COMPARATIVE ANALYSIS OF THE LABORATORY RESEARCH RESULTS FOR PRE-SOWING ELECTRICAL TREATMENT OF TOMATO SEEDS

PRIEŠSĖJINIO ELEKTROS POVEIKIO POMIDORŲ SĖKLAI LABORATORINIŲ TYRIMŲ REZULTATŲ PALYGINAMOJI ANALIZĖ

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The possibility to achieve a stimulating effect on the development of vegetable seeds of two tomato varieties (‘Rio Fuego’ and ‘Rio Grande’), after subjecting them to a pre-sowing treatment in an electrostatic field and in the field of AC corona discharge, has been confirmed.

The initial values of the controllable factors (field intensity, duration of impact and rest period from the treatment to sowing) in the pre-sowing treatment of tomato seeds have been determined. They help to stimulate the monitored parameters: germination power, germination capacity and length of roots and germs.

A hypothesis is raised that, in addition to the stimulating effect on plants, the pre-sowing treatment of tomato seeds helps to equalize the parameters of their growth and suggests simultaneous ripening of the fruits.

Confirmation is given of the statement that, generally, after a long period of rest (T=13 and T=365 days) of tomato seeds, the pre-sowing electrical treatment has a suppressive effect on the monitored parameters.

Seeds of tomato, electrical field, germination power, germination.

INTRODUCTION

The use of chemical fertilizers for yields increase poses a serious threat to the animal and human health. Therefore new means for stimulation of plant growing are investigated. As an example the pre-sowing treatments with magnetic field are used in research of wheat [1], barley [5] and grass seeds [2]. The corona discharge field [4] is also used for pre-sowing treatment. Another way for seed processing is by use of electromagnetic field, with high voltages, for treatment of vegetable seeds [3], maize [7] and plants with high level of oil content as cotton [6] and rape seeds [8] – in electrical field.
In the experiments, the most frequently reported parameters are: germination power, germination capacity, root length and germ length, which are compared to the untreated (the control) batch of seeds. Seed treatment is carried out at different intensities of the electrical or magnetic field, variable duration of impact and different time intervals between treatment and sowing.

This paper provides a systematization of the research results for the influence of these fields on tomato seeds sowing quality, over a period of two years.

SUBJECT AND METHODOLOGY

The subjects of this research are tomato seeds from the similar type varieties ‘Rio Fuego’ and ‘Rio Grande’. For the pre-sowing treatment of seeds, an electrostatic field (ESF) [3] is created between two parallel conducting plates, as well as an AC corona discharge field (AC CDF) in a point-to-plane electrode system, as in [3].

The following controllable impact factors are adopted: voltage $U$, kV between the treating electrodes (electric field intensity $E$, kV/m), duration of impact $\tau$, s, and rest period from the treatment of the seeds to the sowing $T$ - days [7].

The pre-sowing treatment of the seeds was done in May when vegetable seeds are normally sown, with controllable factors values given in Table 1 [3].

Table 1. Values of the controllable factors for the pre-sowing electric treatments of tomato variety ‘Rio Fuego’ – 2009 year

<table>
<thead>
<tr>
<th>Number of treatment variant in:</th>
<th>Electrostatic field</th>
<th>AC corona discharge field</th>
<th>Field intensity $E$, kV/m</th>
<th>Duration of impact $\tau$, s</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>11</td>
<td>400</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>12</td>
<td>300</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>13</td>
<td>200</td>
<td>35</td>
</tr>
<tr>
<td>Control batch</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Following the pre-sowing treatment, the seeds were left to rest respectively for $T_1 = 6$ days, or $T_2 = 13$ days, or $T_3 = 365$ days (i.e. one year). After that they were sown in Petri dishes in three iterations, each containing 100 seeds. The number of germinated seeds in all the variants was calculated after six (germination power) and ten (germination capacity) days. The process of germination took place in a thermostat by a standard methodology. The germination power, germination capacity, root length and germ length of each seed were reported.

In the spring of 2010, pre-sowing treatment was performed on tomato seeds of the similar variety ‘Rio Grande’. As treatment media, ESF and an AC CDF were once again used. The values of controllable factors were selected as
follows: field intensity \( E = 400 \text{ kV/m} \), duration of impact \( \tau = 5 \text{ s} \) (according to Table 2), since the best results in 2009 were obtained with these values [3]. On the other hand, the number of rest day options \( T \) from the treatment to the sowing of seeds was increased.

