1. **Karolina TRZYNIEC**

University of Agriculture, Faculty of Production and Power Engineering,
Department of Machinery Operation, Ergonomics and Production Processes
ORCID: 0000-0003-3178-4410

doi:10.15199/48.2024.06.33

# The impact of the pulse electric field on the germination of common sorrel seed

***Streszczenie.*** *Celem pracy była analiza wpływu impulsowego pola elektrycznego o zmiennych parametrach na zdolność kiełkowania nasion szczawiu pospolitego. Jednorodny materiał siewny tego samego pochodzenia podzielono na 5 części, z których jedna stanowiła próbę kontrolną. Pozostałe części poddano działaniu impulsowego pola elektrycznego o napięciu 15 kV (100 i 200 impulsów) i 25 kV (100 i 200 impulsów), ze stałym odstępem impulsów wynoszącym 10 sekund. Przedstawione wyniki wskazują na wyraźny wpływ pola elektrycznego na proces kiełkowania nasion szczawiu pospolitego. Wpływ ten zależy od parametrów pola oddziałującego. Najlepszym wskaźnikiem zdolności kiełkowania charakteryzowały się nasiona stymulowane polem 25 kV, natomiast nieco niższą wartość tego parametru wykazały nasiona stymulowane polem 15 kV. (**Wpływ impulsowego pola elektrycznego na kiełkowanie nasion szczawiu pospolitego**)*

***Abstract***. *The aim of the work was to analyze the impact of the pulsed electric field of variable parameters on the germination capacity of common sorrel seeds. Homogeneous seed material of the same origin was divided into 5 parts, one of which was a control sample. The remaining parts were subjected to a pulsed electric field of 15 kV (100 and 200 impulses) and 25 kV (100 and 200 impulses), with a fixed pulse interval of 10 seconds. The presented results show a clear influence of the electric field on the germination process of common sorrel seeds. This influence depends on the parameters of the interacting field. The best indicator of germination capacity was shown by seeds stimulated with a 25 kV field, but a slightly lower value of this parameter was shown by seeds stimulated with a 15 kV field.*

**Słowa kluczowe:** pulsacyjne pole elektryczne, kiełkowanie, szczwa zwyczajny
**Keywords**: pulsed electric field, germination, common sorrel

## 1. Introduction

It has been proven many times that magnetic and electric fields affecting plant seed material improve its quality. The first documented research dates back to 1876 [1]. As a result of the conducted experiments, it was found that the magnetic field had no effect on seed germination or plant development, but less than 20 years later, in 1893 [2], completely different results were obtained, in the form of the effect of accelerated germination of plant material in a magnetic field. It has been repeatedly shown that plant seeds and tubers subjected to constant and variable magnetic and electric fields germinate faster, and their seedlings are larger, stronger and more vital [3-12]. In Poland, the first works on the influence of the magnetic field on living organisms appeared in the mid-1980s [13, 14]. They concerned the impact of the magnetic field on sugar beet seeds. The results obtained at that time were inconclusive. Both a positive effect (faster germination and a slight increase in yields) as well as no effects were found in relation to seeds not stimulated before sowing.

Work on the use of the magnetic field continues uninterruptedly to this day [15, 16], and in parallel to them, work is being carried out in which the electromagnetic field is used.

Using an electromagnetic field with a magnetic induction of 20 µT and a frequency of 16.67 Hz for the pre-sowing stimulation of sunflower seeds, an effect was obtained in the form of an increase in the total fresh weight, mass of the shoot and roots, and for wheat seeds, an additional increase in the germination rate [17]. The use of an alternating electromagnetic field with parameters of 750 µT and 7 Hz and 500 µT and 14 Hz was conducive to faster germination of St. John's wort seeds and a local Japanese plant called the hornwort (*Cryptotaenia japonica Hassk*) [18]. The field with magnetic induction of 0.3 mT and frequency of 7.83±0.1 Hz resulted in an increase in the germination rate of mung bean from 8% to 23.3% compared to the control groups, and also an increased increase in the length of the stem by 14% (in 72 hour of growth) in relation to samples not subjected to the electromagnetic field [19].

Common sorrel (*Rumex acetosa*) is a perennial plant belonging to the knotweed family (*Polygonaceae*). This species occurs naturally in many regions around the world, including Poland. The plant grows to a height of up to 100 cm. Edible sorrel leaves are large, green, leathery, lanceolate in shape, set on long petioles. It should be noted that the potassium oxalates contained in the plant in greater amounts are harmful to health, they can, among others, cause bone decalcification. Despite this, the plant is considered medicinal - sorrel leaf infusions are recommended in liver and kidney diseases. Externally, however, they can be used on boils and wounds. Sorrel contains fiber, protein, carbohydrates, vitamins A, B and C, as well as folic acid [20].

