Physical characteristics of the seeds layer and estimation of the degree of the activator volume

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Abstract. Analysis of the results of scientific research suggests that the authors used small volumes of the seed layer to study the effect of an electric field on the seeds. The electrical parameters of the seed layer in a small-sized activator allowed the authors to freely operate with a wide range of impact signals. When switching to the industrial level in the activator, a large volume of a layer of seeds is processed. The actual electrical parameters of the power source, activator, and seed layer limit the range of electrical parameters of possible effects. Therefore, for the industrial development of these electrical technologies, it is necessary to adjust the previously determined parameters of the seed treatment modes. The positive effect of the electric field on the seeds is due to the quantitatively dosed energy impact. However, the assessment of the impact on any one of the electrical parameters (electric field intensity, frequency, etc.) is insufficient. The cause is non-uniform processing of the seed layer. The rational thickness of the seed layer and its maximum compaction in the volume of the activator make it possible to create a uniform electric field strength of the required size and, as a result, an appropriate dose of exposure to increase the sowing qualities of the seeds. For the formation of electrical parameters and the description of the processes occurring in the activator in the presence of a moving seed layer, it is necessary to take into account a number of factors. One of the important factors is the structure of the seeds of plants. The structural and functional unit of a seed is a cell that has, in addition to its biological, chemical properties, a number of physical characteristics. The heterogeneity of the composite components of different seed mass determines its physical properties. These features are also taken into account when developing technological schemes for the operation of an activator with a moving layer.

1. Introduction
Every year the need of the world population in quality environmentally friendly products increases. To give up the use of chemical fertilizers, protectants which improve the yield of cereal and vegetable crops, scientists more often consider alternative methods of treatment, one of them is the pre-sowing treatment with physical factors. Seed treatment with a pulsed electric field (PEF) brings good results. The scientists of the Stavropol State Agrarian University Starodubtseva G.P., Oskin S.V., Khaynovsky V.I., Rubtsova E.I., Khnykina A.G. and other scientists have proven that with using rational treatment regimes, PEF has both stimulating and bactericidal effects by suppressing pathogenic mycoflora on seeds shells [3, 4, 7, 8]. The treatment of stock seeds is practiced abroad, too. In their works Bilalis D.J., Katsenios N., Efthimiadou A., Karkanis A., Dymek K., Dejmek P., Panarese V., Vicente A.A.,
Wadsö L., Finnie C., Galindo F.G. studied the impact of a pulsed electric field on various crops and had good results [1, 2, 5, 6, 9].

The analysis of the results of scientific research leads to the conclusion that the authors worked with small amounts of the seed layer to study the impact of a pulsed electric field on the seeds. The electrical parameters of the seed layer in a small-sized activator let the authors freely operate with a wide range of signals of exposure. With the transition to the commercial scale, the activator starts treating a larger amount of seed layer. Actual electrical parameters of the power source, an activator, and of a seed layer both limit the range of electrical parameters of possible exposures. Therefore, for the commercial development of these electrical technologies, it is necessary to adjust the earlier identified parameters of the seed treatment regimes.

The positive effect of the electric field on the seeds is due to the quantitatively dosed power action. However, the assessment of the exposure on any one of the electrical parameters (electric field intensity, frequency, etc.) is insufficient. The reason is the heterogeneity of a seed layer treatment.

The rational thickness of a seed layer and its maximum compaction in the volume of the activator make it possible to create a uniform electric field intensity of the required value and, as a result, an appropriate dose of exposure to increase the sowing qualities of the seeds.

2. Experiment program

For the formation of electrical parameters and description of the processes occurring in the activator in the presence of a moving seed layer, it is necessary to take into account a number of factors.

The heterogeneity of the constituents of different seed masses determines their physical characteristics. These features are taken into account when developing technological schemes of activator operation with a moving layer.

Seeds contain a certain amount of moisture. In standard seeds, the moisture content is (9...15 %). It doesn’t allow to take the seeds as ideal dielectrics. Water is a highly polar liquid (ε = 88) with a low resistivity of about $10^3...10^4$ Ohm·m. Different parts of the seeds have a complex and heterogeneous chemical composition, that affects the processes occurring inside them during electricity exposure. An increase in the applied voltage leads to an increase in the ion mobility, space charges formation and, as a result, to a decrease in resistance. At high voltages, ejection of electrons out of atoms occurs with the creation of conditions for the rupture.