**Table 2.** Values of the controllable factors for the pre-sowing electric treatments of tomato variety ‘Rio Grande’ - 2010 year

<table>
<thead>
<tr>
<th>Number of treatment variant in an:</th>
<th>Field intensity ( E, \text{kV/m} )</th>
<th>Duration of impact ( \tau, \text{s} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>electrostatic field</td>
<td>1</td>
<td>400</td>
</tr>
<tr>
<td>AC corona discharge field</td>
<td>2</td>
<td>400</td>
</tr>
<tr>
<td>control batch</td>
<td>3</td>
<td>-</td>
</tr>
</tbody>
</table>

Following the pre-sowing treatment (in an ESF or in an AC corona discharge field), the seeds were left to rest for \( T1 = 4, \ T2 = 6, \ T3 = 8 \) or \( T4 = 13 \) days. The experiments were performed by the same methodology as in 2009, which is the one described above.

**RESEARCH RESULTS**

The results from the research carried out on the germination power (g.p.,\%) and germination capacity (g.c., \%) of the seeds treated in 2009 and sown in 2009 (for \( T1 = 6 \) days and \( T2 = 13 \) days), as well as for those sown in 2010 (for \( T3 = 365 \) days) are shown in Table 3 [3].

**Table 3.** Results from the research on germination power (g.p.,\%) and germination capacity (g.c.,\%) of tomato seeds (‘Rio Fuego’) after \( T1, T2 \) (year 2009) and \( T3 \) (year 2010) day rest from the treatment to sowing

<table>
<thead>
<tr>
<th>Rest until sowing, days</th>
<th>Parameter researched</th>
<th>After treatment in an:</th>
<th>Control batch</th>
<th>Electrostatic field</th>
<th>AC corona discharge field</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T1</td>
<td>g.p.,%</td>
<td>62.0</td>
<td>93.3</td>
<td>76.6</td>
<td>80.0</td>
</tr>
<tr>
<td></td>
<td>g.c.,%</td>
<td>67.5</td>
<td>96.6</td>
<td>76.6</td>
<td>86.5</td>
</tr>
<tr>
<td>T2</td>
<td>g.p.,%</td>
<td>62.5</td>
<td>60</td>
<td>62.5</td>
<td>67.5</td>
</tr>
<tr>
<td></td>
<td>g.c.,%</td>
<td>67.5</td>
<td>67.5</td>
<td>65.0</td>
<td>72.5</td>
</tr>
<tr>
<td>T3</td>
<td>g.p.,%</td>
<td>61.5</td>
<td>70</td>
<td>80</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>g.c.,%</td>
<td>67.0</td>
<td>80</td>
<td>80</td>
<td>62.5</td>
</tr>
</tbody>
</table>

A conclusion can be made from Table 3 that, regardless of the duration of the seed rest after treatment with different sources of energy and at different exposure (field intensity and duration of impact), the results in terms of
germination power and germination capacity are generally better for the treated seeds compared to the control batch seeds. An exception occurred in the following variants:

- **T2/1, T2/12** and **T2/13**, where the germination power (g.p.,%) of the control batch is 62.5% and exceeds that of the treatment variants by 2.5%, 2.5% and 10% respectively;
- **T2/2, T2/12** and **T2/13**, where the germination capacity (g.c.,%) of the control batch is 67.5% and exceeds that obtained in the respective treated seeds.

As a whole, the best results for the parameters germination power and germination capacity were observed in variants **T1/1 (ESF)** and **T1/11 (AC CDF)**, i.e. for the shorter rest period **T1 = 6 days**, at a greater field intensity **E = 400 kV/m** and at the shortest duration of impact **t = 5 s**.

From Table 3 it is evident also that, for all treatment variants in an AC corona discharge field, the seeds that rested for **T3 = 365 days** show higher values (compared to the control batch) of germination power: up to 90% for treatment variant **T3/12**, and germination capacity up to 87.5% for variant **T3/11**. Similar, although to a smaller extent (up to 80%), is the increase of the monitored parameters after treatment in an electrostatic field and one-year rest. In this respect, an examination is necessary to be made on how the prolonged rest **T3** from treatment to sowing affects the length of roots and germs.

Figure 1 shows the research results for the roots length of the seeds treated in 2009, and sown respectively: in 2009 (for the **T1** and **T2** rest periods), and in 2010 (for **T3** rest period). All results are shown in percentage of the control batch values, i.e. of the untreated seeds.

