Effect of constant high-voltage electric field on wheat seed germination

S A Krivov1, A V Lazukin1,2, Y A Serdyukov1,2, S V Gundareva1 © and G A Romanov3

1 High Voltage Engineering and Electrical Physics, Moscow Power Engineering Institute, Moscow, Russia
2 Group of Plant Magnetobiology, Timiryazev Institute of Plant Physiology RAS, Moscow, Russia
3 Scientific and Technical Innovation Center for Energy-Saving Technologies and Technological Equipment, Moscow Power Engineering Institute, Moscow, Russia

E-mail: gundareva-sv@rambler.ru

Keywords: constant electric field, spring wheat, contact with an electrode, seedlings.

Abstract

In this work an effect of the 10-min pre-sowing treatment by the constant electric field with the 3 kV cm⁻¹ electric field strength on the soft spring wheat seed germination is studied at various positions of the seeds in a plane-parallel electrode system. The effects of the electric field direction and contact conditions of the seeds with a plane aluminum electrode (no contact, when the seeds lie on the isolating plate; contact with the positive or negative high-voltage or grounded electrode) are compared. The treatment response is estimated by the morphological characteristics of 3-day seedlings—germination, the shoot length and the length of individual roots. At all modes, the treatment does not change seed germination. At each considered variant of seed location, the electric field effect did not reduce the average length of the root system and the shoot length below the ones at the control variant. The significant increase of morphological characteristics is achieved at the seed contact with the high voltage electrode.

Introduction

The influence of electric fields on living organisms is considered from different sides. First of all, the negative effects are evaluated that could be caused by the sources of electromagnetic pollution, such as power transmission lines (the systematic review (Schmiedchen et al 2018) estimates the effects that high-voltage DC power transmission lines could cause in wildlife). On the other hand, there is a group of high-voltage electrical technologies based on the effect of high-voltage electric field on biological objects: electroporation, electrocoagulation, treatment and healing, modification of growth processes. The electric field effect is widely used in the development of food technologies: drying, thawing, refrigeration, freezing (Dalvi-Isfahan et al 2016). The exposure in electric field potentially (through modification of accompanying processes) extends the shelf life (Atungulu et al 2004, Liu et al 2017). Electric field can also be used for pre-sowing seed treatment—it stimulates germination processes (Okumura et al 2013, Bahar et al 2014) and is used for cleaning from unwanted impurities and low-quality fractions (Kovalyshyn and Kovalyshyn 2018). From the point of view of technology of seed pre-sowing stimulation offered on the market, any electrophysical stimulation methods including constant electric field effect lose out to chemical treatments. On the other hand, there are cases with objective obstacles to the wide use of chemical seed treatment, for example, in terms of soil environmental burden. For this reason, electrophysical methods are being developed.

Electric field is created by a pair of electrodes with voltage applied to them. In the case of a constant field (a field created with DC voltage), one of the electrodes is the cathode and the other is the anode. In the simplest electrode configuration (electrostatic field between parallel plates) treated seeds can be located in several ways:

(i) Seeds lie on the cathode (or anode) when it is energized.
(ii) Seeds lie on the cathode (or anode) when it is grounded.
Seeds lie on the cathode (or anode) when it is energized but are isolated from it by a dielectric layer.

Seeds lie on the cathode (or anode) when it is grounded but are isolated from it by a dielectric layer.

It is known that the circumstances of bio-object contact with an electrode (it contacts with the cathode or the anode) during the electric field treatment affect, for example, the antioxidant system of stored tomatoes (Zhao et al 2011). It is also known that the electric field direction can influence the seed treatment results (Atungulu et al 2004, Okumura et al 2013). Therefore, both the electric field direction and the circumstances of seed contact with the electrode could play a role at the electric field treatment.

In this work, the pre-sowing treatment effect of constant uniform high-voltage electric field on the germination of spring soft wheat seeds for various cases of seed location in the electrode system during the treatment and different directions of the electric field is studied.

