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INFLUENCE OF WIDE-APERTURE ROTATING GLIDING DISCHARGE ON SUNFLOWER SEED GERMINATION

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The results of the study of the influence of wide-aperture rotating gliding discharge on the germination of sunflower seeds under different conditions are presented. The emission spectra of the plasma torch of DC wide-aperture rotating gliding discharge are investigated. Vibrational T_v and rotational T_r temperatures of plasma inside the torch at the outlet of the discharge chamber were determined. The dependences of the percentage of germination of sunflower seeds germinated under favourable (sufficient amount of sunlight) and unfavourable conditions (insufficient amount of sunlight) on the 10th and 20th day after planting at different time intervals of treatment with a wide-aperture rotating gliding discharge were investigated. The optimal treatment time was determined.

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INTRODUCTION

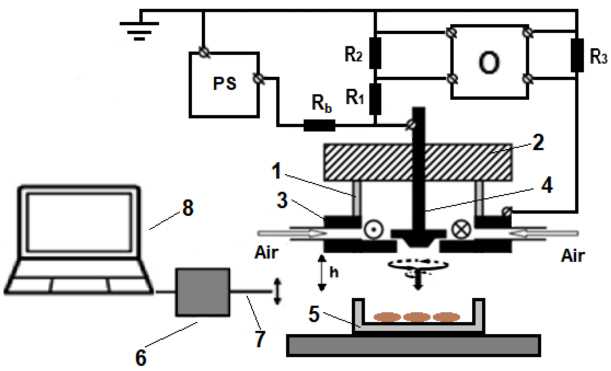
One of the goals of sustainable development is to eliminate world hunger [1, 2]. The ways to achieve this goal include increasing the yields of existing crops, using existing fertile land more efficiently, and establishing and supporting small farms. Several factors can negatively affect crop yields, such as pests and unfavourable weather conditions. Fungi on cereal seeds can affect the quality of the crop and cause spoilage and damage to the embryos during storage. They can infect food grains, producing toxins that cause diseases in humans or animals using these grains as food [3].

One method to prevent fungi's negative impact on plant growth and storage is plasma treatment [4]. Nonequilibrium atmospheric pressure plasma has many applications in various fields, such as surface treatment, combustion enhancement, bacterial inactivation [4-6], and contamination reduction [7]. Plasma is an effective sterilization method and can be used for seed disinfection as an alternative to chemicals [8]. One of the sources of nonequilibrium atmospheric pressure plasma can be a rotating gliding discharge [9-12].

This work is devoted to studying the effect of wide-aperture rotating gliding discharge on the germination of sunflower seeds.

1. EXPERIMENTAL SETUP AND METHODOLOGY

Fig. 1 shows a schematic representation (see Fig. 1,a) and a photo (see Fig. 1,b) of a plasma system with a wide-aperture rotating gliding discharge designed for treating sunflower seeds before planting. The discharge chamber consisted of a quartz tube (1) with an inner diameter of 36 mm, closed from above by a dielectric kaprolon (polycaproamide) flange (2) and from below by a stainless-steel flange (3). A T-shaped stainless-steel high-voltage electrode (cathode) (4) was mounted in the middle of the kaprolon flange. The stainless-steel flange (anode) was grounded and had a 20 mm diameter hole in the middle. The distance between the electrodes was 1 mm.



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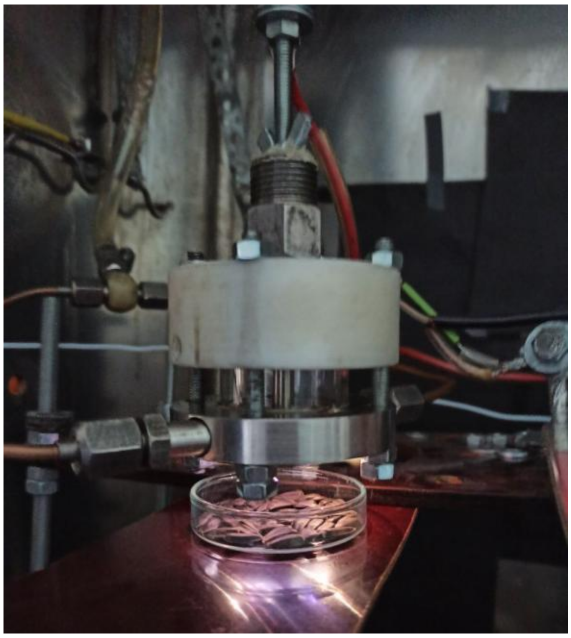

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Fig. 1. Schematic representation (a) and photo (b) of plasma system with rotating gliding discharge designed for treating sunflower seeds before planting

The wide-aperture rotating gliding discharge was powered by a BP-100 power supply unit, which, together with the 33 kΩ ballast resistance R_b, provided a voltage of up to 7 kV at the discharge gap. Voltage and current oscillograms were measured by an oscilloscope (O) using a voltage divider made of resistors R_1 and R_2 (R_1:R_2 = 1000:1) to measure the discharge voltage and a 10 Ohm shunt resistance R_3 to measure the discharge current.

