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Article

Effect of Electrostatic Field on Germination of Primed and Unprimed Soybean Seeds

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Abstract: The aim of this paper was to examine the influence of electrostatic field on the quality parameter of unprimed and primed soybean seeds. The experiment was conducted at the Institute of Field and Vegetable Crops in Novi Sad on soybean seeds of NS Blackstar variety. Seeds were exposed to different values of electrical voltage: 0 V (control), 3 V, 6 V and 9 V. Before exposure, the seeds were primed in water for 0, 1, 2 and 3 hours. Results of the conducted experiment showed that the influence of the electrostatic field on the unprimed soybean seeds depended on the strength of applied electrical voltage to conducting electrodes. By applying electrical voltage of 6 V to conducting electrodes, germination energy was increased by 10%, while germination was increased by 5% compared to control. However, the application of electrical voltage of 3 V and 9 V, showed that germination energy was significantly decreased, 19% and 21%, respectively. On primed soybean seeds, the use of electrostatic field led to a significant reduction in seed quality, regardless of the time of primed. The results also showed that the treatment that significantly increased the germination energy and germination of unprimed seeds, was treatment with applied electrical voltage of 6 V. This treatment had a significant effect on the germination rate parameter, but only on MGT and T50. In other treatments, applied electrical voltage did not affect or prolong the time of seed germination.

Keywords: soybean; electrostatic field; MGT; seed germination; MGR.

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1. Introduction

Crop yield and resource use efficiency depend on successful plant establishment in the field, and it is the vigour of seeds that defines their ability to germinate and establish seedlings rapidly, uniformly and robustly across diverse environmental conditions[1]. Seed directly limit the reach of efficiency in crop production, the productivity levels of all other inputs used in the production process is an extremely important agricultural inputs affecting indirectly. Of the crops produced in the world is produced by means of seed portion close to about 90% [2]. Uneven or poor germination and subsequently uneven seedling growth can lead to great financial losses by reducing crop [3].

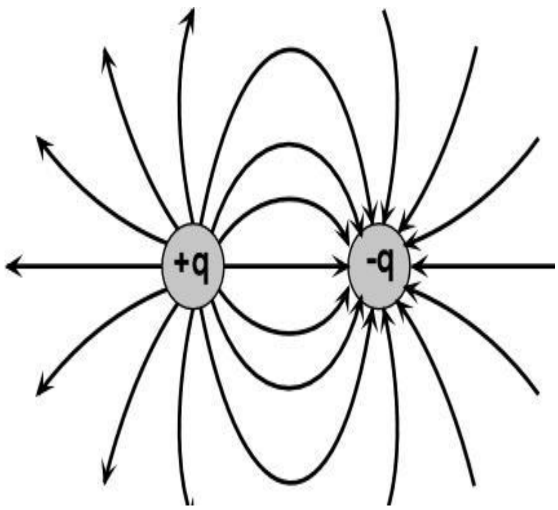
One of the basic conditions for achieving high yields is sowing quality seed [4]. In field conditions germination and germination energy these indicators determine the number of plants per unit area – one of the three basic yield components [5]. For a commercial seed company, seed quality means high germination speed, uniformity of seedlings, high percentage of germination, uniformity of genetics and free of pests and diseases [6]. Therefore, various procedures are applied in seed production technology that aim to improve not only the germination of seeds but also the speed of its germination [7-9]. Physical treatments belong to the oldest known seed treatments. Physical methods include different lasers, ultraviolet radiation [10], magnetic induction and electromagnetic waves [11], etc. Plant growth as well as the biological processes of seeds can be accelerated or inhibited by electric fields. Electrostatic treatment is assumed to enhance seed vigour by influencing the biochemical processes which involve free radicals, and by stimulating the activity of proteins and enzymes [12].