## 2. Aim and scope of research

The aim of the work was to analyze the impact of the pulsed electric field (PEF) of variable parameters on the germination capacity of common sorrel seeds. The tests were carried out in the Laboratory of Experimental Research Techniques for Biological Products and Raw Materials. The scope of work included seed preparation, sowing in homogeneous conditions and observation of the germination process along with a thorough statistical analysis [21].

Utilitarian (1) and cognitive (2) justification of the purpose of research:

stimulation of seeds with an electric field with specific parameters will allow to check the effect of PEF on the germination effect (1) and will allow for deliberate/controlled modification of selected properties of the seed material, translating into its use in production and/or industrial processes (2).

## 3. Material ans research methodology

Homogeneous seed material of the same origin was stabilized in laboratory conditions (air temperature was 23℃ and relative humidity was 31%). Then the material was divided into 5 parts, one of which was a control sample. The remaining parts were subjected to a pulsed electric field with variable parameters: voltage of 15 kV (100 and 200 impulses) and 25 kV (100 and 200 impulses), with a constant interval between pulses of 10 seconds. The tests were carried out on the same day, at the station for generating the Pulse Electric Field (Fig. 1).


Fig. 1. Electrical system for generating PEF pulses (discharge chamber with computer and stationary sterilization cell) [22]

The device allows to obtain a voltage of up to 30 [kV], which at the electrode distance of 0.73 [cm] gives a maximum electric field strength of 41.10 [kV/cm]. It can operate in two modes, i.e. stationary and continuous, for which specially designed cells and a peristaltic pump for a continuous process are used. The impact generator is equipped with 16 protection against electric shock, which makes working with this device as safe as possible.

Seeds in batches were placed in sterilization cells, which were then placed in the measurement chamber (fig. 1).

From each group of prepared seed material (control and after stimulation), 10 samples containing 100 seeds each were isolated for each material separately (i.e. a total of 50 samples of 100 seeds). Seeds were sown in separate petri dishes. Lignin with high water capacity, neutral reaction and free from harmful chemicals was used as the germination substrate (Fig. 3).

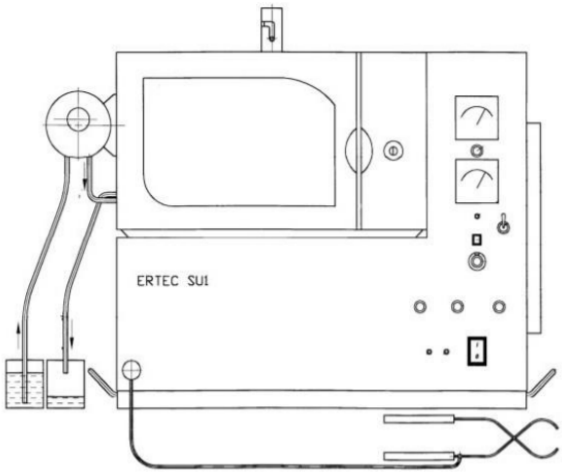


Fig. 2. Visualisation of the PEF generating device (Ertec SU1) [24]

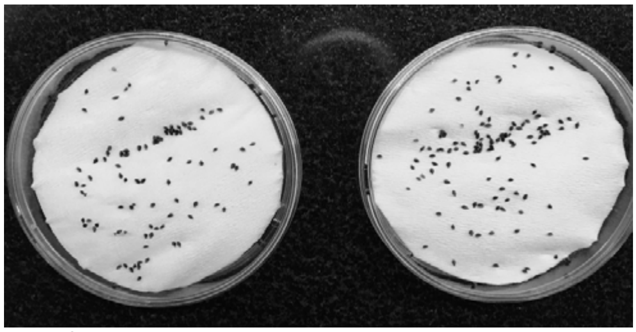

Fig. 3. Common sorrel seeds on a seedbed

Germination was carried out at a temperature of 26°C, with temperature stabilization of +/- 1°C, under a cover. Seeds that formed a sprout of at least 1 mm were considered sprouted. Then, the germination capacity (Zk, %) was calculated for individual batches of material, defined by the formula:

$$Z_k = \frac{n_k}{n_c} \cdot 100\ [\%] \qquad (1)$$

$n_k$ - number of germinated seeds, $n_c$ - total number of seeds sown.

The germination observations and measurements were started after about 24 h, counting the first germinated seeds. They were then counted over a three-week period, recording once a day.