![Bar chart showing roots length percentage comparison](image)

**Fig. 1.** Results from the research on the roots length of tomato seed variety 'Rio Fuego', treated in 2009, in variants 1,2,3 - seeds are treated in an electrostatic field, and in variants 11,12,13 – treatment is performed in an AC corona discharge field.

Figure 1 shows that a shorter rest period (**T1 = 6 days**) from sowing to treatment has boosted the growth of roots to a greater length of 138.1% after...
treatment in ESF (in variant 3, at: $E = 200\text{kV/m}$ and $\tau = 35\text{s}$) and 129.2% (in variant 2, at $E = 300\text{kV/m}$ and $\tau = 20\text{s}$).

The significantly longer rest period ($T_3 = 365$ days) has exerted a suppressive effect after both types of treatment. The roots have reached lengths of only 47.9% (in variant 13) to 76.1% (in variant 2) compared to those of the control batch.

The shorter rest period ($T_1 = 6$ days) from the treatment (in the electromagnetic field of an AC corona discharge) to the sowing has boosted the growth of roots to a greater length of 154.35% (in variant 11, at: $E = 400\text{kV/m}$ and $\tau = 5\text{s}$) and 122.05% (in variant 13, at $E = 200\text{kV/m}$ and $\tau = 35\text{s}$).

The germs research results show, for the same rest period ($T_1 = 6$ days), a slower rate of growth in their length, yet faster compared to the control batch, with values from 109.25% to 112.3%.

The analysis of the given results indicates that the spreading of roots length and germs length around their average value, i.e. the dispersion $s^2$, remains in almost all trials less than that of the control batch.

The above fact is very important because it indicates certain uniformity in the development of roots and germs. This suggests a possible simultaneous ripening of the fruits, which is of essential economic advantage. At this stage of research, the logical explanation for the observed effect is the higher energy level absorbed by the bio-energetically weaker seeds during their energy treatment with an electromagnetic field applied for this purpose in both its forms (ESF and AC CDF).

The analysis of the results given in Table 3, Figure 1 and in previous studies [3] shows that most stimulating effect is achieved by a pre-sowing treatment under field intensity $E = 400\text{kV/m}$ and duration of impact $\tau = 5\text{s}$.

Therefore, these values are adopted for the pre-sowing treatment in 2010, only with a different rest period $T$ until the sowing - Table 2.

In subsequent studies these values of $E$ and $\tau$ can be used as central values of the plan used to find a mathematical model of the process and search for a general extreme point (solving an optimization problem with respect to $E$ and $\tau$ aimed at achieving the highest results for the tomato seed properties being studied).

The comparison of the results from ESF treatment and AC CDF treatment in most cases shows better results after treatment of tomato seeds in the electromagnetic field of an AC corona discharge than in an electrostatic field.

This can be explained by the higher charge density affecting the seeds which fall into the electrical corona impact area compared to that of the electrostatic field, at an equal intensity of the two fields. On the other hand, from a constructive point of view, the uniform electrostatic field allows for the securing of a higher treatment yield. Further research on electrical stimulation of seed material will continue using both types of electric fields and focusing on a more detailed study of the processes.
Table 4 represents the results from the treatment of seed variety ‘Rio Grande’ in 2010 in accordance with Table 2. With a view of identifying the best time for rest before sowing (in one season), the period of rest after treatment \( T \) varies somewhat more here. In subsequent studies, this parameter should be included in the controllable factors used for determining the center of the plan in the mathematical modeling of the process. In this case, the rest periods after treatment are those specified under Table 2, i.e.: \( T_1 = 4 \) days, \( T_2 = 6 \) days, \( T_3 = 8 \) days and \( T_4 = 13 \) days.