Therefore, the goal of our research is a quantitative assessment of the electrical parameters of seeds, such as dielectric permittivity, electrical leakage resistance, electrical rupture voltage of separate seeds and a layer of different thickness using onion seeds as an example.

3. Results and discussion

To meet the goal, we conducted the researches in which we took into consideration the ability of seeds to absorb a significant amount of moisture. This fact significantly affects their electrical characteristics, such as conductivity and dielectric permittivity. A seed absorbs moisture almost equally in its volume. This does not violate the self-sufficiency of the seed as a component of the environment. For sowing, seeds with normalized low humidity $\approx 9$ % are used, which allows to obtain reliable stable electrical characteristics of the seed layers during pre-sowing treatment with PEF.

With the LCR-819 instrument, a sensor capacity and a seed layer were measured to calculate the dielectric permittivity of a seed layer.

The assessment of common factors of changes in the dielectric permittivity of a seed layer was carried out within the frequency range relevant to the treatment modes. Capacitance measurement was made according to two equivalent circuits: parallel and serial ones, with a subsequent comparison of values. A wider range of studies of the dielectric permittivity of a seed layer can be a matter of a separate study.

Measuring of active resistance of a seed layer was carried out at a constant voltage in the range of 100...2500 V in order to estimate the actual values relevant to the working voltage stresses during treatment. The resistivity of a seed layer was calculated on the basis of the measured active resistance.
Measuring of voltage magnitude and form which affects the seed layer in the activator during its treatment was carried out with an oscilloscope and a high-voltage bleeder.

Estimation of rupture voltage was studied on equipment with a variable voltage with a commercial frequency of 50 Hz. The testing of the layer of a minimum height equal to the size of the seed was carried out on three seeds, set at the corners of an equilateral triangle. The high-voltage electrode was placed on the seeds directly. The current rupture voltage was recorded. The tests were carried out on various seed layers of different heights.

An experiment was conducted with seeds shells ground away on both sides contacting with the electrode. A rupture was observed visually as a spark.

The results of the experiment for measuring the dielectric permittivity of the onion seed layer, tightly (i.e. maximum) filling the activator volume, are given in table 1.

| $h_{\text{layer}}, \text{m}$ | 0.004 | 0.006 | 0.008 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 |
|---------------------------|------|------|------|-----|-----|-----|-----|-----|
| $\varepsilon$             | 4.19 | 5.41 | 6.08 | 6.83 | 7.35 | 7.79 | 8.26 | 8.46 |

The indicated experimental results show that the dielectric permittivity of a seed layer depends heavily on its thickness. For the seed layer thickness exceeding 45...50 mm, it tends to a value of $\approx 8.5$.

Measurements are made for equivalent circuits with series and parallel connection of leakage resistance and electrical capacity of a seed layer. The measurement results show almost identical values of the activator capacity for both equivalent circuits.

Another important parameter of a seed layer is its leakage resistance at the maximum filling of the volume inside an activator.

Table 2 presents experimental data for the electrical resistance (leakage resistance) of onion seeds for several layer thicknesses and different magnitudes of the amplitude of the pulse voltage applied to the activator electrodes.

| Agricultural plant | Voltage, V | $h_{\text{layer}}, \text{m}$ | 0.004 | 0.006 | 0.008 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 |
|-------------------|------------|-----------------|------|------|------|-----|-----|-----|-----|-----|
| Onion             | 100        | 5               | 9    | 13   | 30   | 60  | 90  | 130 | 170 |
|                   | 250        | 2               | 4    | 7    | 15   | 30  | 50  | 70  | 90  |
|                   | 500        | 1.2             | 2    | 4    | 6    | 15  | 25  | 45  | 60  |
|                   | 1000       | 0.8             | 1.5  | 2    | 3    | 6   | 13  | 25  | 35  |
|                   | 2500       | 0.5             | 1    | 1.5  | 2    | 4   | 6   | 10  | 15  |

The dependences given in table 2 show a significant decrease in the resistance of the onion seed layer at high voltages on the electrodes of the activator capacitor. This can be attributed to an increase in seed leakage currents, since the electric field strength increases from $2 \cdot 10^3$ V/m to $6 \cdot 10^5$ V/m when changing the seed layer thickness in the range of 4...50 mm and changing voltages in the range of 100...2500 V.

