

## THE INFLUENCE OF ELECTRIC VOLTAGE ON THE GERMINATION OF LEGUMINOUS SEEDS

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**Abstract:** The aim of this paper was to examine the influence of the electrostatic field on seeds of soybean (*Glycine max* L), vetch (*Vicia* spp. L.), pea (*Pisum sativum* L.), grass pea (*Lathyrus sativus* L.) and chickpea (*Cicer arietinum* L.) which were selected at the Institute of Field and Vegetable Crops in Novi Sad. The DC voltage of 9V was used. The durations of seed treatment were 0 (control), 1, 2 and 3 minutes. The trial was set up as a randomized block design with four replications. 4x100 seeds of each variant and control (untreated seed) were treated. After treatment, seed quality was examined using a germination test (optimal temperature) and a cold test (low temperature). The results of the study showed that the effect of the electrostatic field on seed quality depended on the plant species, the time of seed treatment and the temperature conditions in which the seed germinated after treatment. The increase in germination energy ranged up to 18.18% in vetch, and a decrease of up to 12% was observed in chickpea. The application of the electrostatic field had a significantly greater impact on seeds that were exposed to low temperatures in the germination process after treatment. The increase in seed germination ranged up to 82.35% in chickpeas, and the decrease amounted to 92.68% in peas. In addition, the obtained results indicate that it is not possible to talk about the universal application of a certain duration of seed treatment.

**Key words:** electrostatic field, cold test, germination, legumes.

### Introduction

The use of high-quality seeds is one of the most important elements in increasing agricultural production in any farming system. This element has become more crucial than ever for providing enough food for the rising number of people

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in the world, which is expected to exceed nine billion by the year of 2050 (Sabry, 2018). Every year, more than 2/3 of the total workable land in the world is sown with seeds, of which about 90% of humanity's needs in the food and agro-processing industry are met (Miric and Brkic, 2002). One of the basic conditions for achieving high yields is sowing quality seed (Milosevic et al., 1996). The quality of seeds is measured in many ways, including genetic and physical purity, germination, vigor, uniformity in sizes, resistance from seed-borne diseases, and any other factors that may affect seed performance in the field (Sabry, 2018). Success in producing quality seed of a particular crop in one area and failure in another area illustrates the importance of the environmental influence on seed development and maturation (Vujakovic et al., 2015). During seed development and maturation, environmental conditions, including temperature, water stress or excessive rain, lack of nutrients, disease infestation, and insect pressure, influence seed quality (Miladinov et al., 2020a). During prolonged and less than optimum storage conditions, physiological, biochemical, and cytological changes occur in soybean seeds, leading to the deterioration of their quality (Mbofung, 2012). The extent of seed deterioration depends on species, storage environment, length of the storage period, and the initial quality of the stored seeds. The seed germination was used as the basic quality indicator in the international seed trade. Different results of seed germination obtained under laboratory conditions, and field emergence have encouraged the development of the concept of seed vigor (Vujakovic et al., 2011). Seed viability or vigor presents a set of traits that affect seed germination and the formation of strong and healthy seedlings under different environmental conditions (ISTA, 2019).

In seed production, different treatments are designed to improve the quality of the seeds (Miladinov et al., 2020b; Nabi et al., 2020). Physical treatments belong to the oldest known seed treatments. Physical methods include different lasers, ultraviolet radiation (Hernández Aguilar et al., 2009), magnetic induction and electromagnetic waves (Djukic et al., 2017), etc. In recent years, there has been an increased interest in the application of a particular voltage and current as alternate physical dimensions for seed treatment (Cvijanovic and Djukic, 2020). In many studies, the exposure to electric, magnetic and electromagnetic waves showed positive or negative effects, influencing germination rate, germination percentage, seed weight, plant height, protein content, productivity, leaf surface, fruit weight and yield. Research results depend on the frequency, duration of exposure, seed traits and plant species. Proper combinations are necessary to achieve positive effects (Parsi, 2007).

The aim of this study was to investigate the influence of the electrostatic field on germination parameters (germination energy, germination percentage, atypical seedling, dead seed). Tests were performed on soybean seed, peas, beans, grass pea and chickpea using the standard and cold tests.