Table 4. Results from the research of germination power (g.p.,%) and germination capacity (g.c.,%) of tomato seeds (‘Rio Grande’) after \( T_1 \), \( T_2 \), \( T_3 \) and \( T_4 \) – days of rest from the treatment to sowing – year 2010

<table>
<thead>
<tr>
<th>Period of rest after treatment</th>
<th>Control batch</th>
<th>After treatment in an:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>electrostatic field</td>
</tr>
<tr>
<td></td>
<td>g.p.,%</td>
<td>g.c.,%</td>
</tr>
<tr>
<td>( T_1 ) – 4 days</td>
<td>67,0</td>
<td>80,0</td>
</tr>
<tr>
<td>( T_2 ) – 6 days</td>
<td>67,5</td>
<td>80,5</td>
</tr>
<tr>
<td>( T_3 ) – 8 days</td>
<td>67,5</td>
<td>80,5</td>
</tr>
<tr>
<td>( T_4 ) – 13 days</td>
<td>67,5</td>
<td>80,0</td>
</tr>
</tbody>
</table>

Table 4 points to a much more pronounced positive effect of the treatment on the germination power of seeds. For the periods of rest: \( T_1 \), \( T_2 \), \( T_3 \) and \( T_4 \) it is much higher both after treatment in an AC CDF and in an ESF. Concerning the germination capacity, the best result is obtained for a rest period after treatment \( T_3 = 8 \) days (ESF) and \( T_2 = 6 \) days (AC CDF), and that is 87.5% against 80.5% of the control batch. The comparison between germination capacity values of the studied variants indicates that much better germination is achieved with the short rest periods \( T_2 \) and \( T_1 \) after treatment both in ESF and AC CDF. This confirms the results obtained in 2009 [3] and the data available from Table 3.

The longest period of rest \( T_4 = 13 \) days exerts an adverse effect as much as to suppress the germination power and capacity of seeds. An explanation to this could be the fact that the time for sowing the seeds during the spring has already elapsed therefore the influence of the Earth’s electromagnetic field is no longer the same as at the proper time of sowing.

The good results for the germination power and germination capacity of seeds after a rest of \( T_3 = 365 \) days following treatment (Table 3) suggest that tomato seeds store the energy they have accumulated during treatment. Thus, after sowing them a year later, and at an appropriate time so as to benefit from the
Earth’s electromagnetic field, a positive effect is obtained on the germination power and germination capacity. Whether this stored energy would be sufficient to secure the growing of seedlings and longer roots is to be established by future experiments.

Fig.2a and Fig.2b represent the results (expressed as a percentage of the control batch values) for roots and germs length of tomato seed variety ‘Rio Grande’, treated in accordance with table 2 and sown after T1, T2, T3 or T4 days following exposure, in 2010.

**Fig. 2a.** Results from the research of roots length of tomato seed variety ‘Rio Grande’, after treatment in 2010, rest periods from the treatment to sowing: T1 = 4 days, T2 = 6 days, T3 = 8 days and T4 = 13 days

Fig.2.a and Fig.2.b lead to the conclusion that a shorter rest period (T1 = 4 days) after treating tomato seed variety ‘Rio Grande’ in an AC corona discharge field has a favorable effect both on the germination power and germination capacity (according to Table 4) and on the length of roots and germs. These are respectively 156.5% and 109.1% compared to the control batch values.

Similar results are obtained after treatment of the seeds in an electrostatic field but with duration of the rest period T3 = 8 days. It is confirmed once more [3], with the test results in 2010 showing it again, that the longer rest period (T4 = 13 days) after the treatment of the seeds (in an ESF and in an AC CDF) to their sowing has a suppressive effect on the length of tomato seed roots and germs. Hence, the results from the research on germination power and germination capacity, as shown in Table 4, are confirmed.
Germs length, \%C

<table>
<thead>
<tr>
<th></th>
<th>ESF</th>
<th>CDF</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1'</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>T2'</td>
<td>80</td>
<td>60</td>
</tr>
<tr>
<td>T3'</td>
<td>60</td>
<td>40</td>
</tr>
<tr>
<td>T4'</td>
<td>40</td>
<td>20</td>
</tr>
</tbody>
</table>

Fig. 2b. Results from the research of germs length of tomato seed variety ‘Rio Grande’, after treatment in 2010, rest periods from the treatment to sowing: T1 = 4 days, T2 = 6 days, T3 = 8 days and T4 = 13 days

The analysis so far reveals that unlike maize seeds [7], which require a 14 to 21-day rest time from the treatment to sowing, tomato seeds need less time to rest (T = 4 days after treatment in the field of an AC corona discharge and T = 8 days after ESF exposure). Same as with maize seeds, tomato seeds need a certain time of rest in order to undergo those internal changes, which at a next stage activate the process of development of the seeds.

The fact that shorter rest duration from the treatment to sowing is needed for tomato seeds finds an explanation in their significantly lower mass compared to the mass of maize seeds.

