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

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The results of the study of the influence of wide-aperture rotating gliding discharge on the germination of microgreen seeds under different conditions are presented. Vibrational T_v and rotational T_r temperatures of wide-aperture rotating gliding discharge plasma were determined. The dependences of the germination percentage of microgreen seeds germinated after planting at different time intervals of treatment with a wide-aperture rotating gliding discharge were investigated. The optimal treatment time of microgreen seeds by wide-aperture rotating gliding discharge was determined.

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INTRODUCTION

To eliminate world hunger [1, 2] is one of the goals of sustainable development. 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].

To prevent fungi's negative impact on plant growth and storage is a method of plasma treatment [4]. Atmospheric pressure plasma has many applications in various fields, such as surface treatment, combustion enhancement, bacterial inactivation [4–6], and contamination reduction [7]. Nonequilibrium 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 [9–13].

This work is devoted to studying the effect of wide-aperture rotating gliding discharge on the germination of microgreen seeds (Lepidium sativum).

1. EXPERIMENTAL SETUP AND METHODOLOGY

Fig. 1 shows a schematic representation of a plasma system with a wide-aperture rotating gliding discharge designed for treating microgreen 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 (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 dielectric 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. 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 Ω 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 [14]. 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 (5) of a rotating gliding discharge to a glass table (6) containing microgreen seeds (7).

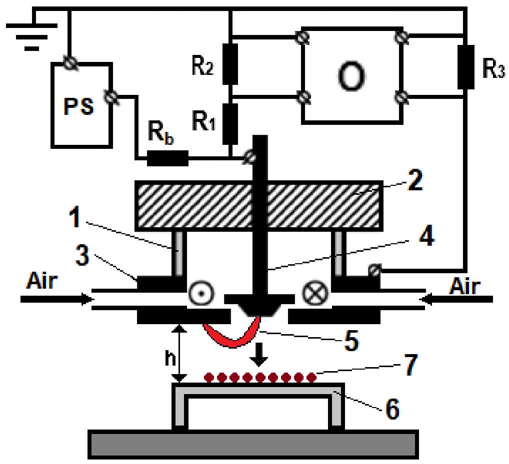
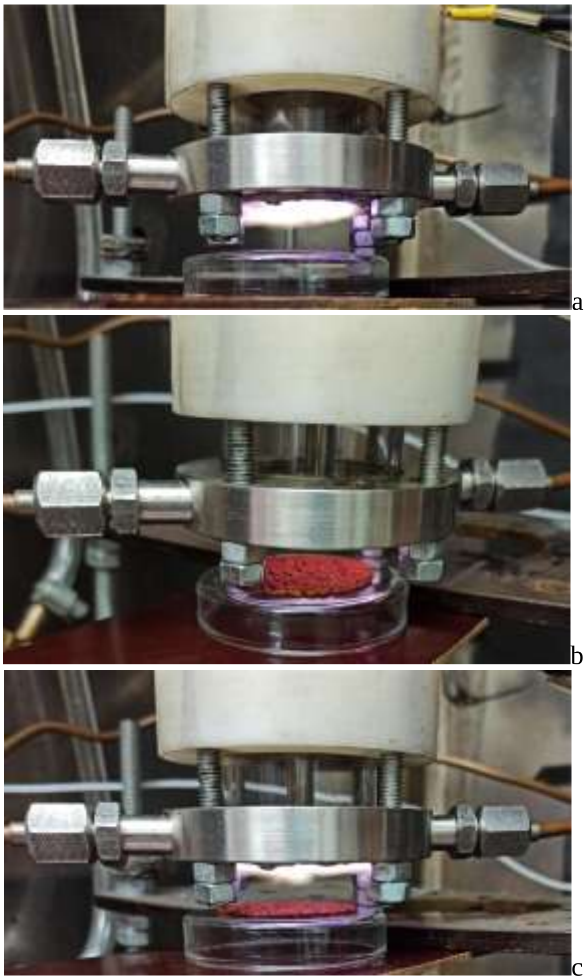


