff (1981)** in his experimental results indicated the impact of magnetic fields to increase of the intensity of photosynthesis and water penetration during the growth of the treated plants.

Earlier germination in magnetically treated seeds of tomatoes in their study was also mentioned by **Martinez et al. (2009)**. **Vashisth and Nagarajan (2010)** attributed to a shorter period of germination of magnetically treated sunflower seed increased activity of hydrolytic enzymes.

De Souza et al. (2006) and **Socorro et al., (1999)**, **De Koning (1993)**, his experiments with magnetically treated seeds of tomatoes confirmed higher mean fruit weight of tomatoes, as well as their overall higher yields, which is consistent with our findings.

CONCLUSION

In the experiment, we investigated the effect of low-frequency electromagnetic field on seed germination, growth of young plants and fruit size of tomato variety „Pavlína“. We found that:

1. Low-frequency electromagnetic fields had a stimulatory effect on germination, growth characteristics and size of tomato fruit.
2. The effects of magnetic fields on growth apices of tomatoes varied depending on the level of induction.
3. Treatment of tomato seeds and young plants with electromagnetic field at the time before planting in field conditions influences also the production of fruit.
4. Exposure of seeds and young plants to magnetic field in all the variations lead to achieving better quantitative results compared to that obtained with the control treatment, we observed better fruit quality parameters also.
5. Faster germination and growth of young plants during their growing in protected areas can have a major economic impact, whereas shortening of growing period saves energy costs and subsequent earlier ripening can bring direct benefit due to higher prices of produce.

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