An important electrical parameter of the seeds is the voltage magnitude (electric field strength), which causes electrical rupture and is an upper limit. The data obtained in the experiments confirm the acceptable high level of the electric field strength in the technology of seed activation and impact on mycoflora.

In this case, a significant influence of seeds contact resistances was established. For example, measuring of resistance was made for two separate seeds. Measuring of the total resistance of the seeds connected in series (put one on another) gave a value that exceeded significantly a sum of
separate seeds resistances. For a thick layer of seeds, its total active leakage resistance depended on a surface and volume conductivities of separate seeds and transitional contact resistances.

Table 3 shows the experiment results for determining the electrical rupture voltage of separate seeds and the layer as a whole. The measurements are made at a commercial frequency of 50 Hz.

**Table 3.** Experimental data for the electrical rupture voltage of separate onion seeds and their layer of different thickness.

| \( h_{\text{layer}}, \text{m} \) | \( U_{\text{of rupture}}, \text{kV} \) | \( E, \text{V/m} \) |
|---|---|---|
| 3 seeds | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 |
| - | 2.03 | 4.76 | 12.88 | 21 | Withstands 50 kV |
| - | - | - | - | \( 4.76 \cdot 10^4 \) | \( 6.4 \cdot 10^4 \) | \( 7 \cdot 10^4 \) | \( \approx 1 \cdot 10^6 \) |

Thus, with an increase in the thickness of a seed layer, the strength of the critical electric field increases, reaching a value of \( 2 \cdot 10^3 \cdot 10^6 \) V/m.

Estimation of the rupture values of voltage and electric field strength makes it possible to estimate the limits of the maximum permissible modes of exposure on the seeds during treatment. These values are necessary for the design of plants and optimization of treatment modes.

If we take a margin of strength as 50 %, then the maximum permissible effective voltage for treatment in the plant, measured at a frequency of 50 Hz for a layer thickness of 50 mm, is calculated according to the formula:

\[
U_{\text{before rupture}} = \frac{1}{\sqrt{2}} \left( \frac{U_{\text{of rupture}}}{2} \right),
\]

where \( U_{\text{before rupture}} \) is a voltage before the rupture; \( U_{\text{of rupture}} \) is a rupture voltage.

\( U_{\text{before rupture}} \) is 17.7 kV, i.e. big enough.

It is established experimentally that a positive effect in increasing the seeds sowing qualities can be also achieved at very low PEF voltages equal to 200 V.

For comparison of transient electrical processes in the activator with the results of mathematical modeling, some direct measurements of the durations of charging and discharging of the activator volume are important. The experiment was carried out on onion seeds 50 mm thick and with the amplitude of voltage pulses of 200 V. The measurements were carried out with the classic oscillographic method. To reduce the voltage magnitude and compensate the output capacity of the oscillograph, which is \( \approx 25 \text{ pF} \), a standard high-voltage divider ("probe") with a division ratio of 1:10 was used. Measurements made using oscillograms gave front and slice durations \( \approx 1500 \text{ ns} \).

**4. Conclusions**

The conducted experiment resulted in the following conclusions:

- experimentally obtained values of dielectric permittivity (electrical capacity of a seed layer), as well as its leakage resistance, were used to simulate the electrical modes of the activator;
- measurements results show substantially identical values of the activator capacity for both equivalent circuits;
- a significant decrease in the resistance of an onion seed layer at high voltages on the electrodes of the activator capacitor is found, which can be explained by an increase in seed leakage currents;
- estimation of rupture values of the voltage and the electric field strength makes it possible to estimate the limits of the maximum permissible modes of exposure on the seeds during treatment. These values are necessary for the design of plants and the optimization of treatment modes.
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