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OPTIMIZATION OF TOMATO CULTIVATION TECHNOLOGY UNDER GREENHOUSE THROUGH THE USE OF CONTINUOUS ELECTRIC CURRENT

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Abstract

One of the most important groups of vegetables grown in our country is represented by Lycopersicon esculentum, due to the importance of tomato fruits in the food sector. The present study follows the reaction of the plant to the external stimulation of electrical and magnetic nature on the metabolism of the plants, which will be reflected in the indicators of quality and quantity of the production. The study was carried out on a population of tomatoes in the research greenhouse of the teaching Farm "V. Adamachi", from the University of Agricultural Sciences and Veterinary Medicine of Iaşi. The most favourable results in terms of morphological parameters were recorded when using a magnetic field that used a DC with an intensity of 0.15 A, and the most favourable results regarding the quality of the actual fruit production were recorded using a magnetic field generated by a DC with an intensity of 0.45 A.

Key words*: tomato, electrical current stimulation, magnetic field.*

INTRODUCTION

The need for food is one that is increasingly accentuated, an aspect that results from the statistics that envisage population growth, which leads to new innovations in the scientific field that can solve this disadvantage.

Over time, scientists have tried to use various technical methods in order to obtain higher output, using electricity as one of the boldest attempts to increase production.

Nowadays, the influence of electric, electromagnetic (EM) and static magnetic fields on cells, tissues, plants, animals, and human beings in the laboratory and in the environment is of considerable interest (Berg, 1993).

Electrical stimulation of plants is an attractive hypothesis but relatively unexplored scientifically (Black et al., 1971).

Electrostimulation of plants was studied by scientists which had studied the influences of an electric current to observe the plant movement under the effect of electrostimulation, ion transport, activation of ion channels, plant growth, plant cell damage, enhanced wound healing, enzymatic system activation, gene expression, electrical signalling (Valkov et al., 2018).

The purpose of application of low intensity electric and electromagnetic stimuli was to determine the effect they have on the morphological characteristics of the plants (Belyavskaya, 2004).

Parvaiz Ahmad also studied the application of DC in tomato plants and concluded that the DC current can cause significant differences in root development, showing a typical gradient with high developed plants (Ahmad et al., 2013).

MATERIALS AND METHODS

Plants of *Lycopersicon esculentum* Mill., Qualitet F1 hybrid with a determined growth, were used to carry out the study. The dominant feature of this hybrid is that it lends itself well to growing conditions in protected areas. The experiment was carried out in the greenhouse within the Farm "V. Adamachi" Iasi, under controlled conditions of humidity and temperature, during 2019. The experiment was organised in a split plot design with four replicates.

The seedlings were sown in alveolar tray, on 15^{th} of March 2019, after which the seedlings were transplanted in pots with 9 cm diameter. At the 45 day after sowing, plants were

transplanted in 12 l pots, on 01st of May, at which point the experiment began, by assembling the equipment which will follow the influence that the electric current has on the metabolism of plants (Popescu et al., 2013; Voican et al., 2004).
The substrate used was peat, using ORGEVIT® as a fertilizing agent. The experience was realized on a group of 24 plants which were divided into 6 variants of 4 repetitions.
The equipment used were: 5 DC sources stabilized by the laboratory 0-30V/0-5A; electrical conductors with a length of 4.5 m, arranged in the form of a spiral with a diameter of 5 cm, these having a resistance of 1.3 Ω, the two ends of the spiral being each connected to a different electric conductor with a length of 4 m and 1.7 Ω resistance; 3 electrical resistors of 20 W and 15 Ω that were used in the case of variants 1, 2 and 3, these being connected at the output of the terminal + within the circuit.
The voltage sources were adjusted in such a way as to provide in the electrical circuit created, currents of different intensities, linking in parallel to the terminals of the laboratory source the electrical conductors for each of variants 1, 2 and 3.
A low intensity DC was used in order to prevent the plant death whereas the polarization time up to membrane breakdown is influenced by the field strength wich can cause the plant death (Angersbach et al., 2000).
Version 1 - used an electric current that crossed the circuit thus created using a current with an intensity of 0.15 A, DC.
Version 2 - used an electric current that crossed the circuit thus created using a current with an intensity of 0.30 A, DC.
Version 3 - used an electrical current that crossed the circuit thus created using a current with an intensity of 0.45 A, DC.
In the case of variant 4 (polarity) were used syringe needles that crossed the plant stem, these being inserted in number of two for each plant of the 4 repetitions, one being mounted in the apical area, and the other at the base of the stem. In this version, the 4.5 m wire was not used as a spiral, but only the 2 wires with the length of 4 m and the resistance of 1.7 Ω, the electrical conductors being connected to the two Syringe needles with the help of crocodile clips. The DC power applied was 1.5 V, DC.
For the 5th version (soil variant), the entire circuit was mounted using the same conditions as in the case of the 4th version, the difference being that the two electrical conductors were connected to 2 electrodes that were inserted in the soil.
The 6th version was represented by control, they served as a reference sample.
The experiment was conducted between 01st of May 2019 - 30th of June 2019.
During this period, all the plants were watered daily with 2 liters of water each, being applied practical measures of growing according with Stoleru et al., 2014.
To fight pests and diseases were applied four treatments, according with Munteanu, 2003. The treatments were applied foliar to all the plants, using an automatic pesticide sprayer.
The existing climatic conditions in the greenhouse compartment where the experiment was conducted are shown in Tables 1 and 2.