Fig. 1. Schematic representation of plasma system with wide-aperture rotating gliding discharge designed for treating microgreen seeds before planting

Optical emission spectroscopy of plasma radiation was carried out using a Solar TII S-150-2-3648 USB spectral device and an optical fibre installed at some distance from the bottom surface of the metal flange. Emission spectra were processed using a PC.



a

b

c

Fig. 2. Photos of plasma system with wide-aperture rotating gliding discharge designed for treating microgreen seeds before planting from different angles

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

A typical plasma emission spectrum of a wide-aperture rotating gliding discharge 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. Hydroxyl can be formed from water vapour (H_2O), which is present in the atmospheric air, and nitrogen is the main component of air. By comparing the experimentally measured optical emission spectra with the ones simulated using the SpecAir 2.2 program [15], the rotational and vibrational plasma temperatures were determined from the hydroxyl OH bands ($T_r = (2500 \pm 200)$ K, $T_v = (4000 \pm 500)$ 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, 11,13].

Fig. 2 shows a photo of a plasma system with a wide-aperture rotating gliding discharge designed for treating microgreen seeds before planting. Before the treatment with wide-aperture rotating gliding discharge (see Fig. 2,a), microgreen seeds were placed in a glass table (see Fig. 2,b). The glass table 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 glass table was 15 mm (distance was chosen to investigate possible thermal damage to seeds) and 25 mm (distance was chosen to avoid thermal damage to the seeds). The operating mode for the microgreen seeds treatment had a discharge current set to $I_d = 60$ mA and airflow into the discharge chamber $G_d = 10\ L{\cdot}min^{-1}$. The seed treatment time varied from 0 to 180 s. After treatment with a wide-aperture rotating gliding discharge, the microgreen seeds were planted in special containers with soil-filled cells (Fig. 3). Control group of untreated microgreen seeds was also planted in the containers. Eleven cells were used for each treatment time. Fifteen microgreen seeds were planted into each cell. Microgreen seeds germination was monitored 5 days after planting.

2. RESULTS AND DISCUSSION

Fig. 4 shows the photo of microgreen seeds germinated on the 1st and 5th day after planting. Fig. 5 shows the percentage of germination of microgreen seeds on the 5th day after planting relative to the number of planted seeds at the distance 15 mm (see Fig. 5,a) and 25 mm (see Fig. 5,b) from the lower plane of the metal flange (anode) to the glass table for seeds.

The most optimal treatment time of microgreen seeds for the distance 15 mm (see Fig. 5,a) from the lower plane of the metal flange (anode) to the glass table for seeds was 30 s. The germination percentage of seeds that were treated with a wide-aperture rotating gliding discharge for treatment time range of 0…30 s was increased under the treatment time increasing.

In the treatment time range of 60…180 s germination percentage of seeds was decreased compared to the untreated seeds. No seeds germinated during discharge treatment for 180 s. In the time range of 0…30 s, the seeds were disinfected and their germination stimulated. In the treatment time range of 60…180 s, in addition to disinfection and stimulation of germination, a mechanism of thermal effect on seeds occurs, which suppresses germination and damages seeds. Therefore, the number of seeds that germinate decreases.