The constant electric field effect on the seed, in addition to ‘delayed’ effects such as stimulation of growth characteristics, is related to the effects of polarization which form the basis of a number of electric separation methods of seeds. Thus, a wheat seed having a distinctive elongated form experiences a rotation in electric field (figure 1) under a certain electric field strength depending on seed mass, humidity, and a number of secondary electrical and mechanical parameters. If the interelectrode gap is not wide compared to the size of the seed then at such rotation even of a small number of seeds, distribution of electric field changes in the gap. Corona discharge may occur near the tips of raised seeds. At that, corona discharge can significantly affect treatment results because the atmospheric pressure corona discharge is a source of low-temperature plasma. Along with other types of gas discharge, it is studied in works on seed stimulation, for example, Lynikiene et al 2006. A preliminary study of the electric field effect on the rotation of seeds used in this work showed that the first seed movements were observed when the electric field strength in the gap exceeded 7 kV cm$^{-1}$. Taking this into account, it was decided to carry out treatment at an electric field strength of 3 kV cm$^{-1}$.

Methods

Seed treatment is carried out in a plane-parallel configuration of two electrodes made of aluminum, located at a distance of 1 cm from each other. The work was carried out in humid (50%–55%) atmospheric air at room temperature (20 °C–22 °C). One electrode is under high voltage in all cases, the second one is grounded. The variants of seed positioning are as follows:

![Figure 1.](image)
– on the energized anode (‘+3 kV on HV’);
– on the energized cathode (‘−3 kV on HV’);
– on the grounded cathode with applied positive high voltage to the anode (‘+3 kV on GND’);
– on the grounded anode with applied negative high voltage to the cathode (‘−3 kV on GND’);
– and each aforementioned variant, but with the seeds isolated by a dielectric layer (‘insulated’).

The variants of seed positioning with positive high voltage are shown schematically in figure 2 (similar schemes for negative high voltage).

The electric field effect was evaluated using the morphological characteristics estimation of 3-day seedlings of high quality soft spring wheat seeds (variety ‘Novosibirskaia−29’) of 2018 year yield from the collections of The Core Facilities Center <<Bioresource Center>> SIPPB SB RAS (Irkutsk).

At each aforementioned variant of seed positioning the seeds were treated for 10 min. The treated seeds were germinated for three days in the dark in a thermostat (24 ± 1 °C) on two layers of filtering paper moistened with distilled water (10 ml per sample). The seeds were spread out in plastic containers of 100 seeds per sample, 400 seeds per container, at a distance of about 5 mm from each other. The paper was daily moistened with 2 ml of distilled water, the containers were ventilated and rearranged in the thermostat. On the third day morphological indicators (sprout length, length of individual roots) and 3-day germination (the ratio of the number of normally germinated seeds to the total number of seeds) were estimated. On the histograms the average values are shown with 95% confidence intervals. Significant differences between the variants were confirmed by the Tukey multiple comparison test. The variants without significant differences are indicated with the same letters. Statistical data processing was performed using the programming language R. All germination experiments were carried out in the first-second quarters of 2019.

Results and discussion

Figure 3 shows the results of measuring the morphological indicators of seedlings obtained from the seeds treated in the considered variants of their positioning. Three-day seed germination was 94%–98% in all experiments and did not show a response to the treatment.

First, it should be noted that the response to the treatment is organ-specific. For root system, only one treatment mode (‘+3 kV on HV’) makes significant differences not only from the control samples, but also from the other modes. The response of the shoot to the treatment is more multidirectional:

1. The very fact that the seeds are located in the electric field of 3 kV cm⁻¹ for 10 min (without taking into account the influence of the contact circumstances and the direction of the electric field strength vector) does not give a clear result. There are variants (‘+3 kV on GND’, ‘−3 kV on HV’, ‘−3 kV on HV insulated’, ‘−3 kV on GND insulated’) when the gap is energized, but the morphological response is not observed.

