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Ozonizers For Agricultural Problems and Their Use in Pre-Sowing Treatment of Cotton and Other Crops

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Annotation: The article presents the results of studies of the effect of ozone treatment on the sowing qualities of seeds, including cotton. The parameters of the developed corona discharge ozonator with a capacity of up to 10-12 g/h, used for pre-sowing treatment of seeds and solutions, are given. The sowing qualities of seeds were studied depending on the modes of ozone treatment and the optimal effects of ozone were established at a dose of about 22-30 g/ton. A noticeable decrease in the microbial contamination of seeds and the expediency of using pre-sowing ozone treatment are shown.

Key words: Corona discharge, ozone, ozonator, cotton, seeds, pre-sowing treatment, ozone -containing gases

The yield of agricultural crops significantly depends on the quality of the seed and its preparation. According to scientists of seed growers, seeds predetermine the yield level by 30÷35%. High quality seeds provide a noticeable increase in grain yield compared to conventional seeds [1, 2].

Modern technologies for presowing seed treatment include the use of pesticides that stimulate growth processes and reduce pest damage. To date, scientific and practical interest is the search for effective, environmentally friendly methods of influencing seeds in order to increase productivity and product quality, in which the use of pesticides is excluded or reduced to a minimum.

Pre-sowing seed treatment has a positive effect on improving the sowing and yielding qualities of grain crops, allows stimulating biochemical processes in seeds, which increases germination energy and germination, affects the growth and development of plants. One of the promising methods of presowing treatment of seeds is their electric discharge treatment and ozonation [3–6].

The main properties of ozone, methods of its production and application in various industries are well known [7 - 12]. It is known that ozone treatment processes can effectively disinfect, sterilize, and deodorize treated objects. In particular, exposure to ozone can be successfully used for presowing seed treatment. The most promising and encouraging technology for pre-sowing seed preparation is ozone technology. Ozone, as a seed growth stimulator, began to be used in various complex devices that combine the use of magnetic fields for seed treatment with the simultaneous injection of a small amount of ozone already in the mid-80s of the last century. However, in these devices, ozone played a minor role. An analysis of the accumulated data on the effect of ozone on seed growth leads to the conclusion that ozone (O_3), being a strong oxidizing agent, has a complex effect on seeds. Destroyed under the influence of ozone, microbial cells lose a relatively large amount of cellular components that remain on the seeds and serve as a nutrient medium for developing plants. In the future, this leads to the activation of physiological processes directly in the seedlings.

Another advantage of ozone technology is the fact that ozone can be obtained directly at the place of its use from atmospheric air. The advantages of ozone technology should also include the fact that when treated with ozone, no substances are formed in products that have a mutagenic or carcinogenic effect. Over time, ozone technology for pre-sowing treatment may become one of the main technologies used in agriculture [13]. The effect of ozone treatment on cotton has been relatively little studied [14].

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The purpose of the research is to determine the options for the optimal design of the ozone generator and equipment for agricultural tasks, to establish the features of ozone treatment and the modes of pre-sowing treatment of cotton seeds with ozone.

Materials and methods

For the treatment of cotton seeds and other crops, a special ozone generator (generator of ozone -air or ozone -oxygen mixture) on a corona discharge was developed. For the synthesis of ozone, a cylindrical ozone synthesis reactor was used, which has pointed electrodes in the central part under an adjustable high positive potential. The power supply provided positive corona discharge currents up to 10–20 mA at voltages up to 12–20 kV.

The choice of an ozone generator on a corona discharge was associated with the actual conditions for seed treatment with ozone, namely: in the field or in unequipped storage facilities, with increased dust content and air humidity, and a noticeable temperature variation. Under such conditions, the widely used barrier discharge ozone generators operate unstable and quickly fail, as they require air purification, low temperature and low moisture content.

A photograph of the developed corona discharge ozone generator from the front side of the main unit is shown in Figure 1.