During the experiment, the atmospheric air was the plasma gas. Air was supplied to the discharge chamber using a Fiac Cosmos compressor. The airflow was controlled using a Dwyer RMA-22 SSV rotameter [13]. It was introduced through an inlet made in the metal flange into the discharge chamber tangentially to the quartz tube's side wall, forming a vortex flow. The air introduced into the discharge chamber was used to generate plasma containing chemically active ions, free radicals, and excited particles. The resulting components moved via the torch of a rotating gliding discharge to a Petri dish (5) containing sunflower seeds.

Optical emission spectroscopy of plasma radiation was carried out using a Solar TII S-150-2-3648 USB spectral device (6) and an optical fibre (7) installed at a distance *h* from the bottom surface of the metal flange. The light guide was oriented along the beam of vision parallel to the surface of the metal flange. Emission spectra were processed using a PC (8). The obtained optical emission spectra were used to determine the rotational and vibrational temperatures of hydroxyl (OH) inside the plasma. The temperatures were determined by comparing the experimental optical emission spectra with the spectra simulated using the SpecAir 2.2 program [14]. More information about this method and the obtained temperatures is available in our previous works [9-11].

Before the treatment with wide-aperture rotating gliding discharge, sunflower seeds were placed in a Petri dish, as shown in Fig. 2. The Petri dish was placed under a plasma system with a wide-aperture rotating gliding discharge. The distance from the lower plane of the metal flange (anode) to the bottom of the Petri dish was 20 mm. This distance was chosen to avoid thermal damage to the seeds. The operating mode for the seed treatment had a discharge current set to I_d = 60 mA and airflow into the discharge chamber G_d = 10 l min^{-1}. The seed treatment time varied from 0 to 8 minutes with a step of 2 minutes. After treatment with a wide-aperture rotating gliding discharge, the seeds were planted in special containers with soil-filled cells (Fig. 3). Control group of untreated seeds was also planted in the containers alongside treated seeds. Only one sunflower seed was planted into each cell. Seeds from one treatment batch were planted in two containers, one installed in a well-lit area of the laboratory and the other in a poorly lit area. These two regimes for sunflower seed germination were chosen to test the effect of plasma on the germination of seeds planted under adverse conditions (cloudiness, smoke, etc.). Sunflower seed germination was monitored 10 and 20 days after planting.

Fig. 2. Photo of sunflower seeds placed in Petri dish before treatment with wide-aperture rotating gliding discharge

Fig. 3. Photo of typical container with soil-filled cells in which both untreated and treated with wide-aperture rotating gliding discharge sunflower seeds were planted

2. RESULTS AND DISCUSSION

A typical plasma emission spectrum of a wide-aperture rotating gliding discharge is shown in Fig. 4. The emission spectrum includes bands of such components as hydroxyl OH, nitric oxide NO and nitrogen N_2. The main components in the emission spectrum are hydroxyl OH and nitrogen N_2. Nitrogen is the main component of air, and hydroxyl can be formed from water vapour (H_2O), which is also present in the atmospheric air. By comparing the experimentally measured optical emission spectra with the ones simulated using the SpecAir 2.2 program [14], the rotational and vibrational plasma temperatures were determined from the hydroxyl OH bands (T_r = (2500 ± 200) K, T_v = (4000 ± 500) K). More detailed results of optical emission spectroscopy of the plasma of a wide-aperture rotating gliding discharge under different operating modes can be found in previous works [10, 11].

Under the influence of airflow, the current channel rotates, and the ends of the current channel glide along the surface of the T-shaped electrode (cathode) and the metal flange (anode). As a result of this movement, specks corresponding to cathode spots are observed on the cathode surface (Fig. 5).

Fig. 6 shows the photo of sunflower seeds germinated under favourable conditions on the 10th, 20th and 30th day after planting.