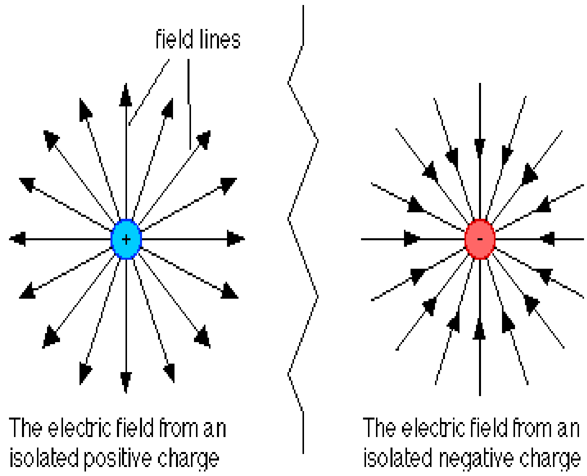
The aim of this paper was to examine whether the electrostatic field had any effect on unprimed, primed soybean seeds and how different values of applied electrical voltage affect germination of soybean seeds.

2. Materials and Methods

Plant material. The experiment was performed on seeds of soybean variety NS Blackstar, which was selected at the Institute of Field and Vegetable Crops in Novi Sad. Seeds were selected on the basis of having no visible deformities.

Basics about electrical field and electrical voltage. An electric field is a space in which the action of electric forces is felt. Every stationary charged body creates an electrostatic field around itself that propagates through space at a constant speed equal to the speed of light propagation in a vacuum. The interaction between stationary charged bodies is realized through a material mediator - an electrostatic field. An charged body acts on another charged body with its field. The consequence of this interaction is the creation of an electric force. Whether there is a field at some point in space or not, we find out by entering a test charge into the examined point of space (Picture 1, 2).





Picture 1, 2. Interaction between two charged bodies.

The use of the electric field was performed in the following way electrodes with an area of 10 cm × 10 cm were made of aluminum foil. Each of the electrodes is connected to one of the terminals of the DC batteries. The DC voltage values used are 3, 6, 9 V. A switch is placed between one electrode and the battery terminal so that the circuit between the mentioned electrodes can be interrupted at any moment, and between which soybean seeds are placed, which are subjected to treatments. The distance between the electrodes was 1 cm, and it was fixed during the experiment, in order to preserve that the field was evenly distributed between the electrodes. A voltmeter was placed at the end of the electrode to measure the presence of electrical voltage. During the experiment, the voltage values were monitored during the complete experiment, in order to determine whether the electrostatic field between the electrodes during the experiment was constant, i e. invariable over time.

Electrostatic field and seed treatment. To determine the influence of the electrostatic field on the germination and germination rate of soybean seeds, the seeds were exposed to different values of the electrical voltage: 0 V (control), 3 V, 6 V and 9 V. Before exposure, the seeds were immersed in water for 0, 1, 2 and 3 hours. The ratio between seed weight and solution volume was 1 : 5 (v/v). Seeds were distributed on a sterilized filter paper, in Petri dishes 9 cm in diameter. Then, 4 x 50 seeds were treated with 10 ml of distilled water and set as a randomized block design. Petri pots were closed using paraffin tape in order to prevent moisture loss and avoid contamination. Petri pots were placed in chambers to germinate at 25 °C and 95% relative humidity for 8 days. Seed germination results were collected daily, and seed germination was defined by protrusion of the radical by at least 2 mm.

Six measures of the relative rates of germination were calculated:

Germination energy was recorded after 5 days and germination after 8 days [13].

The mean time required for maximum seed lot germination (MGT) was determined based on the application of the following equation:

$$\mathrm{MGT} = \frac{\sum D * n}{\sum n}$$

where is:

D - number of days counting from the beginning of germination,

n - number of germinating seeds per day D [14].

Mean germination time is the time to reach 50% of final / maximum germination (T50 [15].

$$T50 = t_i + \left(\left(\frac{N}{2} - n_i\right) * \left(\frac{t_j - t_i}{n_j - n_i}\right)\right)$$

where is:

N- final number of germinating seeds,

n_j and n_i- represent the cumulative number of germinating seeds over time t_j and t_i, that is, when the number of germinating seeds $n_i < \frac{N}{2} < n_j$

Mean germination rate (MGR) is the reciprocal of MGT [16].

MGR=1/MGT

The coefficient of velocity of germination (CVG):

$$CVG = 100 \times \sum N_i / \sum N_i T_i$$

where is:

Ni = Number of germinated seeds per day

Ti = Number of days from the start of the experiment [17].