Figure 1- Ozone generator for agricultural tasks

In the ozone generator, an alternating mains voltage (220 V, 50 Hz) is supplied to the rectifier and converted to a constant voltage of 12 V. A constant voltage of 12 V is supplied to a high-voltage power supply and is converted by the circuit into a voltage of 12 ÷ 20 kV, which feeds the ozone synthesis reactor. The control device provides a stable output current with a wide range of corona discharge parameters: active resistance, voltage drop in the discharge gap, and operating temperature. The unit contains a temperature and humidity sensor (DHT-21), a single-board computer (raspberry-pi 3B+), a gsm-modem.

If the humidity in the ozonizer operation area exceeds 90%, the ozonator operation is blocked by a relay and an external message is issued about critical environmental conditions. When the humidity drops below 90%, the control system gives permission for the ozone reactor to work. Since the load of the ozonator is a corona discharge in air or oxygen, which easily turns into a spark, and even an arc form of a discharge, the active and reactance of the load can vary over a very wide range.

The hardware of the data collection unit is a temperature and humidity sensor DHT 21 with power elements of the EBP of the ozonator, an electronic-mechanical relay for turning on and off the ozone reactor, a display mounted in the ozonator case to determine its performance and a USB modem (GSM module) connected to a single-board computer raspberry-pi. The components are assembled into a single electronic computing functional unit, which allows:

- control the work-pause time of the ozone synthesis reactor in cyclic and single modes.

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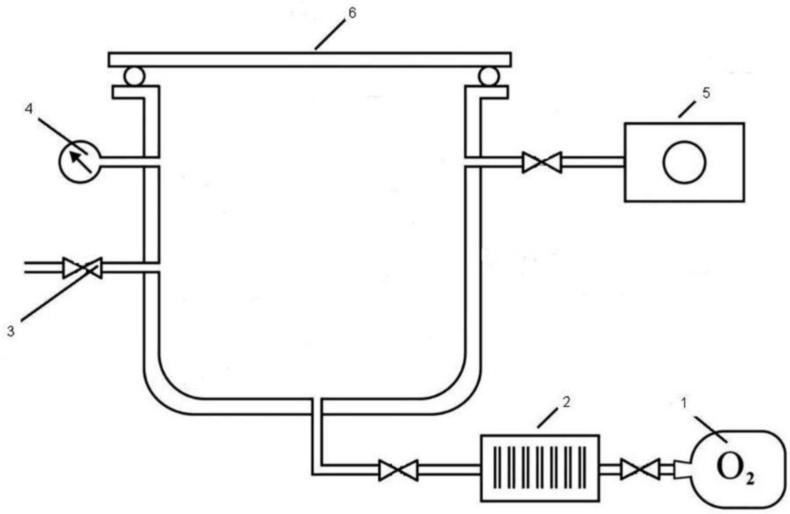
- display the current temperature and air humidity in the ozonator housing locally on the digital display of the device itself and remotely - on the interface for accessing physical resources,
- turn off the power to the reactor at unacceptably high temperatures and humidity, low rotational speed of the cooling system fans,
-carry out local and remote control, registration of the device as a physical resource with the ability to remotely start and change the operating mode.

Communication with the local data storage is provided through the built-in raspberry-pi wi - fi - module, remote via replaceable GSM -module. The unit is capable of relaying data from ambient temperature and humidity sensors and the state of the ozonizer to a remote cloud storage.

All this real-time data is accumulated in the cloud storage time series database, visualized and controlled by the operator and the ozone generator supplier at the cloud access interface. Functions of definition of emergency conditions of work of an ozonator are programmatically implemented. The hardware-software implementation of the “error” function, based on the analysis of the dynamics of the voltage drop, is able to track the deterioration of the properties of high-voltage electrodes (contamination, surface oxidation) and give recommendations for their cleaning or replacement.