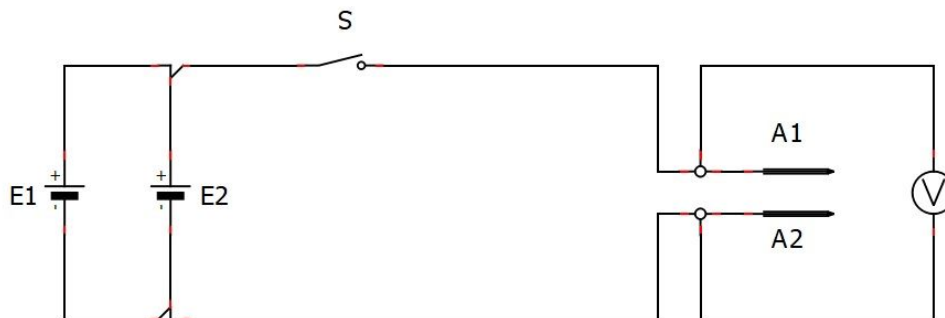
## Material and Methods

### Plant materials

The experiment was performed on seeds of soybean (*Glycine max* L), vetch (*Vicia spp.* L.), pea (*Pisum sativum* L.), grass pea (*Lathyrus sativus* L.) and chickpea (*Cicer arietinum* L.), which were selected at the Institute of Field and Vegetable Crops in Novi Sad. Seeds were selected on the basis of having no visible deformities. Seed used in this experiment were sown in 2020 on the experimental field of the Institute of Field and Vegetable Crops. After harvesting, the seeds were stored in paper bags at a temperature of 10–15°C.

### Electric field treatments

Electrodes with an area of 10 cm × 10 cm were made of aluminium foil. Each of the electrodes was connected to one of the terminals of the DC batteries (Picture 1).



Picture 1. The representation of electrical wiring (E1, E2 – batteries, S – electrical switch, A1, A2 – aluminium electrodes, V – voltmeter).

The DC voltage of 9 volts was used. The durations of seed treatment were 0 (control), 1, 2 and 3 minutes. A switch was placed between one electrode and the battery terminal so that the circuit between the mentioned electrodes can be interrupted at any moment. Seeds, which were subjected to treatments, were placed between the electrodes. The distance between the electrodes was 1 cm, and it was fixed during the experiment 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 to determine whether the

electrostatic field between the electrodes during the experiment was constant, i.e. invariable over time.

#### Seed testing

The working sample consisted of  $4 \times 100$  seeds for each plant species, applied treatment and test used. Sterile sand was used as the substrate in the germination test. Sand sterility was achieved by sand washing and drying at high temperatures. Seeds were incubated in the germination chamber at 25°C (soybean) and 20°C (pea, chickpea, grass pea, vetch). The final germination was determined after 8 days (soybean, pea, chickpea), 14 days (vetch, grass pea) (ISTA, 2019). The cold test simulates early spring field conditions by germinating the seeds in wet soils (70% water holding capacity) and incubating them at 5–10°C for a specified period. At the end of the cold period, the test is transferred to a favorable temperature for germination. The samples were exposed to 7°C for seven days and afterwards placed in the germination chamber at 25°C (soybean) or 20°C (other species) for six days. The percentage of normal seedlings is considered as an indication of seed vigor. Vigorous seeds germinate better under cold environments (Hampton and TeKrony, 1995).

#### Statistical analysis

The data were analyzed using statistical software ‘Statistica’ (StatSoft, Inc., Tulsa, Oklahoma, SAD). A two-way ANOVA was used to test the effect of legumes and exposure time. When the ANOVA test produced significant results, the Duncan’s test was used to separate means in different groups ( $p \leq 0.05$ , and  $p \leq 0.01$ ). The AMMI model was used to analyze the interactions. AMMI analysis of variance and AMMI1 biplot were done using the GenStat software (VSN International, UK).

### Results and Discussion

In addition to the positive impact, the application of the electrostatic field also had a negative impact. The results on chickpea seeds showed that the application of the electrostatic field led to a decrease in germination energy by exposing the seeds to electrostatic fields during treatments of 1 and 3 minutes. Germination energy was reduced by 8% and 12%, respectively. Ghodbane et al. (2013) point out that the results depend on the characteristics of the seed, the type of plant, the frequency and duration of seed stimulation. Miladinov et al. (2018) came to similar results in the case of soybean seeds. The authors point out that the effect of pre-sowing treatment depends not only on applied treatments but also on the genotype. Some genotypes show a positive response to pre-sowing treatment and improve seed

germination, as well as germination rate parameters, MGT and T50, a measure of the rate and time-spread of germination, while others have a significant inhibitory effect. In two genotypes, a decrease in seed germination was observed by as much as 11% (Miladinov et al., 2018) (Figure 1).