Fig. 7 shows the percentage of germination of sunflower seeds germinated under favourable conditions on the 10th and 20th day after planting relative to the number of planted seeds. The most optimal treatment time for sunflower seeds germinating in favourable conditions (sufficient sunlight) was 2 and 4 min on the 10th day. As of the 20th day, the most optimal time is 2 min at which all seeds have germinated. As of the 20th day after planting, the germination was better in sunflower seeds treated with wide-aperture rotating gliding discharge compared to the untreated seeds.

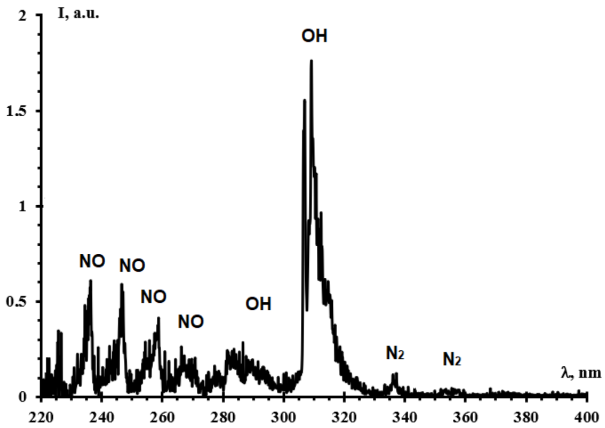


Fig. 4. Typical emission spectrum of plasma of wide-aperture rotating sliding discharge at discharge current I_d = 60 mA, airflow into discharge chamber G_d = 10 l/min^{-1}

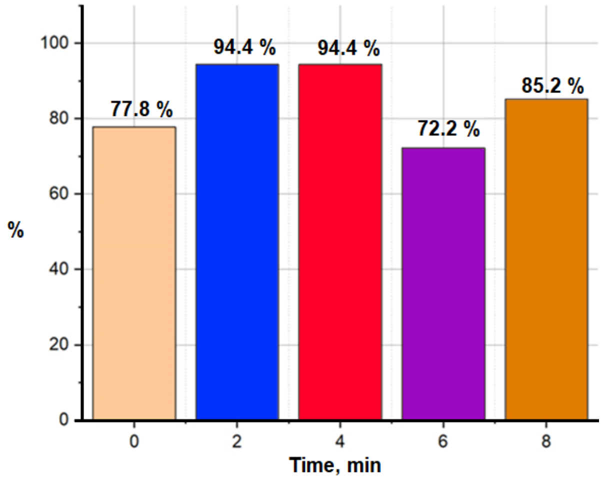
Fig. 5. Typical photo of T-shaped cathode after long-term operation

a

b

c

Fig. 6. Photo of sunflower seeds germinated under favourable conditions on the 10th (a), 20th (b) and 30th (c) day after planting



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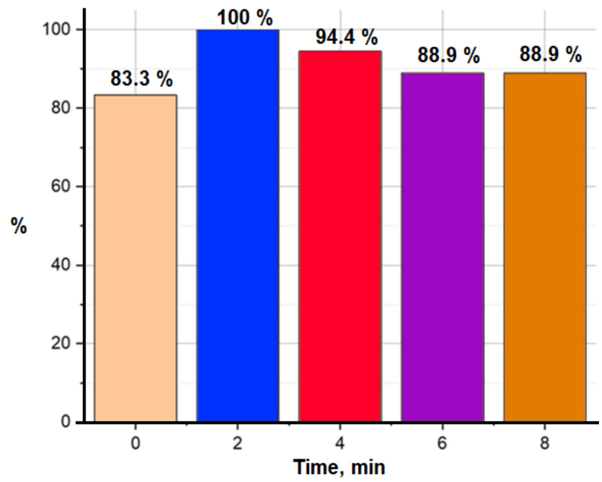

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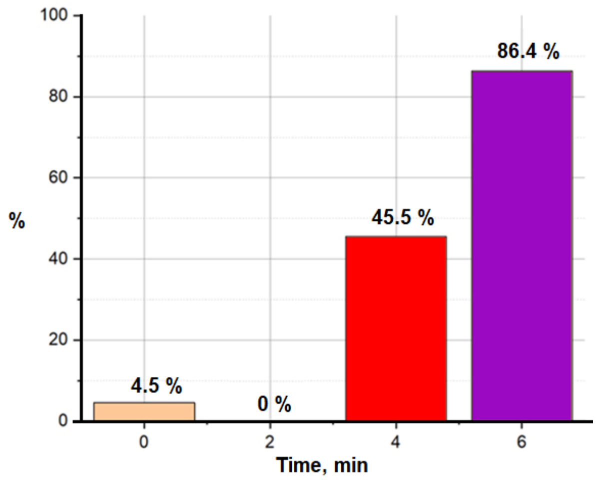
Fig. 7. Dependence of percentage of germination of sunflower seeds germinated under favourable conditions on 10th (a) and 20th (b) day after planting relative to number of seeds planted for different modes of operation: 0 (control), 2, 4, 6, 8 min