Cotton seeds of various varieties were stored in stacked bags on a wooden deck in a dry, ventilated room (in bags according to Russians national standard 30090 weighing no more than 40 kg or three-layer paper bags of 25 kg each). The treated seeds were loaded into a sealed container with a volume of 15 liters made of steel 12Kh18N10T with a fluoroplastic seal, into the middle part of which an ozone-air mixture was supplied using an oil - free compressor. In another version, an ozone -oxygen mixture was supplied to the container. Depending on the flow rate of the ozone -containing gas and the discharge current, it was possible to obtain ozone concentrations in the range of 0.1÷8.0 g/m ^{3}. The scheme of the device for pre-sowing treatment of seeds with ozone -containing gases is shown in Figure 2.



1 oxygen cylinder, 2 ozone generator, 3 valve, 4 pressure vacuum gauge,
5-pump that creates reduced pressure, 6-sealed container.
Figure 2 - Scheme of the device for pre-sowing seed treatment

Processing in ozone was subjected to a batch of 5-6 thousand pubescent seeds. The treatment was carried out with a preliminary decrease in pressure in the tank to a level of 50 mm Hg, then ozone-containing gas was supplied at normal pressure. The treatment of seeds in ozone was carried out at an ambient humidity of 50÷60% and a temperature of 20÷ 25 ^{0}C. After treatment, the seeds were stored for a certain time (time of " resting ") in linen bags at a temperature of 20-25 ^{0} C and then sown in batches of 150 pieces in standard galvanized iron trays filled with sand. Previously, the sand was sieved through sieves in such a way as to select grains of sand 0.5-1.0 mm in size. The sifted sand was thoroughly washed with running water; after which it was calcined at a temperature $^{of\ 300\ °}$ C for 2 hours.

Sowing qualities of cotton seeds are determined according to Russians national standard 21820.0, 21820.4 -76. Seed germination was carried out at an average daily temperature of + 25÷27^{0} C and relative

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humidity of 65%. Watering the seeds was carried out at the same time of the day with boiled water cooled to $+25^0$ C. Germination energy was determined on the fifth day, and seed germination - on the seventh day after planting. The laboratory experiment was performed in triplicate. According to the results of counting in three repetitions, the average value of the energy of germination and germination of seeds for each concentration, exposure and time of "resting" of seeds after treatment was determined.

The ozone concentration in the ozone- containing gas was determined by the optical method using an SF-26 type spectrophotometer tuned to a wavelength of λ=254 nm. The length of the gas cell was 100 mm. The sensitivity of the optical method for measuring ozone concentration is up to 10^{-7} mol/l. The ozone exposure dose D (exposure dose) was calculated as the product of the ozone concentration C_{oz} in the gas and the duration of exposure t:

$$D = C_{oz}\, t$$

where– C_{oz} is the concentration of the air mixture, mg/m3; *t* – exposure time, sec.

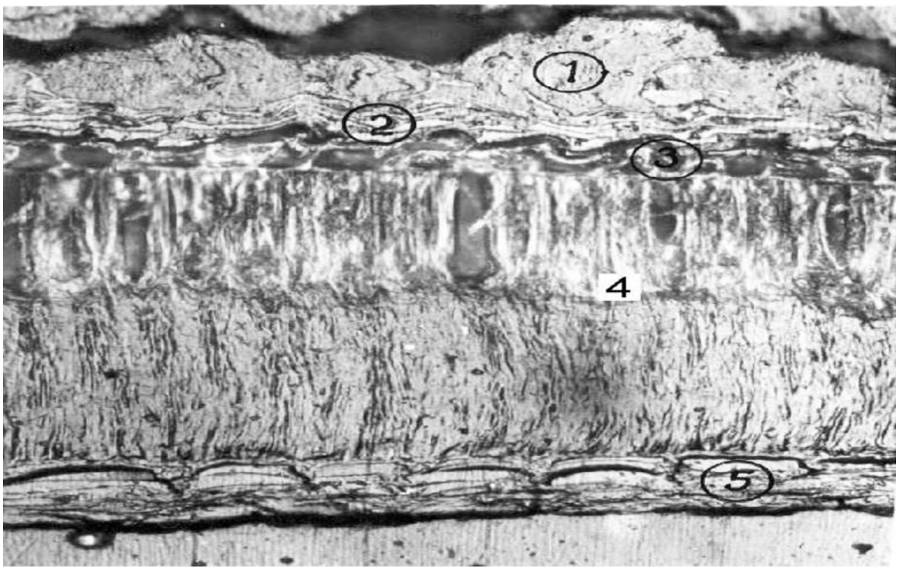
Microscopic studies of the surface of the control and treated cotton seeds were performed using a Neophot-2 optical microscope. X-ray studies of seeds were carried out on the "Electronics-25" installation. Studies of the structure of the cross section of cotton seeds were performed on an electron microscope UEMV-100K using the method of single-stage carbon replicas shaded with tungsten oxide at an angle of 35–40°.