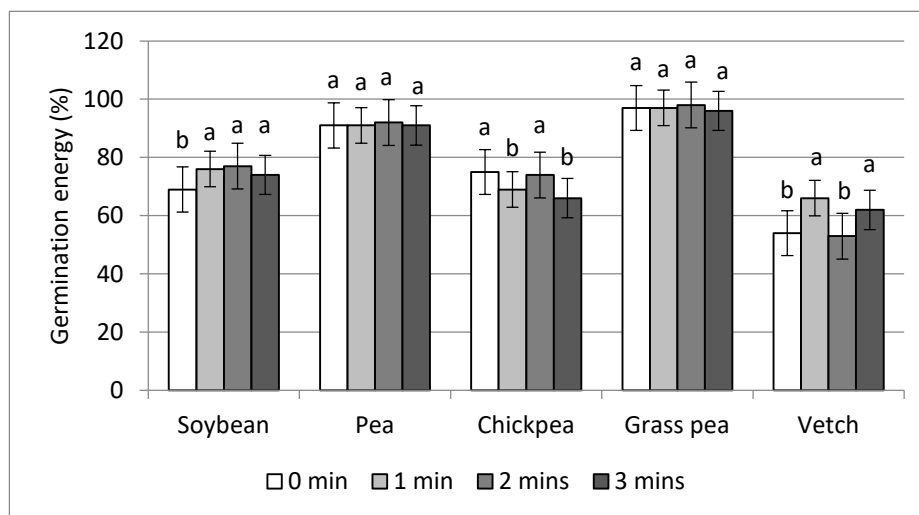


Figure 1. The influence of electric voltage on the germination energy of leguminous seeds (germination test).

#### Germination (using the germination test)

Within the physical treatment, which includes the use of an electrostatic field, the energy introduced into the cells creates the conditions for molecular transformations, and as a result, the necessary substances are created for the cells (Atak et al., 2007). Researches indicate that electric fields affect biological process including free radicals, excite the activity of proteins and enzymes to increase seed vigor (Morar et al., 1999). Results showed that the application of an electrostatic field could significantly increase the germination of beans, depending on the duration of treatment. The 1-minute treatment increased germination by 7.06%, while the 2- and 3-minute treatments had no significant effect. Lynikiene et al. (2006) reported that the electric field not only increased the rate of germination but also increased the germination percentage of carrot by 24%, that of radish and beetroot – by 12%, beet seeds – by 7%, and barley seeds – by 9%. Moon and Chang (2000) reported that electric fields increased the rate and percentage of germination in treated seeds during short time periods. In comparison with control seeds, the germination rate of treated seeds increased up to 1.2 to 2.8 times (Figure 2).

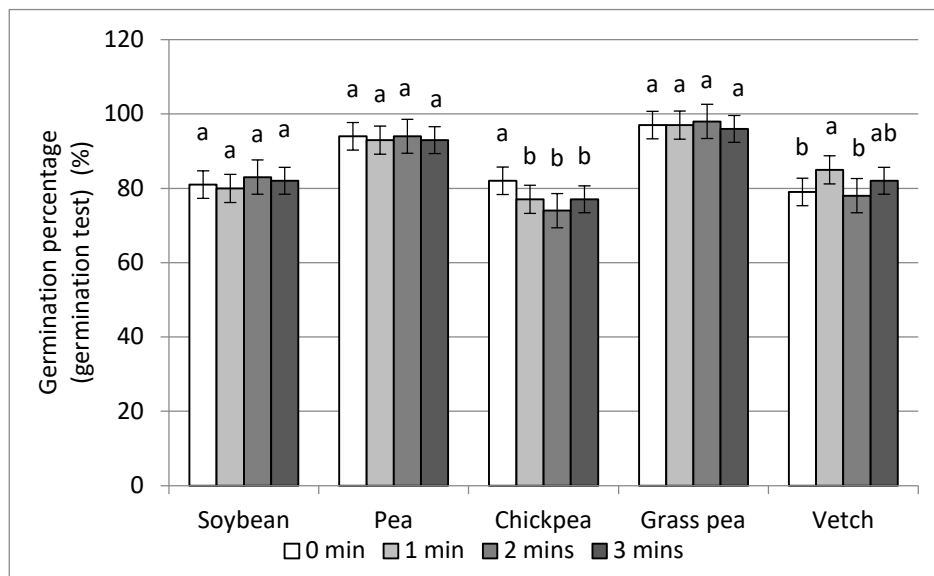


Figure 2. The influence of electric voltage on the germination percentage of leguminous seeds using the germination test.