Another fact to note is that after treatment in the field of an AC corona discharge a shorter rest period is required, T = 4 days, to intensify growth, while treatment in an ESF requires a longer period of T = 8 days of rest. This can be explained by the greater charge density of the field of AC corona discharge.

The study on the tomato seed roots and germs length also shows that, as a whole, the dispersion (s^2) of a significant number of tests performed with treated seeds is less than the dispersion value of the control batch. This comes in support of the hypotheses raised above, that different seeds absorb different amount of energy, which at a later stage of the plant development leads to equalization of parameters.
CONCLUSIONS

1. The possibility to achieve a stimulating effect on the development of vegetable seeds of different tomato varieties (‘Rio Fuego’ and ‘Rio Grande’), after subjecting them to a pre-sowing treatment in an electrostatic field and in the field of AC corona discharge, has been confirmed.

2. The initial values of the controllable factors (field intensity \( E = 400 \text{ kV/m} \), duration of impact \( \tau = 5 \text{ s} \) and rest period \( T \) from the treatment to sowing) in the pre-sowing treatment of tomato seeds in an electrostatic field (\( T = 8 \text{ days} \)) and in the field of AC corona discharge (\( T = 4 \text{ days} \)), have been determined. They help to stimulate the monitored parameters: germination power, germination capacity and length of roots and germs. These values of the controllable factors can be used as a base (center of the plan) in the mathematical modeling of the process (obtaining a regression equation and finding the optimum for these factors).

3. A hypothesis is raised that, in addition to the stimulating effect on plants, the pre-sowing treatment of tomato seeds helps to equalize the parameters of their growth and suggests simultaneous ripening of the fruits.

4. The conclusion made in item 3 must be confirmed by monitoring the development of the plants to their full maturation, and by experimenting with seeds of other crops.

5. It has been found that, after treatment of tomato seeds in the electromagnetic field of AC corona discharge, the obtained results for the monitored parameters are usually better than after treatment in an electrostatic field.

6. Confirmation is given of the statement that, generally, after a long period of rest (\( T = 13 \) and \( T = 365 \text{ days} \)) for tomato seeds, the pre-sowing electrical treatment has a suppressive effect on the germination power and germination capacity, and on the lengths of the roots and germs.

REFERENCES


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Reziumė

Nustatyta pradinės valdomų faktorių (elektros lauko stiprio, poveikio trukmės ir laiko nuo poveikio iki sėjos) reikšmė. Minėti faktoriai turi įtakos sėklų
дигимо энергий и даигумо стимулирования роста и даиго илгюй. Искела гипотеза, что предсёшенный электрический поле помогает сбалансировать параметры развития и иметь эффект созревания плодов. Бандымахар, кар гилёян атсигулийно лаикуну апдорою икі сёзо (T=13, T=365 днёй), стимулирующий эффект сёко эффекту зымай уміжеліва.

Elektros laukas, pomidorų seklos, dygimo energija, daigumas.

Е. Кузманов, И. Палов, Н. Армянов, К. Сираков

СРАВНИТЕЛЬНЫЙ АНАЛИЗ РЕЗУЛЬТАТОВ ЛАБОРАТОРНЫХ ИССЛЕДОВАНИЯ ПРЕДПОСЕВНОЙ ЭЛЕКТРИЧЕСКОЙ ОБРАБОТКИ СЕМЯН ПОМИДОРОВ

Резюме

Установлена возможность стимулирующего воздействия предпосевной электрической обработки семян помидоров сорта Rio Fuego и Rio Grande на их всхожесть и дальнейшее развитие. Электрическая обработка проводится в электростатическом поле, или в поле коронного разряда переменного тока.

Определены начальные величины управляемых факторов предпосевной обработки семян помидоров: напряженности полей, длительности воздействия и срока отлежки от обработки до посева. Эти факторы оказывают влияние на стимулирование энергии прорастания и всхожести семян, а также на длину корней и ростков.

Выдвинута гипотеза, что кроме стимулирующего эффекта на развитие растений, предпосевная обработка семян способствует выравниванию параметров их развития и предполагаемому одновременному созреванию плодов. Результаты опытов показали, что с увеличением срока отлежки (Т=13, Т=365 дней) стимулирующий эффект предпосевной обработки семян помидоров, значительно снижается.

Электрическое поле, семена помидоров, энергия прорастания, всхожесть.