Results and its discussion

Preliminary studies, based on x-rays of randomly selected cotton seeds, showed that the percentage of fullness of the seeds is 95-98%. This figure indicates the maximum possible number of viable seeds. Despite the relatively high viability index, the germination rate (mean value) of the control untreated seeds for variety C-6524 was 72%, and for variety C-6540 it was 64%, that is, about 25-35% of the seeds died at the initial stage of development.

Seeds arriving for sowing, as a rule, are in a state of forced dormancy and are characterized by a suspension of their development at the embryonic stage, which is achieved using special inhibition mechanisms. In this regard, the activation of the seed growth process with certain types of pre-sowing treatment is of practical interest.

When ripe, cotton seeds dry to an air-dry state. The loss of water brings the seeds to an inactive dormant state. The structure of mature dried cotton seeds is somewhat different from the schematic representations of immature seeds. Conducted electron microscopic studies of the cross section of cottonseed made it possible to obtain an image of the structure of the peel of mature cottonseed. This image is shown in Figure 3.



1 - outer epidermis of the outer integument, 2 - outer pigment layer,
3-crystalline layer; 4-column palisade layer,
5- inner pigment layer.
Figure 3 - The structure of the shell of the cotton seed in the middle part.

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The outer epidermis of the outer integument (Figure 3, pos. 1) is represented by a dense row of large cells closely adjacent to each other with a layered internal structure. Some of these cells form the fibrous covering of the seed. Cellulosic cell walls are strongly thickened and impregnated with tannin -containing substances, which give the outer epidermis a brown color. On the surface of the outer epidermis there are stomata, the average density of which is 50-60 mm $^{-2}$. The outer pigment layer (pos. 2) is revealed in the form of a narrow strip of compressed flat cells lying almost perpendicular to the cells of the outer epidermis.

The thickness of this layer depends on the variety of cotton and for some of them it ranges from 3 to 12 rows of highly pigmented cells. The crystal -bearing layer (pos.3) is visualized as a row of cells, the transverse shapes of which look like squares, rectangles, rounded along the vertices of triangles. During life, the cavities of these cells are filled with substances such as calcium oxalate.

The most developed in the cotton skin is the so-called columnar or palisade layer (pos. 4). It is formed by strongly elongated prismatic thick-walled cells, tightly adjacent to each other. In the upper third of the cells there are small cavities, which during life are filled with colored contents. During maturation, the walls of prismatic cells become very stiff. Near the outer ends of the palisade cells, the so-called "light line" is observed. Breakthrough and violation of the integrity of this line leads to swelling of the seeds.

The columnar layer is of paramount importance in the water and gas permeability of seeds. According to some reports, the columnar layer of cotton seeds has a uniquely high micro hardness. The inner pigment layer (pos. 5) is visible in the form of a narrow structural strip, consisting of several rows of flattened, poorly distinguishable cells. It should be noted that when the peel is removed from cotton seeds, the kernels of the latter germinate without exception. In this case, the embryo, as it were, does not have a dormant period. This gives grounds to look for the reasons for the delay in germination precisely in the seed coat.

Analysis of the research results shows that at low concentrations of ozone (0.1÷2.0 g/m ^{3}), depending on the exposure time, the germination of cotton seeds of the C-6524 variety increased by approximately 10÷15%, and for the C- 6540 by 5÷10% compared to control untreated seeds. The most significant change in germination was not observed immediately, but only some time after treatment.