Cai and Wang (2003) found that the electrostatic field can be an effective method for increasing the germination of seeds of many crop and tree species, when properly treating seeds, otherwise, there is a decrease in seed germination. The germination of chickpea seeds decreased by 6.10% and 9.76%, respectively, by applying 3- and 1-minute treatments. The electrostatic field had no effect on the germination of soybean seed, pea and grass pea. Mericle et al. (1964) reported no difference between germination percentages of treated and untreated barley seeds. Moreover, no significant difference has been reported regarding the seedling growth of treated and untreated seeds. Miladinov et al. (2020c) found that the effect on soybean seeds depended on the strength of the electrostatic field. The application of an electrostatic field of 9 V had no effect on seed germination, while the use of 6 V increased germination by 5%. The same authors determined that a better result was achieved with seeds that were not immersed in water before the application of the electrostatic field.

#### Germination percentage (using the cold test)

Testing the viability of soybean seeds in optimal conditions provides information on the maximum possible germination and initial growth. As field conditions are rarely optimal, it is necessary to perform testing under conditions that are close to environmental conditions to obtain a more reliable forecast of crop

behavior in the initial stages of growth and development (Srebric et al., 2010). Regarding beans, the application of the cold test had a positive effect on seed germination, but only in 2- and 3-minute treatments. Germination improved by 8.57% and 17.95%, respectively. The results are partly consistent with research conducted by Kerdonfag et al. (2002). They point out that the exposure of rice seeds to the electric field during different time durations had positive effects on germination. Soybean seeds also have improved seed germination, but only in a 2-minute treatment. Germination increased by 38.30%. Within the increased treatment time or the 3-minute treatment, germination reduced to 34.48% in soybean. In chickpea, the application of the electrostatic field had a negative effect. However, at low temperatures, an increase in germination was achieved. Regardless of the time of exposure to the electrostatic field, germination increased from 36.84% to 82.3% in chickpea. The results showed that the applied treatments had the ability to improve seed quality (Figure 3).

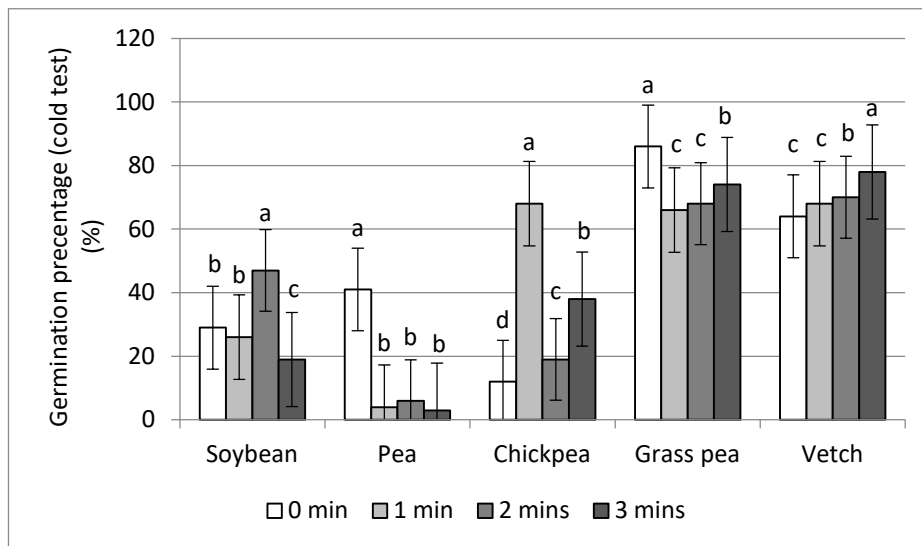


Figure 3. The influence of the electric voltage on the germination of leguminous seeds using the cold test.