## 4. Research findings and their analysis

Based on the experiments, the germination capacity was determined for four samples: unstimulated seeds and stimulated seeds (15kV 100 impulses, 15kV 200 impulses, 25kV 100 impulses, 25kV 200 impulses). The table 1 shows the results.

The graph below (fig. 4) shows the average germination capacity for individual samples, along with the standard deviation.

The presented results indicate a clear influence of the electric field on the germination process of common sorrel seeds. The influence depends on the parameters of the interacting pulsed electric field. The best germination rate was found in seeds stimulated with a 25 kV field, while seeds stimulated with a 15 kV field showed a slightly lower value of this parameter.

It should be noted that the seeds stimulated with the field of 15 kV (200 impulses) and 25 kV (100 impulses) obtained the best germination rate. The greatest variability of germination capacity was shown by the seeds of the control sample (standard deviation = 10), and the lowest by seeds stimulated with 25kV 200 impulses (standard deviation = 4).
Below are illustrative photos of samples on the 8th day of germination.

Table 1. Germination capacity for individual batches of seeds

| sample | control sample | 15kV 100 impulses | 15kV 200 impulses | 25kV 100 impulses | 15kV 200 impulses |
|---|---|---|---|---|---|
| 1 | 57 | 89 | 90 | 95 | 94 |
| 2 | 50 | 88 | 89 | 99 | 93 |
| 3 | 54 | 92 | 95 | 100 | 98 |
| 4 | 62 | 86 | 96 | 94 | 88 |
| 5 | 52 | 79 | 97 | 94 | 86 |
| 6 | 49 | 91 | 85 | 84 | 94 |
| 7 | 68 | 88 | 79 | 98 | 98 |
| 8 | 76 | 86 | 92 | 95 | 97 |
| 9 | 42 | 89 | 88 | 88 | 93 |
| 10 | 56 | 99 | 85 | 98 | 94 |

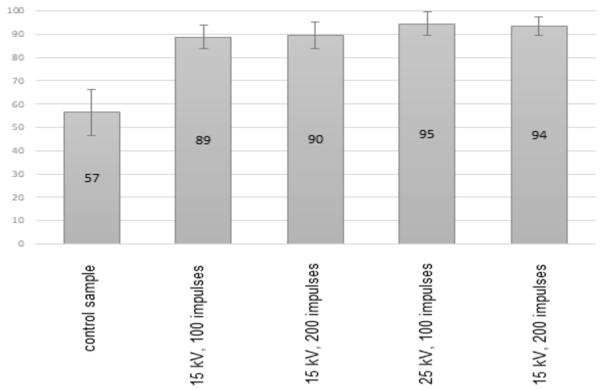


Fig. 4. Average germination capacity for individual samples, along with standard deviation

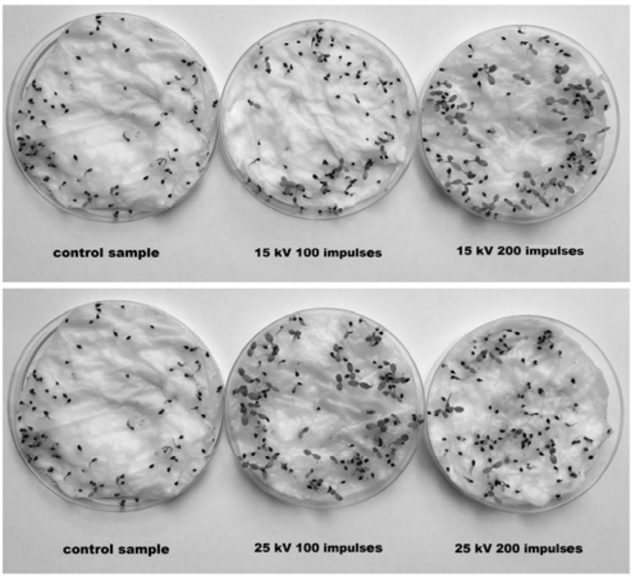


Fig. 5. Common sorrel seeds on the eighth day of germination

In addition, two samples of sown seeds from each batch were selected and counts of germinated seeds were made daily for a period of 14 days. Then, the curves showing the germination rate of seeds from each group were determined. The counting results are presented in the table 2.