Analysis of variance (ANOVA) was used to analyse the data, and the significant differences of the means were compared using the Duncan's multiple range tests at 5% significant level using STATISTICA10.

3. Results and Discussion

Germination energy and germination. Seed treatment with electricity, includes methods, such as low and high frequency electric fields. Electrostatic field is a special case arising from d-c potential differences between conducting electrodes, and the direction and magnitude of the electric field does not change during the exposure [18]. The results on soybean seeds showed a significant influence of the electrostatic field on the germination energy and germination of soybean seeds. The influence of electrostatic field on germination energy and germination was best expressed in seeds that were unprimed, and with applied electrical voltage of 6 V. Germination energy was increased by 10% and germination by 5% compared to primed seeds (Figure 1, 2).

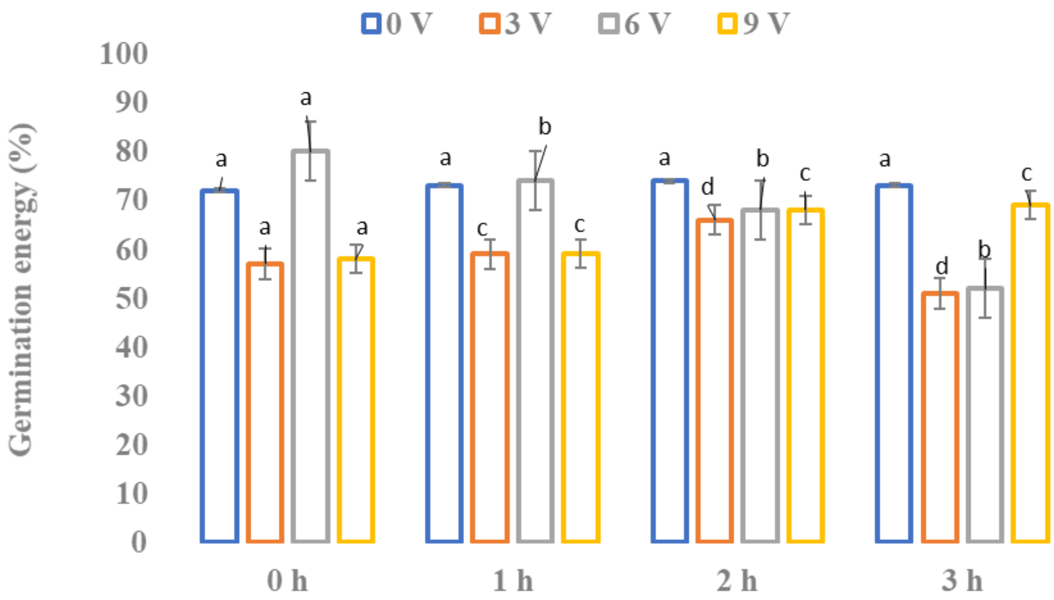


Figure 1. Effect electrostatic field on germination energy.

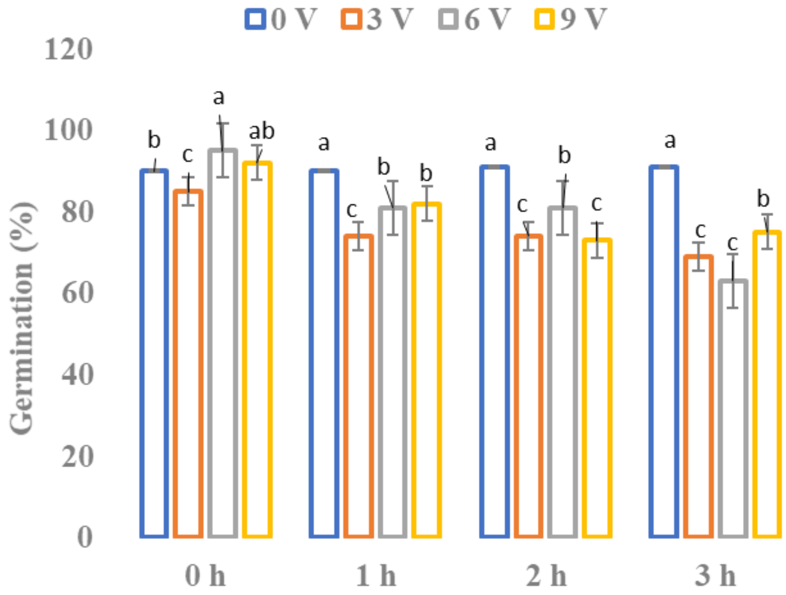


Figure 2. Effect electrostatic field on germination.

