Surface barrier discharge pre-sowing treatment of winter wheat seeds in a three-electrode arrangement with dc bias

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Abstract. In the present work, the experimental results of reaction of morphological indicators (sprout and root length, number of roots, 3-day germination) of seedlings of high quality winter wheat seeds treated by plasma byproducts in the three-electrode system of surface dielectric barrier discharge with dc bias on the third electrode in humid air of atmospheric pressure at different polarity of the bias voltage are shown. The treatment was carried out for 15 min in a strip electrode system (eight 1 mm width strips with 4 mm distance between them, a sinusoidal voltage of 2.7 kV (rms) with a frequency 23 kHz) made on a corundum ceramic barrier (1 mm thickness) with the additional third electrode which is a stainless steel grid distant 10 mm from the surface of the dielectric barrier. Direct-current bias of 8 kV of positive or negative polarity was applied to the third electrode. Seeds were located on the surface of the third electrode. The treatment was also carried out with vibration of the system (the imitation of seeds movement along the third electrode). It is shown that the efficiency of treatment depends on the month of carrying it out. It was succeeded to get a reliable stimulation with weak control. With strong control (potential sowing months) it was not obtained. The imposing of dc bias in any considered case is less efficient than plasma products affection without bias. The vibration of electrode system leads to seeds damage during the treatment and notable germination reduction.

1. Introduction

A surface dielectric barrier discharge (SDBD) in the air of atmospheric pressure is a complicated dynamic system due to combination of electric, chemical and hydrodynamic processes depending not only on dimensional and time conditions, but also on prehistory of discharge processes. The imposition of a constant electric field on the SDBD area makes it possible to separate charged particles drifting close to the dielectric barrier after passing through series of microdischarges. It means that at the each polarity of alternating (pulse) supply voltage the discharge transfers ions, which are captured by the dc bias field and create an electric current.

Technologically, the imposition of dc bias allows using of SDBD electrode system as ion charging system, for example. Even a small (60–80 V/cm) electric field of bias saturates the air with aero ions and increases the efficiency of plasma interaction with solutions. The use of a liquid as an additional electrode allows accumulating various products of chemical reactions...
and nanoparticles in it. The imposition of dc bias could also give significant effect during pre-sowing treatment of various seeds with SDBD plasma products as an improvement of their sowing qualities. This is due to the fact that additional constant electric field strength may significantly change motion of charged particles in the gap and the nature of near surface interactions in the layer of seeds.

The third electrode with dc bias (in addition to the first corona electrode and the second reverse (grounded) electrode) is called an extraction electrode or collector electrode. It is located under dielectric barrier surface and forms quasi uniform electric field with reverse electrode of SDBD electrode system.

The treatment of seeds in the three-electrode system allows maximize number of factors due to electric field bias. For classic two-electrode system, the efficiency of SDBD plasma products effect is shown for seeds of a large number of cultivated plants [1], including wheat. For this crop, within up-to-date research, a significant range of methodological issues on the low-temperature plasma products effect has been solved. For example, in paper [2] is shown that SDBD plasma effect on wheat seeds is well expressed even after subsequent chemical seed treatment (rinse in a 70% alcohol solution for 2 min). In paper [3] is estimated how the time of delay between plasma treatment and the beginning of germination effects on treatment results. It should be noted that among other crops winter wheat is the most responsive to the treatment [4], what is probably related with the activity of antioxidant system.

The purpose of this work is investigation of seedlings reaction of winter wheat seeds treated by plasma products in SDBD three-electrode system with dc bias on the third electrode in humid air of atmospheric pressure at different polarity of the bias voltage.

2. The experimental setup
The experimental setup scheme is represented in figure 1. Three-electrode SDBD system was put in a plastic air duct installed on a vibrating table. In the air duct was created an air flow for ozone entrapping. The vibration of the system imitated seeds movement along the extraction
Figure 2. Data on control seedlings (without treatment) depending on the month of evaluation: the number of seedlings examined for (a) the sprout length, (b) the total length of root system and (c) the number of roots estimation are shown in brackets after the months; for (d) germination, the number of experimental sets is indicated.

3. Results and discussion

Figure 2 shows the results of measuring the morphological indicators of control seedlings obtained in different months of 2018.

The estimation was carried out for four months: June, July, August and October. Closer to the autumn months, the control plants become stronger, probably, due to the reaching of optimal sowing months and effective selection work with the variety. This is reflected in the increase of sprout and root system length. Thus, two groups of seedlings with significant differences between the control batches treated in June and July were distinguished.

In figure 3, the results of morphological tests of seedlings obtained from seeds treated with surface dielectric barrier discharge in the three-electrode system without bias voltage (SDBD), with positive (SDBD+dc) or negative (SDBD−dc) constant bias of 8 kV are summarized. With a weaker control (June), the effect of SDBD plasma treatment appears reliably both in sprout...
Figure 3. The influence of positive dc bias (+dc) and negative dc bias (−dc) on efficiency of SDBD treatment of seeds revealed by estimation of morphological indicators: (a) the sprout length; (b) the total length of root system; (c) the number of roots; (d) germination.

length and total length of root system. On morphological indicators treatment with dc bias does not provide advantages over the control variant. With a stronger control (July) with dc bias, a tendency is observed with the sprout length inhibition and the germination of treated seeds decrease.

The vibrating table is a part of the experimental setup. The vibration of the system imitated seeds movement along the third electrode during flow treatment by SDBD plasma products. Seeds were mixing in the layer, contacted with the surface of the barrier and for a while with
Figure 4. The effect of vibration of the electrode system upon the results of morphological tests: (a) the sprout length; (b) the total length of root system; (c) the number of roots; (d) germination.

the corona electrode. The results of morphological tests of seedlings obtained from seeds treated in the electrode system with dc bias and vibration (+V) are shown in figure 4. The effect of vibration on the control variant and the variant without dc bias (SDBD) is not shown on the histograms, because it was not observed for all estimated indicators.

An analysis of the sprout length does not show differences between variants with and without vibration, with the exception of a noticeable expansion of confidence intervals in variants with
vibration. In case of the root system length, there is a tendency to length increase in the variants with vibration. It is associated with a noticeable germination decrease in these variants, the most significant (up to 50%) for negative dc bias. Probably, a significant germination decrease is result of short-circuiting the gap between the corona and reverse electrodes by the seeds during vibration from time to time. A pulse current flows along the surface of the seed coat and causes internal damage.

4. Conclusions
The experimental results of this work lead to the following conclusions:

- The efficiency of treatment of winter wheat depends on the calendar month of carrying it out. With a stronger control no positive effect on morphological indicators under considered modes of treatment was observed.
- The imposition of dc bias of any polarity decreases the efficiency of SDBD plasma products effect on the germination of winter wheat seeds.

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