Table 2. Germination rate of individual batches of seeds

| a y | 1 ) | 2 ) | 1 ) | 2 ) | 1 ) | 2 ) | 1 ) | 2 ) | 1 ) | 2 ) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 0 | 1 | 0 | 1 | 2 | 21 | 19 | 1 | 0 |
| 3 | 4 | 2 | 5 | 6 | 6 | 8 | 29 | 26 | 10 | 16 |
| 4 | 16 | 12 | 30 | 31 | 16 | 15 | 48 | 51 | 22 | 35 |
| 5 | 21 | 23 | 38 | 40 | 44 | 46 | 63 | 66 | 38 | 62 |
| 6 | 46 | 42 | 44 | 46 | 72 | 69 | 77 | 74 | 58 | 81 |
| 7 | 48 | 45 | 60 | 58 | 82 | 85 | 80 | 85 | 81 | 90 |
| 8 | 50 | 51 | 76 | 72 | 89 | 86 | 93 | 92 | 89 | 93 |
| 9 | 52 | 54 | 81 | 80 | 90 | 87 | 93 | 95 | 95 | 93 |
| 10 | 56 | 54 | 84 | 84 | 90 | 88 | 93 | 95 | 95 | 93 |
| 11 | 56 | 54 | 89 | 86 | 90 | 88 | 93 | 95 | 95 | 93 |
| 12 | 56 | 54 | 89 | 88 | 90 | 88 | 93 | 95 | 95 | 93 |
| 13 | 56 | 54 | 89 | 88 | 90 | 88 | 93 | 95 | 95 | 93 |
| 14 | 56 | 54 | 89 | 88 | 90 | 88 | 93 | 95 | 95 | 93 |

On the basis of the obtained results, a graph of the growth rate of individual groups of seeds was prepared, which is presented in the graph below (Fig. 6).

In the graph it can be seen, that the fastest rate of germination was found in seeds stimulated by a pulsed electric field of 25 kV (100 and 200 impulses). On the fourth day after sowing, almost half of the sown seeds sprouted;

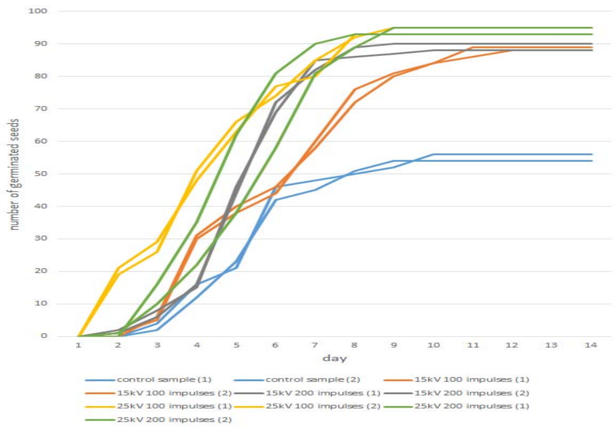


Fig. 6. Seed germination rate from individual samples

## 5. Summary and conclusions

Modern Agricultural Engineering is looking for new, safe methods of increasing the quality of crop yields, using the interdisciplinary combination of sciences in the field of biophysics, molecular biology and physics. Good quality and proper preparation of seed material is one of the most important yield factors. The use of certain physical factors creates new opportunities to stimulate seed growth. Methods of pre-sowing seed treatment stimulate the course of physiological and biochemical changes in seeds. Among these methods, one can distinguish, among others, stimulation with a magnetic or electric field with variable parameters [23].

The study attempted to assess the germination capacity of common sorrel seeds stimulated by a pulsed electric field. On the basis of the obtained results of stimulation of sorrel seeds with a pulsed electric field, a significant effect of this treatment on the improvement of germination capacity, germination time and germination rate was demonstrated.

Based on the conducted research and analysis of the results, the following conclusions were formulated:

1. stimulating the seed material with a pulsed electric field has a positive effect on both the ability and the rate of germination of common sorrel seeds;
2. the highest average number of germinated seeds was characterized by seed material stimulated by a pulsed electric field of 25 kV (100 and 200 impulses);
3. The fastest rate of germination was found in seeds stimulated by a pulsed electric field of 25 kV (100 impulses). On the fourth day after sowing, almost half of the sown seeds sprouted;
The 4th control samples were characterized not only by lower germination capacity, but also by the most diversified capacity (as evidenced by the highest value of the standard deviation).