During the " dwelling " period, the treated seeds were stored in linen bags at a constant temperature of about 20 $^\circ$C. For variety C-6524, the fifth day after treatment turned out to be favorable, and for variety C-6540, 8-10 days after treatment. At the same time, the germination energy of seeds of the C-6540 variety increased by about 10%, and the C-6524 variety was even lower than that of the control untreated seeds.

An increase in ozone concentration to average values (3.0÷5.0 g/m ^{3}) led to an increase in the germination of seeds of both varieties by 15÷20% with an exposure time in ozone of 35-40 minutes. When treating seeds of cotton variety C-6540 with ozone with a concentration of 5 g/m ^{3}, with an exposure time of 40 minutes, the germination of seeds increased from 64% for untreated seeds, to 80% for treated ones, with a “resting” time of 10 days. With the same treatment parameters, the germination energy of the above seeds increased from 21% to 51% with a “resting” time of 7 days, and with a “resting” of 10 days, this figure varied within 21÷30%.

For cotton variety C-6524, the following values were obtained: germination on the 7th day of “laying out” increased from 72% to 88 %, germination energy from 28% to 70%. An increase in the time of exposure to ozone above 60 minutes and an increase in the period of “resting” of seeds after treatment for more than 10 days led to a decrease in the parameters under consideration.

Figure 4 shows the dependence of the germination of cotton seeds on the time of treatment in ozone - containing gas.

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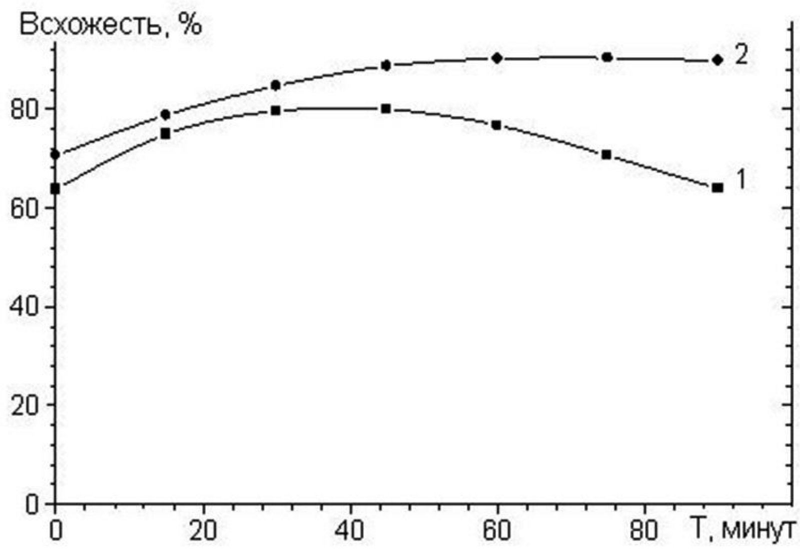

1st grade C6540, aging 10 days, 2nd grade C6542, aging 7 days

Figure 4- Dependence of the germination of cotton seeds on the processing time in ozone with a concentration of 5 g / m ^{3}

The marked activation of the growth of cotton seeds was also recorded visually. Cotton sprouts obtained from control untreated and ozone-treated seeds differed markedly. Sprouts from treated seeds germinated more uniformly and were taller

Conclusion.

Thus, the conducted studies have shown that pre-sowing treatment of cotton seeds with ozone-containing gases has an effective effect on improving the sowing qualities of seeds, in particular, germination and germination energy. The specificity of the structure of cotton seeds requires significantly higher exposure doses of ozone in comparison with seeds of grain crops. The suppression of bacteria and the activation of the enzyme systems of the seed, which may occur under the influence of the ozone flow, contributes to a more amicable germination of seeds. As a result, this ultimately leads to an increase in plant density and higher yields.

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ISSN NO: 2770-0003
Date of Publication: 04-03-2022

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