The electrostatic field is a special case arising from d-c potential differences between conducting electrodes, and the direction and magnitude of the electric field do not change during the exposure. Seed vigor was apparently changed by the electrostatic field force. The germination percentage of seeds was accelerated by an electrostatic field because each seed has some electrical nature with electric potential differences existing in all tissue cells (Morar et al., 1999). As in optimal temperature conditions, the application of an electrostatic field at a lower

temperature had a negative impact on seed germination. In peas and grass pea, germination in grass pea seeds was reduced from 13.95% to 22.26%. However, a significantly higher reduction was found in pea seeds, from 85.37% to 92.68%. Observing the influence of the electrostatic field on seed germination under lower temperature conditions, a significant difference was noticed in most plant species in relation to the optimal conditions for germination. Bean is the only plant species whose seeds reacted positively to the use of the electrostatic field, regardless of temperature conditions during germination, while the 2- and 3-minute treatments did not give significant effects. However, at a lower temperature, there was no effect in the 1-minute treatment while the 2- and 3-minute treatments increased germination. Analyzing each test, i.e., temperature conditions during germination, it can be noticed that at a lower temperature, the influence of the electrostatic field on the germination of vetch seeds was greater. In chickpea, the application of electrostatic field had a negative effect in optimal temperature conditions, while at lower temperatures, an increase in germination was achieved regardless of the duration of treatment. The electrostatic field had no effect on the germination of soybean, pea and grass pea seeds in optimal temperature conditions. However, at low temperatures, there was a significant reduction in the germination of peas and grass pea, while in soybean seeds, the effect depended on the time of seed treatment.

### Conclusion

The influence of the electrostatic field on the seed germination energy depended on the plant species and exposure time. Also, the influence of the electrostatic field depended on the applied tests (germination and cold tests).

In soybeans and vetch, the application of electrostatic field led to an increase in germination energy, then in chickpeas, to a decrease, while in pea and bean seeds, there was no effect. The largest increase of 18.18% was found in vetch, while the largest decrease of 12% was found in chickpeas.

After using the germination test, the increase in germination ranged up to 7.06% in vetch, and a decrease of up to 9.76% was observed in chickpea. There was no effect in soybean, peas and grass pea.

After using a cold test, the effect was significantly greater. The increase ranged up to 82.35% in chickpeas, and the decrease amounted to 92.68% in peas. The obtained results indicate that it is not possible to talk about the universal application of a certain duration of seed treatment because it can happen that it does not correspond to a certain plant species, so the quality of seeds can deteriorate.



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UTICAJ ELEKTRIČNOG NAPONA NA KLIJAVOST  
SEMENA LEGUMINOZA

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## R e z i m e

Cilj rada je bio ispitivanje uticaja elektrostatičkog polja na seme soje (*Glycine max* L.), grahorice (*Vicia spp.* L.), graška (*Pisum sativum* L.), sastrice (*Lathyrus sativus* L.) i nauta (*Cicer arietinum* L.) koji su selekcionisani na Institutu za ratarstvo i povrtarstvo u Novom Sadu. Za tretiranje je korišćen jednosmerni napon jačine 9 V. Vreme tretiranja semena iznosilo je 0 (kontrola), 1, 2 i 3 minuta. Nakon tretiranja, ispitan je kvalitet semena primenom standardnog testa klijavosti (optimalna temperatura) i hladnog testa (niska temperatura). Rezultati istraživanja su pokazali da je efekat elektrostatičkog polja na kvalitet semena zavisio od biljne vrste, vremena tretiranja semena i temperaturnih uslova u kojima je seme klijalo nakon tretiranja. Povećanje energije klijanja se kretalo do 18,18% kod grahorice, a smanjenje do 12% kod nauta. Značajno veći uticaj primena elektrostatičkog polja imala je na semenu koje je posle tretiranja izloženo niskoj temperaturi u procesu klijanja. Povećanje klijavosti semena se kretalo do 82,35% kod nauta, a smanjenje do 92,68% kod graška. Takođe, dobijeni rezultati ukazuju na to da se ne može govoriti o univerzalnoj primeni određenog vremena tretiranja, jer se može dogoditi da ono ne odgovara određenoj biljnoj vrsti, pa može doći do pogoršanja kvaliteta semena.

**Ključne reči:** elektrostatičko polje, klijavost, hladni test, leguminoze.

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