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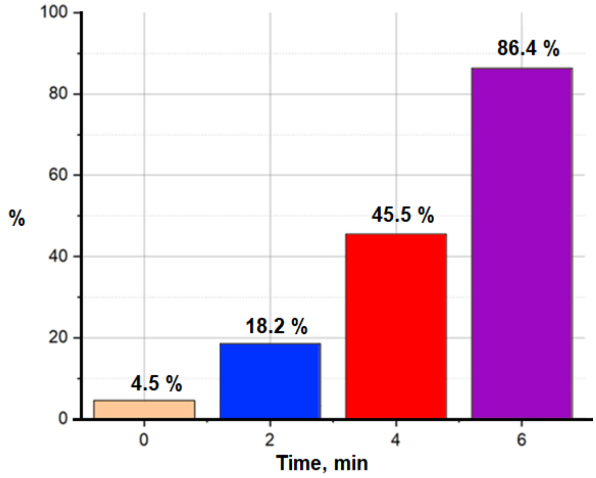

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Fig. 8. Dependence of percentage of germination of sunflower seeds germinated under unfavourable conditions on 10th (a) and 20th (b) day after planting relative to number of seeds planted for different modes of operation: 0 (control), 2, 4, 6, 8 min

Fig. 8 shows the percentage of germination of sunflower seeds growing under unfavourable conditions on the 10th and 20th day after planting relative to the number of planted seeds. In this case, germination occurred under unfavourable conditions (insufficient sunlight). As of the 20th day, the germination percentage of seeds that were treated with a wide-aperture rotating gliding discharge for 6 min ang germinated under unfavourable conditions coincided with the germination percentage of the untreated seeds germinated in favourable conditions. For the shorter treatment times and the control group, the observed germination percentage was very small. In the case of insufficient sunlight, the percentage of germination of sunflower seeds rises with the increase of treatment time. The observed results show that it is better to treat sunflower seeds with wide aperture rotating gliding discharge before planting.

These findings can have a significant impact on the agricultural sector, as the described method of treatment is independent of logistics (all that is needed is air and electricity), does not require the purchase of pesticides and improves seed germination even in case of changing weather conditions when plants do not receive enough sunlight. Also, this method reduces harmful emissions into water (chemical industry waste) and air (waste from transportation), which, together with independence from the delivery of chemical treatments, is extremely important.

CONCLUSIONS

The influence of wide-aperture rotating gliding discharge on the germination of sunflower seeds under favourable conditions (sufficient amount of sunlight) and unfavourable conditions (insufficient amount of sunlight) was investigated.

As of the 20th day after planting sunflower seeds under favourable conditions, the germination of sunflower seeds treated with a wide-aperture rotating gliding discharge is better for all processing times (in the range of 2 to 8 min) compared to untreated seeds. The optimal treatment time with a wide-aperture rotating gliding discharge for germination under sufficient sunlight is 2 min.

The percentage of germination of sunflower seeds under unfavourable conditions (lack of sunlight) increases with the longer treatment time (in the range from 0 to 6 min) using a wide-aperture rotating gliding discharge. For actual unpredictable weather conditions (insufficient sunlight), it is better to treat the seeds with a wide-aperture rotating gliding discharge just before planting. The positive effect of treatment may stem from stimulation of germination in sunflower seed by the plasma of wide-aperture rotating gliding discharge.

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ВПЛИВ ОБЕРТОВОГО КОВЗНОГО РОЗРЯДУ НА ПРОРОСТАННЯ НАСІННЯ СОНЯШНИКА

О.А. Недибалюк, Л.Ю. Мордвінцева, І.І. Федірчик, М.С. Марущак, Д.Л. Чернолуцький

Представлені результати дослідження впливу широкоапертурного обертового ковзного розряду на проростання соняшникового насіння за різних умов. Досліджено емісійні спектри плазми факелу широкоапертурного обертового ковзного розряду постійного струму. Визначено температури (коливні T_v та обертові T_r) плазми факелу на виході з розрядної камери. Побудовано залежності відсотку проростання насінин соняшника за сприятливих (достатня кількість сонячного світла) та несприятливих (недостатня кількість сонячного світла) умов на 10- та 20-й день після висадження за різних проміжків часу обробки широкоапертурним обертовим ковзним розрядом. Визначено найбільш оптимальний час обробки.