Different research has proved that electrostatic field enhance germination of seed [19-20]. Such type of increased germination rate and germination percentage due to application of electricity is attributed to the physiological and biochemical changes [21], such as free radical excitement, increase in the activity of protein and enzymes to increase seed vigour [22]. The Germination percentage of seeds was accelerated by electrostatic field because each seed has some electrical nature with electric potential differences existing in all tissue cells [18]. However, in addition to positive impact, application of electrostatic field can also have a negative effect on the quality of soybean seeds. Application of electrical voltage of 3 V and 9 V at the end of electrodes reduced germination energy for 19% and 21% respectively. The use of 3V electrical voltage had a negative impact on seed germination, but significantly less impact on germination energy, while 9 V improved germination. Electrostatic field in primed soybean seeds generally had a negative effect on germination energy. In soybean seeds primed for 1 h, the of 3 V and 9 V led to significant reduction, while the application of 6 V had no effect. With primed soybean seeds, seed germination is significantly reduced after the use of electrostatic field. How much germination is reduced depended on the priming time and the strength of applied electrical voltage at the end of the electrodes. In soybean seeds that where primed for 1h, the application of 3 V had the biggest impact on reducing germination by 18%. At 2h, the use of 9V reduced germination by 20%, while the application of 6 V electrical voltage in soybean seeds that were primed for 3 h had the greatest effect on reducing germination by 31%.

Mean germination time (MGT) and Median germination time (T50). Seed germination is one of the most important and the first stage of plant growth, and it generally is defined as protrusion of the radicle from the tissue(s) enclosing it [23]. Measurement of germination can provide valuable information about the start, rate, uniformity and final percentage of germination. For example, two seed lots can have the same germination percentage but differ in speed or uniformity. Therefore, total percentage germination after a specific period of time does not give a full explanation of the dynamics of germination [24]. MGT and T50 are another way to calculate germination speed and is widely used by seed scientists and other plant biologist.

The results on soybean seed showed that the electrostatic field on primed soybean seeds had no effect on MGT and T50 while on unprimed seeds the effect depended on the value of the applied electrical voltage at the end of the electrodes, thus electrostatic field. Application of 6 V electrical voltage on non primed soybean seed reduced MGT by 7.51% and T50 by 9.32% (Figures 3, 4). It has been determined that a consequence of slow germination is a smaller number of germinating seeds on paprika seeds, which is in accordance with the results of our research [25]. Similar results were found on rapeseed, but in field conditions [26]. Slower germinating seed produced a higher population of abnormal seedlings, which is a well recognized sign of deterioration as a result of seed aging [27]. There is much evidence that low vigor and slow germination is the result of physiological aging in, for example, *Brassica* seed [28], pepper [25] and maize [29].

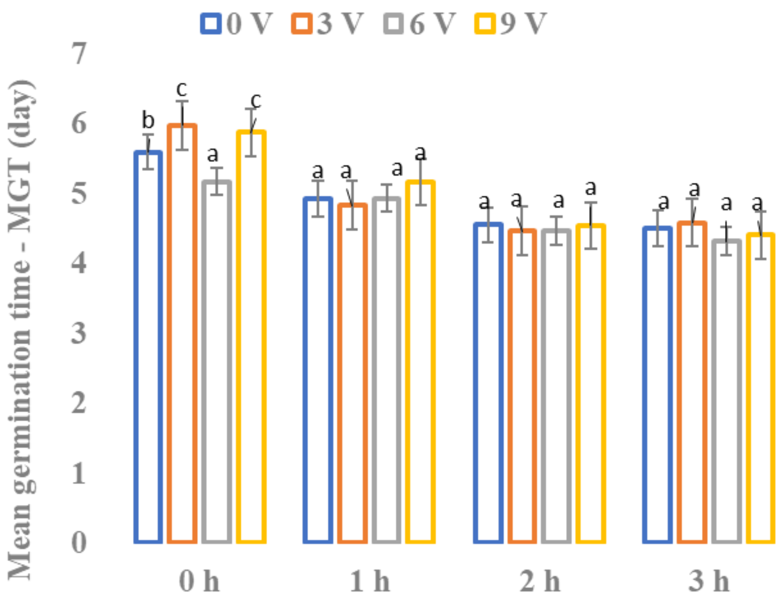


Figure 3. Effect electrostatic field on MGT.