a

b

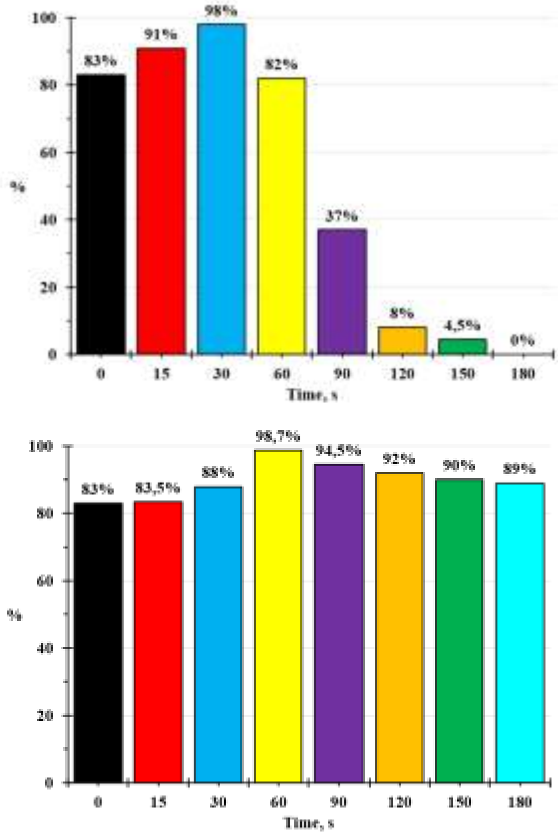
c

Fig. 4. Photo of microgreen seeds on the 1st (a) and 5th (b, c) day after planting:
b – the sunlight lamp is off;
a, c – the sunlight lamp is on

Fig. 5,b shows that the germination percentage of seeds that were treated with a wide-aperture rotating gliding discharge for treatment time range of 0…60 s, also observed a section of germination percentage of seeds increasing under the discharge treatment compared to the untreated seeds. The most optimal treatment time of microgreen seeds for the distance 25 mm from the lower plane of the metal flange (anode) to the glass table for seeds was 60 s. For the treatment time range of 60…180 s the germination percentage of seeds that were treated with a wide-aperture rotating gliding discharge, also observed a section of germination percentage of seeds decreasing under the influence of a discharge, but it was not less than in the case of untreated seeds. This may be due to the fact that the thermal effect of the discharge was present, but it was less due to the greater distance between seeds and discharge (anode).

Increasing the distance between discharge (cathode of plasma system) and seeds from 15 to 25 mm leads to increasing treatment time at the same discharge power. To improve energy efficiency, it is necessary to investigate the optimal distance between discharge and seeds. In addition, taking into account the results obtained in previous studies [13], it is also necessary to take into account the seeds size.

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. 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.



a

b

Fig. 5. Dependence of percentage of germination of microgreen seeds on the 5th day after planting relative to the number of planted seeds at the distance from the lower plane of the metal flange (anode) to the glass table 15 mm (a) and 25 mm (b) for different modes of operation: 0 (untreated seeds), 15, 30, 60, 90, 120, 150, 180 s of treatment

CONCLUSIONS

The influence of wide-aperture rotating gliding discharge on the germination of microgreen seeds for different treatment time and different distance between discharge and seeds was investigated.

The most optimal treatment time of microgreen seeds for the distance 15 mm from the lower plane of the metal flange (anode) to the glass table for seeds was 30 s and for the distance 25 mm – 60 s at the same discharge power.

The dependence of the percentage of seed germination, which was treated with a wide-aperture rotating gliding discharge, on the treatment time has two area. In the first area, during short treatment times, seeds disinfection and germination stimulation was dominate. In the second area, with longer treatment times, the thermal effect of the plasma of the wide-aperture rotating gliding discharge begins to dominate, which decreased percentage of seed germination. The dominance of the thermal effect occurs faster when microgreen seeds is closer to the discharge.

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ВПЛИВ ШИРОКОАПЕРТУРНОГО ОБЕРТОВОГО КОВЗНОГО РОЗРЯДУ НА ПРОРОСТАННЯ НАСІННЯ МІКРОЗЕЛЕНІ

О.А. Недибалюк

Представлено результати дослідження впливу широкоапертурного обертового ковзного розряду на проростання насіння мікрозелені за різних умов. Визначено коливну T_v і обертову T_r температури плазми широкоапертурного обертового ковзного розряду. Досліджено залежності відсотка схожості насіння мікрозелені, яке проросло після висадження за різних проміжків часу обробки широкоапертурним обертовим ковзним розрядом. Визначено оптимальний час обробки насіння мікрозелені широкоапертурним обертовим ковзним розрядом.