2. In the case of upward direction of the electric field strength vector when the seeds lie either on the energized cathode, or on the grounded cathode, there is unreliable shoot stimulation (it is reliable only in the case of ‘+3 kV on HV insulated’).

3. In the case of downward direction of the electric field strength vector when the seeds lie either on the energized anode, or on the grounded anode, almost in all variants (‘−3 kV on GND’, ‘+3 kV on HV insulated’, ‘+3 kV on HV’) there is shoot stimulation, except for the ‘−3 kV on GND insulated’ mode.
4. In variants without the contact between seeds and the electrode (the ‘insulated’ modes), the effect is always less shown than in the same applied voltage modes, but with the contact. The reverse situation is observed only in the mode when the seeds are in contact with the grounded anode (+3 kV on GND and +3 kV on GND insulated) modes).

5. When the seeds contact directly with the high-voltage anode (+3 kV on HV), significant stimulation of shoot length is observed. This mode has an ‘alternate’ in terms of ‘field direction/strength’ combination, when the seeds lie on the grounded anode (−3 kV on GND). At the alternate mode, the shoot length is also stimulated.

6. When the seeds contact with the energized cathode (−3 kV on HV) as well as in its alternate mode (+3 kV on GND’), there is no difference from the control samples.

Analysis of the results shows that the circumstances of seed contact with the electrode play an important role in the success of seed treatment by constant electric field.

**Conclusion**

The results show that the circumstances of seed contact with the electrode play a significant role in the seed treatment by constant electric field. The effect of contact is even more significant than the effect of electric field direction. From this point of view, there is a question of the role of contact resistance between the seed and the electrode. In this work the aluminum was used which is known to be coated with an oxide film in atmospheric air. The use of graphite electrodes would clarify this point. As for the effect of electric field direction, it could become greater in electric fields of low strength. The effects of contact electrode material and the electric field strength are planned to study in subsequent works.

**Acknowledgments**

This work was funded by the Russian Science Foundation through a grant No. 18-76-10019.

**Data availability statement**

The data that support the findings of this study are available upon reasonable request from the authors.

**ORCID iDs**

S V Gundareva https://orcid.org/0000-0001-9671-1373
References

Atungulu G, Nishiyama Y and Koide S 2004 Respiration and climacteric patterns of apples treated with continuous and intermittent direct current electric field J. Food Eng. 63 1–8

Bahar M, Sojoodi J and Yasaei Y 2014 Study of DC and AC electric field effect on Pisum sativum seeds growth Eur. Phys. J. Appl. Phys. 67 11201

Dalvi-Isfahan M, Hamdami N, Le-Bail A and Xanthakis E 2016 The principles of high voltage electric field and its application in food processing: a review Food Res. Int. 89 48–62

Kovalyshyn S and Kovalyshyn O 2018 Improvement of the efficiency of perennial seed mixtures separation on a Drum Vibro electric separator Acta Univ. Agric. Silvic. Mendelianae Brun 66 1157–64.

Liu C-E, Chen W-J, Chang C-K, Li P-H, Lu P-L and Hsieh C-W 2017 Effect of a high voltage electrostatic field (HVEF) on the shelf life of persimmons (Diospyros kaki) Lwt-Food Science and Technology 75 236–42

Lynikiene S, Pozeliene A and Rutkauskas G 2006 Influence of corona discharge field on seed viability and dynamics of germination Int. Agrophys. 20 195–200

Okumura T, Muramoto Y and Shimizu N 2013 Polarity effect on growth acceleration of arabidopsis Thaliana by DC electric field 2013 IEEE Int. Conf. on Solid Dielectrics. (Bologna, Italy)

Schmiedchen K, Petri A-K, Driesen S and Bailey W H 2018 Systematic review of biological effects of exposure to static electric fields. II: Invertebrates and plants Environ. Res. 160 60–76

Zhao R, Hao J, Xue J, Liu H and Li L 2011 Effect of high-voltage electrostatic field pretreatment on the antioxidant system in stored green mature tomatoes J. Sci. Food Agric. 91 1680–6