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Effect of negative corona discharge on the contamination of sunflower seeds

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Studies of the influence of negative corona discharge on the contamination of sunflower oilseeds have been conducted. Treatment of seeds of this crop with cold plasma corona discharge helps to reduce their infection with fungi that cause plant diseases. As the duration of exposure increases, the effectiveness of cold plasma increases. With an exposure of 180 and 240 minutes, the negative corona reduced the rust contamination of medium-sized sunflower seeds by 100 %, but was ineffective on large ones.

Keywords: corona discharge; sunflower seeds; infestation; germination; disinfection; fungal diseases.

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Introduction

To combat fungal diseases of sunflower (such as rust – *Puccinia helianthi* Schwein., *Phomopsis* – *Diaporthe helianthi* (*Phomopsis helianthi*) Muntañola-Cvetković, Mihaljcevic & Petrov. white rot (*Sclerotinia rot*) – *Sclerotinia sclerotiorum* (Lib.) de Bary, gray rot – *Botrytis cinerea* Pers. ex. Fr. and many others), seed treatment with chemicals is commonly used. Widespread use of pesticides in agriculture is known [1] to have led to environmental problems – environmental pollution and deterioration of human health. The trend toward production of healthy organic products has been growing and requires the greening and biologization of agricultural technologies. Papers [2, 3] show that plasma has a sterilizing effect on fungi, bacteria, and viruses. Its application does not harm the natural environment, humans, or animals, is more economically beneficial than the use of chemical or natural fungicides, and represents a promising direction for the greening and biologization of agricultural production.

Cold plasma treatment has been evaluated in various studies as a successful technology for surface contamination and seed germination stimulation [3, 4]. Our research has established that low-temperature plasma has a decontaminating capability, for which reason this property needs more thorough investigation to determine the optimal application parameters for greening the preparation of field crop seeds for sowing [5–8]. The effects of corona discharges on the surface of winter wheat and barley seeds were examined in our papers [6–8]. Exposure to positive and negative corona has been shown to reduce fungal disease infection in a number of cases, which indicates that use of corona discharges for grain disinfection can be promising. This paper continues those studies [6–8]. It investigates the impact of a negative corona discharge on the overall infection level of sunflower seeds. Such studies have not been conducted previously, although the need to explore methods for affecting fungi on sunflower seeds was indicated in paper [1]. The choice of a negative corona is based on experiments [6–8]

which demonstrated that fungi are eradicated by a negative corona more intensively than by a positive one.

Experimental unit

This study utilized the same setup described in papers [7, 8], which presents the schematic diagram and photographs of the setup used to study the effect of a corona discharge on fungal diseases. It consists of a cuvette filled with the substance under study and an electrical circuit. The upper electrode assembly of 19 needles (with a tip radius of 0.4 mm) was positioned 8 mm above the grain surface. The space between electrodes in the multi-electrode configuration was 11 mm. The electrodes were under the negative voltage. The cuvette was dielectric, with a metal electrode at its bottom, cylindrical, with a cuvette diameter of 90 mm, the treated area equaled to 6400 mm², and the cuvette height was 18 mm. To treat the substance in the cuvette more uniformly, an electric motor was used to mix grains in the vertical plane. The grain mass in the cuvette was 70 g in all cases. Grains in the cuvette formed approximately 12 layers. Each layer contained 98–100 grains, with a layer weight of about 6 g. A DC power supply was used; the voltage in the experiment varied within $U = 8\text{--}10\text{ kV}$, and the current varied within $I = 20\text{--}100\text{ }\mu\text{A}$.

Measurement results

The table presents data on the time dependence of average parameters of the negative corona discharge. The table shows that discharge parameters changed during measurements, which was due to the inconstancy of current and voltage magnitude at the discharge. At the same time, the amount of energy deposited into the grain changed by an average of 30 % for treatment durations of 3 and 4 hours.

Table

Time dependence of average parameters of the negative corona discharge

Time	1 h	2 h	3 h	4 h
Voltage, kV	8	8.7	8.7	8.6
Current, μA	6.5	8.3	9.1	5

Sunflower seeds were monitored for inspection extent according to the procedures

developed by the Federal State Budgetary Institution “All-Russian Center for Plant Quarantine” FSBI “VNIKR” and outlined in their methodological recommendations 67-2021, using the “Plant Disease Identification Guide” [9]. Seeds were placed in Petri dishes sterilized in an autoclave, with two layers of sterilized filter paper moistened with water that had been boiled for 30 minutes in a closed flask (or sterilized). Seed germination was carried out in a thermostat at a temperature of 22–23 °C. After 10 and 14 days, the infection of sunflower seeds was determined using a microscope. Tests were performed for all major fungal diseases of sunflower. It was established that the seeds were infected only with rust.

After the exposure during 180 and 240 minutes, the negative corona contributed to complete disinfection of medium-sized seeds (weight of 1000 seeds – 55.8 g) of oilseed sunflower from rust and had no effect on this disease in large seeds (weight of 1000 seeds – 79.7 g). Our experiment did not reveal any provable effect of decontamination by cold plasma on large sunflower seeds. This is most likely related to the thickness of the seed coat and the degree of seed plumpness (Seed plumpness refers to the degree of its maturity and filling, the completion of synthesis processes for the substances constituting the mature seed). In the case of small and medium-sized sunflower seeds, their seed coat is thin and smooth, whereas in the case the seed coat of large seeds is denser and ribbed.

According to the results, plasma ions and active particles generated in the corona discharge do not manage to penetrate the thickened seed coat of sunflower seeds during the treatment time. Therefore, the treatment time or, correspondingly, the setup power becomes important when the corona discharge plasma is used. When small and medium-sized sunflower seeds are treated, the discharge voltage can be increased to 20–25 kV, which would halve the grain treatment time.

Another important factor is the seed coat thickness. The use of corona discharge plasma is only effective in the case of thin seed coats. It should be noted that our experience of working with wheat and barley grain shows that the results of treatment with a negative corona are better than with a positive corona. This is primarily related to the different molecular composition of

the plasma, as in the negative corona plasma, more negative atomic oxygen ions O^- and oxygen atoms O are produced via dissociative sticking of electrons e to oxygen molecules O_2 ($e + O_2 \rightarrow O + O^-$) [10]. These particles are converted into ozone molecules O_3 in the reactions $O^- + O_2 \rightarrow e + O_3$ и $O + O_2 + N_2 \rightarrow O_3 + N_2$ [10], which enhance the sterilizing effect of the grain surface.

Conclusion

The treatment of oilseed sunflower seeds with cold corona discharge plasma contributes to

significant reduction of their infection with rust (*Puccinia helianthi* Schwein). As the exposure duration increases, the effectiveness of cold plasma application improves. After the exposures during 180 and 240 minutes, the negative corona led to complete (100%) disinfection of medium-sized sunflower seeds from the rust germ and had no decontaminating effect on large sunflower seeds. To use corona discharge for treating sunflower seeds, varieties with a thin seed coat should be selected. When considering the impact of cold plasma on potato seeds, there is no difference from treating sunflower grain and potato seeds.

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