***Authors**: dr inż. Karolina Trzyniec, University of Agriculture, Faculty of Production and Power Engineering, Department of Machinery Operation, Ergonomics and Production Processes, al. Mickiewicza 21, 31-120 Kraków, e-mail: karolina.trzyniec@urk.edu.pl;*

## REFERENCES

[1] Reinke J. Untersuchungen der Wachstrum. Botan. Ztg., 34 (1876), 129
[2] Tolomei, G. (1893). Anzione Del Magnetismo Sulla Germinazione. Malpighia, 7, 470.
[3] Carbonell M.V., Martinez E., Amaya J. M., (2000). Stimulation of germination in rice (Oryza Sativa L.) by a static magnetic field. Electro- and Magnetobiol. 19 (1), 121–128.
[4] Namba K., Sasao A. Shibusawa S. (1995). Effect of magnetic field on germination and plant growth. Acta Hort. 399, 143–147.
[5] Kopeć B. (1983). Wykorzystanie energii pola elektrycznego do przedsiewnej obróbki nasion. Postępy Nauk Rolniczych, 3, 51-64.
[6] Pietruszewski S. (2002). Wpływ pól magnetycznych i elektrycznych na kiełkowanie nasion wybranych gatunków roślin uprawnych. Acta Sci. Polon. Tech. Agraria, 1 (1), 75-81.
[7] Prokop M., Pietruszewski S., Kornarzyński K. (2002). Wstępne badania wpływu zmiennych pól magnetycznych i elektrycznych na kiełkowanie, plony oraz cechy mechaniczne korzeni rzodkiewki i rzodkwi. Acta Agrophysica, 62, 83-93.
[8] Anzin L. A., Shmigel V. N., Zimukov N. A. (1983). Podwyższenie jakości materiału siewnego pod wpływem pola elektrostatycznego (ros.) Selskohoz. Biol. Moskwa 11, 44–45.
[9] Gładyszewska B., Koper R., Kornarzyński K. (1999). Matematyczny model procesu kiełkowania nasion. Inżynieria Roln. 2(8), 7–12 .
[10] Herzog K., Zerjeski V. (1984). Untersuchungen zur Beeifluβbarkeit der Laborkeimung und des Feldaufganges von Zuckerrübensaatgut durch Vorbehandlung im elektrischen Feld. Wiss Beitrübe Univ. Halle 53 (4, 42), 1, 244–255.
[11] Karimova Sh. W. (1984). Elektroekspozycja bulw (ros.). Kartofel i ovošci. 15.
[12] Shmigel N., Odegova S., Grigorev V. (1984). Elektrostymulacja bulw (ros.). Uralskie Nivy. 5, 52–53.
[13] Kopeć B. (1984) Wpływ pól elektrycznych i magnetycznych na właściwości biologiczne nasion. PhD thesis. Agriculture Academy in Lublin
[14] Kopeć B. (1985) Zastosowanie pola magnetycznego do przedsiewnej obróbki nasion. Postępy Nauk Rolniczych, 1, pp. 93–100.
[15] Ferrada P., Rodríguez S., Serrano G., Miranda–Ostojic C., Maureira A., Zapata M. (2020) An analytical–experimental approach to quantifying the effects of static magnetic fields for cell culture applications. Applied Sciences 10(2) 1–22.
[16] Lu H., Wang X., Hu S., Han T., He S., Zhang G., He M., Lin X. (2020) Bioeffect of static magnetic field on photosynthetic bacteria: evaluation of bioresources production and wastewater treatment efficiency. Water Environment Research 98(2), 1131–1141.
[17] Fischer G., Tausz M., Köck M., Grill D. (2004) Effects of weak 16 2/3 Hz magnetic fields on growth parameters of young sunflower and wheat seedlings. Bioelectromagnetics 25(8), 638–641.
[18] Kobayashi M., Soda N., Miyo T., Ueda Y. (2004) Effects of combined DC and AC magnetic fields on germination of hornwort seeds. Bioelectromagnetics 25(7), 552–557.
[19] Huang P.C., Tang J.Y., Feng C.H., Cheng P.Y., Jang L.S. (2018) Influences of extremely low frequency electromagnetic fields on germination and early growth of mung beans. IEEE International Conference on Consumer Electronics–Taiwan, 1–2.
[20] Mirek Z. et al. (2020). Vascular plants of Poland. An annotated checklist. Rośliny naczyniowe Polski. Adnotowany wykaz gatunków.
[21] Yucel A., Markovic M.; Jakubowski T. et al. (2022). Investigation of Annual Lake Water Levels and Water Volumes with Sen Innovation and Mann-Kendall Rank Correlation Trend Tests: Example of Lake Egirdir, Turkey. Renewable energy sources: engineering, technology, innovation , pp.333-343.
[22] Popardowski E., Kiełbasa P. (2022). Influence of Broadleaved Wood Conditioning by Pulsed Electric Field on Its Combustion Heat Characteristics. Applied Sciences, 12(10), pp. 1-13.
[23] Skowron M. (2011). Analiza teoretyczna i eksperymentalna wpływu stałego pola magnetycznego na kiełkowanie i wzrost ziarniaków wybranych roślin. PhD thesis. University of Science and Technology, Krakow