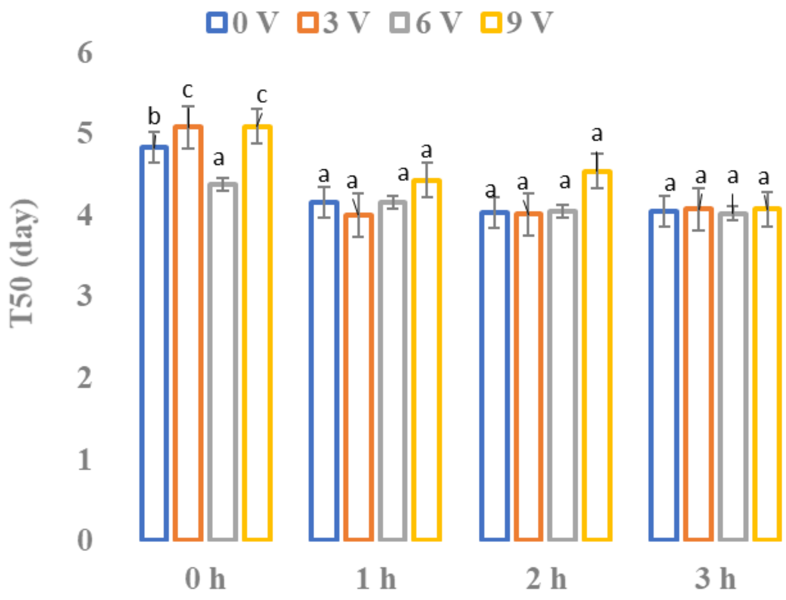


Figure 4. Effect electrostatic field on T50.

Mean germination rate (MGR) and Coefficient of velocity of germination (CVG). In addition to MGT and T50, many other parameters are used to analyze seed germination, including MGR and CVG. MGR shows the germination speed of seed. Generally it was predicted that a higher germination percentage, higher CVG and lower MGT seed lots having a higher rate of germination. Germination percentage represents only the number of seed germinated of particular day. Real germination potential of seed evaluated by the help of number of parameters [30]. The results on soybean seed showed that the influence of electrostatic field on non primed soybean seed has not led to a significant decrease in MGR and CVG but only to an increase in these parameters using electrical voltage of 3 V and 9 V. Application of 3V electrical voltage increased MGR by 8,45%, and 9V by 11,61% (Figure 5, 6). In primed soybean seeds, the influence of the electrostatic field depended on the immersion time and the strength of electrostatic field. Depending on the strength of the electrostatic field, i.e. Electrical voltage and immersion time, there was no effect on MGR and CVG or there was a decrease in their value, i.e. the germination time was extended.

The literature indicates that electrically treated seeds result in better seedling growth, stem height and root length compared with non-exposed seeds [31]. Plant growth as well as the biological processes of seeds can be accelerated or inhibited by electric fields. Electrostatic treatment is assumed to enhance seed vigour by influencing the biochemical processes which involve free radicals, and by stimulating the activity of proteins and enzymes [12]. The position of sessile cells rather than their lineage has a predominant role in dictating their developmental fates [32], because of this polarity the electric current can affect the direction and movement of storage nutrients of the seeds to the cell walls and accelerate meristem cells [33]. Likewise may be DC electrical field affect on the direction of plant hormones: cytokinin and auxin that stimulate a metabolism of seedlings, like change the auxin and cytokinin ratio in the seeds which leading to the germination seeds [34].

With the increase of priming time, i.e. with seeds that were primed for 2 and 3 hours, there is no significant increase, nor decrease of MGR and CVG in relation to seeds that were not treated with electrostatic field.