Table 1. Average temperature

Period	Max. temp. (ºC)	Min. temp. (ºC)	Average temp. (ºC)
01st of May 2019 - 31st of May2019	33.7	10.9	20.9
01st of June 2019 - 30th of June 2019	39.9	16.9	26.1

Table 2. Average humidity and light intensity

Period	Average humidity	Light intensity (Lx)
01st of May 2019 - 31st of May2019	73.4%	45609.7
01st of June 2019 - 30th of June 2019	70.2%	53543.3

On 30th of June 2019, the aerial part of the plant (fruits, leaves and stem) was harvested for analysis, followed by the dismantle of the crop. Immediately after dismantling the crop, measurements were made on the morphological and physiological particularities of the tomato plants: the height of the plant; number of leaves; number of fruits; area surface; the mass of the plant; fruit mass; determination of the content of chlorophyll pigments (Dannehl et al., 2012).

RESULTS AND DISCUSSIONS

On 30th of June 2019, measurements were made in order to determine the results of the experiment, in order to observe whether the application of an DC current directly or indirectly on tomato plants by using a low intensity electromagnetic field which can induce morphological changes and/or physiological changes, similar observations were being made by De Souza using magnetic treatments on tomato seeds before sowing, magnetic treatments increasing the growth and yield of tomato crops (De Souza et al., 2006).

The results of the variance analysis are presented in Table 3, in order to determine the significance of the differences for the Duncan test.

Table 3. The analysis of the variant

Analysis of variance (ANOVA) using $p \leq 0.05$					
Plant hight					
Interaction	Sum of squares	df*	Mean square	F**	Sig.***
Between Groups	1741.00	5	348.20	0.864	0.524
Within Groups	7251.00	18	402.83		
Total	8992.00	23			
Plant weight					
Interaction	Sum of squares	df*	Mean square	F**	Sig.***
Between Groups	39088.77	5	7817.75	8.671	0.000
Within Groups	16228.58	18	901.58		
Total	55317.36	23			
Numer of fruits					
Interaction	Sum of squares	df*	Mean square	F**	Sig.***
Between Groups	31.70	5	6.34	2.272	0.091
Within Groups	50.25	18	2.79		
Total	81.95	23			
Average weight of a fruit					
Interaction	Sum of squares	df*	Mean square	F**	Sig.***
Between Groups	6968.97	5	1393.79	3.947	0.014
Within Groups	6356.16	18	353.12		
Total	13325.14	23			
Average weight of fruits per plant					
Interaction	Sum of squares	df*	Mean square	F**	Sig.***
Between Groups	243260.87	5	48652.17	3.005	0.038
Within Groups	291430.36	18	16190.57		
Total	534691.24	23			
Leaves number					
Interaction	Sum of squares	df*	Mean square	F**	Sig.***
Between Groups	29.33	5	5.86	1.072	0.408
Within Groups	98.50	18	5.47		
Total	127.83	23			
Leaf area					
Interaction	Sum of squares	df*	Mean square	F**	Sig.***
Between Groups	8310116.50	5	1662023.30	3.141	0.033
Within Groups	9524845.50	18	529158.08		
Total	17834962.00	23			
Clorophyll					
Interaction	Sum of squares	df*	Mean square	F**	Sig.***
Between Groups	109.07	5	21.81	2.023	0.124
Within Groups	194.06	18	10.78		
Total	303.13	23			

* - Degree of freedom; ** - Fischer factor; *** - Significance

Regarding the morphological parameter that refers to the height of the plant. the differences are insignificant, these being based on the genetic characteristics of the variety used, which shows that the use of DC does not significantly influence this parameter (Figure 1).

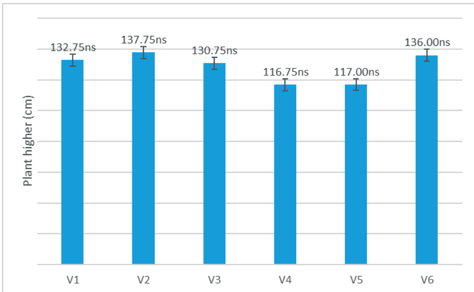

Figure 1. Plant height under continuous electric current

On the other hand, the average weight of the plants can be influenced by the electric current used, both positively as is the case of variant V1, where the highest value was recorded, slightly exceeding the weight of the control variant, while in the case of variant V4 plants were significantly negatively affected (Figure 2).