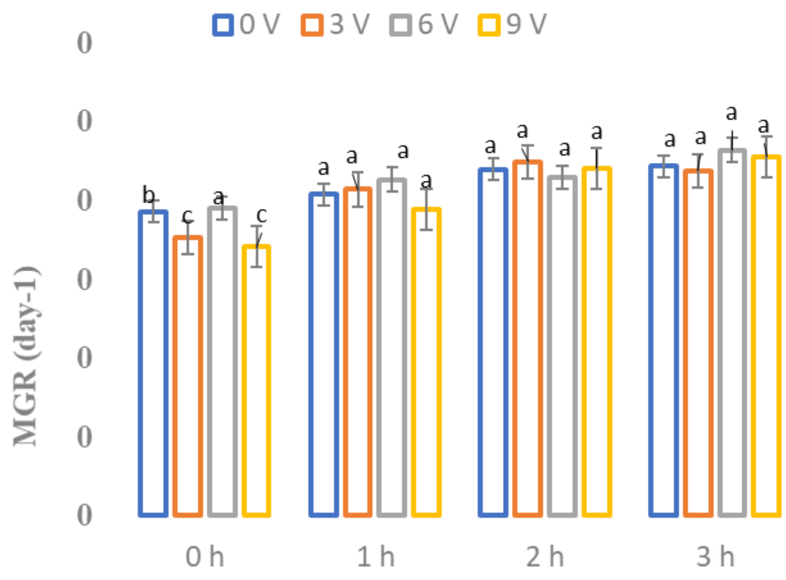


Figure 5. Effect electrostatic field on MGR.

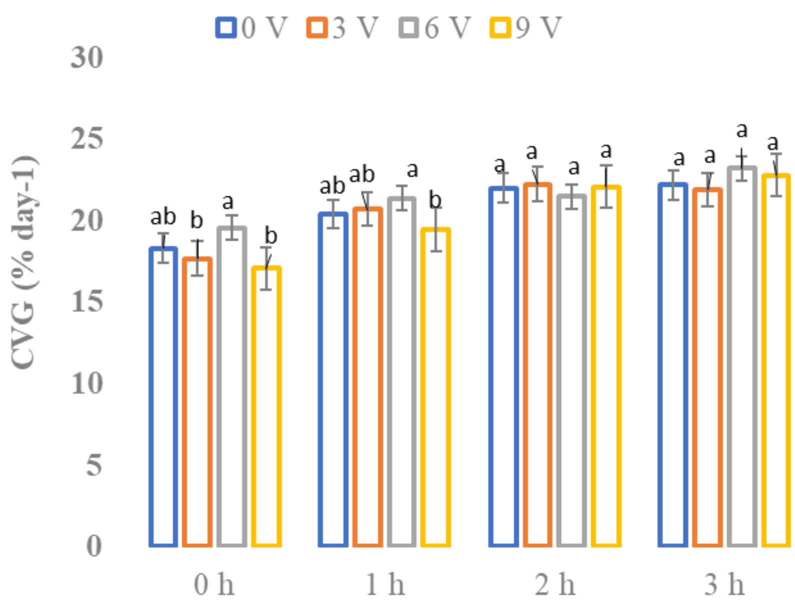


Figure 6. Effect electrostatic field on CVG.

4. Conclusions

The influence of the electrostatic field ie electrical voltage on non primed soybean seeds depended on the strength of the electrostatic field. By applying an electrical voltage of 6V, germination energy was increased by 10%, and germination by 5% in relation to unprimed seeds. However, the application of electrical voltage of 3 V and 9 V germination energy is significantly reduced, 19% and 21%, respectively. The electrostatic field on primed soybean seeds had no effect on MGT and T50, while in unprimed seed the effect depended on the strength of the electrostatic field i.e. applied electrical voltage ate the end of the electrodes. Application of 6 V electrical voltage on non primed soybean seeds reduced MGT by 7.51% and T50 by 9.32%, while the application of 3 V and 9 V electrical voltage prolonged germination time. The effect of electrostatic field on MGR and CVG of unprimed and primed soybean seeds depended on the strength of the electrostatic field i.e. electrical voltage and priming time. The results showed that either there was no effect or there was a decrease in their value, i.e. the germination time was extended.

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