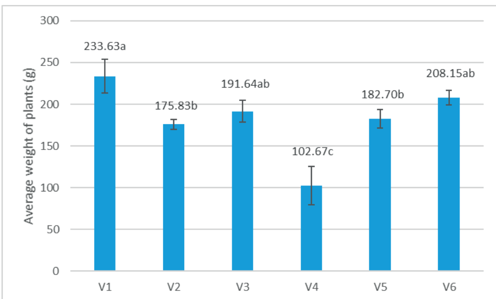

Figure 2. Influence of direct current on plant weight
*Letters are significantly different according to the Duncan test using $p \leq 0.05$, the letter a represents the highest value

Positive results regarding the use of electric currents and low intensity magnetic fields were obtained for the plants of *Helianthus annuus* and *Triticum aestivum* (Fischer et al., 2004), *Hordeum vulgare* (Lebedev et al., 1977, cited by Dannehl, 2018).

The average values of the number of fruits varied significantly, the lowest being recorded in the case of variant V4, followed by the variant V6 (reference), while the highest number of formed fruits was recorded in the case of variant V5 (Table 4).

Table 4. Influence of the direct current on the number of fruits, average weight of the fruit per plant and the average weight of a fruit

Electric treatment	Number of fruits	Average weight of a fruit (g)	Average weight of fruits per plant (g)
V1	7.75±0.48a	75.13±6.09bc	576.11±32.31ab
V2	6.00±0.91ab	60.05±12.53c	368.37±108.43b
V3	6.00±0.58ab	107.99±4.71a	642.70±47.99a
V4	5.00±1.08b	78.38±13.56bc	367.91±59.25b
V5	8.25±0.75a	60.88±7.04c	490.16±39.88ab
V6	5.75±1.03ab	93.06±8.90ab	510.67±63.86ab

*Within each column, letters are significantly different according to the Duncan test using p≤0.05, the letter a represents the highest value.

In the case of the weight of the fruits per plant there are significant differences, the best results were recorded in the case of V3, where the average mass of a fruit also recorded the highest value. Variant 3 is followed by Variant 1 as the average weight of fruits per plant, while Variant 5 shows an insignificant difference from Control.

Favourable results for fruit production efficiency (calculated as the number of fruits harvested from an area of 100 square meters, divided to the average weight of the fruit) using the electric current for 20 days at the parameters of 1500 nT, 10 Hz, were obtained by at the plants of *Glycine max* (Radhakrishnan and Kumari., 2012).

The number of leaves registered insignificant differences (Figure 3), the same results being obtained using the phenomenon of electrostimulation on the plants of *Solanum scabrum* (Gogo et al., 2016).

The parameters related to the leaf area have varied by registering the highest values in the V1 variant, being followed by the V3, V6 and V2 variants, while the V4 variant has recorded the lowest leaf area (Table 5).

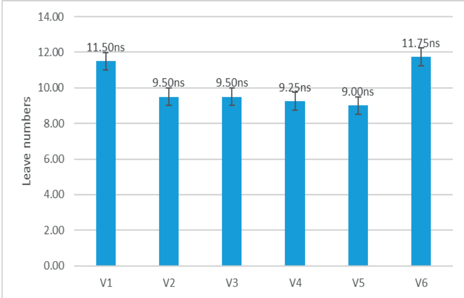

Figure 3. Leaves number under continuous electric current treatment

Table 5. Influence of direct electric current on leaves number, leaves area and chlorophyll content index

Electric treatment	Number of leaves	Leaves area (mm^2)	CCI
V1	11.50± 0.86ns	4,290.25±343.38a	21.03±1.48a
V2	9.50± 1.19ns	3,265.50±344.93ab	14.62±0.73b
V3	9.50±0.29 ns	3,695.50±203.61a	16.25±0.47ab
V4	9.25± 2.06ns	2,358.50±630.75b	18.78±2.90ab
V5	9.00± 1.08ns	3,201.75±215.82ab	17.36±1.62ab
V6	11.75± 0.75ns	3,636.50±266.37a	15.60±1.45b

CCI - chlorophyll content index
ns - insignificant; within each column, letters are significantly different according to the Duncan test using p≤0.05, the letter a represents the highest value.

Similar to the leaf area, the chlorophyll content index also presented the highest values for V1 Chlorophyll parameters were analysed using electric current on *Lepidium sativum* plants where favourable results were also obtained (Dannehl et al., 2018).

CONCLUSIONS

The plants weight variation was significant, best results being obtained for the sample that used a DC current with an intensity of 0.15 A. For the samples that used a DC current with an intensity of 0.30 A, 0.45 A, a DC of 1.5 V and the reference sample the results were very similar, while for the sample that used a DC of 1.5 V by using syringe needles in the apical area and at the bottom of the stem of tomato plants could be observed a significant lower rate of development.

The best results for the average fruits weight per plant was registered by the sample that used DC current with a intensity of 0.45 A, followed by the sample that used a DC with a intensity of 0.15 A.

The average number of leaves was relatively similar for each sample, the higher number of leaves being observed for the reference sample and for the sample that used a DC current with 0.15 A.

The leaves area was measured using Li-3100 LI-COR. The best results were obtained again for the sample that used an DC current with an intensity of 0.15 A.

Based on the measured values it was concluded that a low intensity electric current stimulates the vegetative growths (they develop at a faster rate), but the higher intensities lead to a better absorption of the nutritional elements corroborated with a higher growth of fruit mass.

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