Modes of treating pre-sowing grain seeds with ozone

I V Baskakov, V I Orobinsky, A M Gievsky, A V Chernyshov and V A Gulevsky
Voronezh State Agrarian University named after Emperor Peter I, 1, Michurina str., Voronezh, 394087, Russia
E-mail: vasich2@yandex.ru

Abstract. Ozonation enables to abandon the pre-sowing seeds treatment with pesticides, reduce their possible use. The effectiveness of ozone application equals to that of chemical disinfection. However, during pre-sowing ozone treatment of seeds, it is difficult to maintain the specified operating modes of the ozonizer. Therefore, it is much easier to vary the operation time with regards to the capabilities of a particular ozonation plant. Thus, the most rational modes of pre-sowing ozone treatment of seeds were determined based on the crop and the average concentration of ozone in the ozone-air mixture. The ozonation time should be in the range 23 ... 41, 32 ... 52, 40 ... 60 and 17 ... 45 min during pre-sowing ozone treatment of the seeds of winter wheat, spring barley, oats and maize with ozone concentration in the ozone-air mixture equal to 4.21, 2.57, 1.45 and 1.87 mg/m³, respectively. If the ozonizer fails to maintain a specified operating mode, then the dose of ozone treatment should be regarded. The ozone treatment dose for winter wheat varies from 96 to 234 min mg/m³, for spring barley – from 84 to 116 min mg/m³, for oats – from 45 to 86 min mg/m³, for maize – from 32 to 75 min mg/m³. In this case, it will be necessary to calculate the ozonation time depending on the actual concentration of ozone in the ozone-air mixture. The average duration of pre-sowing ozone treatment of grain crops is 38 minutes.

1. Introduction
Recently in Russia there has been a consistently heavy yield of grain crops. At the enterprises of the agro-industrial complex, intensive technologies, which involve the use of mineral fertilizers to maintain the required amount of microelements in plants for their full development as well as pesticides to combat diseases and pests, are being increasingly used. The latter, if used incorrectly, can cause irreparable harm not only to cultivated crops but also to the environment and the ecology in general. Pesticides tend to accumulate in the soil and plants, some of them get to the windbreaks and water bodies adjacent to the field. The flora and fauna of nearby territories is under potential threat of poisoning as well. Therefore, nowadays more and more environmentally friendly methods of crop production are used. At the same time, the effectiveness of such techniques must be maximized (for example, the effect of pesticides), and the impact on nature – minimized. It is possible to reduce the flow of chemicals into the soil by reducing the use of pesticides especially during pre-sowing seed treatment. Currently, the surface seed treatment is the most widespread. This method has many disadvantages.

Ozonation is a promising and environmentally friendly method for pre-sowing grain crops treatment [1-2]. In terms of efficiency, ozone disinfection equals to chemical one, and sometimes even surpasses it [3]. At the same time, there is an increase in the yield of various agricultural crops. Ozone has a number of specific properties that benefit its wide use in various agricultural operations [4-6].
These properties expand the variability of the ozonizer use in the household, which assists in reducing the ozone treatment cost. In addition, ozonation can be carried out directly in the granary [7-8], which results in excluding a number of transport operations from seed technology.

High concentrations of ozone in the ozone-air mixture have a depressing effect on the seed, while the low-concentration of pre-sowing ozone treatment stimulates the growth processes in the seeds, increasing their germination energy and capacity. However, the ozonizer operation modes are somewhat different. Since the ozonizer installation most often does not contribute to varying the ozone concentration during pre-sowing treatment, studies aimed to clarify the operation time are relevant. The variety of options is very wide and the parameters need to be specified in each case. In this regard, the most rational modes of pre-sowing ozone treatment of seeds were determined based on the crop and the average ozone concentration in the ozone-air mixture.

2. Materials and methods

Experimental studies were undertaken according to the following methodology. When conducting research, four seed grain samples sets were placed in a glass container with an inlet and outlet for the ozone-air mixture. The fifth sample was outside the vessel and therefore was not subjected to ozonation, i.e. it was control. The agent consumption during the research was 0.6 m$^3$/h. Laboratory germination was determined in accordance with GOST 12038-84 (Agricultural seeds. Methods for determining germination).

Moreover, each set consisted of 400 grains, and for maize – 200 seeds. The vessel was ventilated with an ozone-air mixture for 2 hours. Every 30 min of the experiment, one set of seeds was removed from the container. The ozone concentration was determined every 5 min in the outlet channel using a Sigma-03 gas analyzer with a corresponding Sigma-03.DE electrochemical sensor. The same instrumentation was used to control the maximum allowable level of the gas in the researcher’s working area and this was implemented through the second channel. During the pre-sowing treatment of winter wheat seeds, the ozone concentration in the ozone-air mixture varied from 1.62 to 5.06 mg/m$^3$. For the first half hour, this indicator averaged 4.28 mg/m$^3$, for one hour – 4.15 mg/m$^3$, for an hour and a half – 4.4 mg/m$^3$, for two hours – 4.21 mg/m$^3$.

During pre-sowing ozonization of spring barley seeds, the ozone concentration in the ozone-air mixture varied from 0.76 to 3.34 mg/m$^3$. For the first half hour, this indicator averaged 2.79 mg/m$^3$, for one hour – 2.84 mg/m$^3$, for an hour and a half – 2.6 mg/m$^3$, for two hours – 2.57 mg/m$^3$. During the presowing ozonization of oat seeds, the ozone concentration in the ozone-air mixture varied from 1.16 to 1.7 mg/m$^3$. For the first two half-hour periods, this indicator averaged 1.56 mg/m$^3$, and over the next two hours – 1.45 mg/m$^3$. During the pre-sowing treatment of maize seeds, the ozone concentration in the ozone-air mixture varied from 1.62 to 2.1 mg/m$^3$. For the first half hour, this indicator averaged 1.88 mg/m$^3$, an hour and an hour and a half – 1.85 mg/m$^3$, for two hours – 1.87 mg/m$^3$.

3. Results

Pre-sowing ozonation of the seeds of winter wheat, spring barley, oats and maize contributed to the change in their laboratory germination depending on the treatment period. Statistical processing of research results during pre-sowing ozonation of the seeds of winter wheat, barley, oats and maize with an average ozone concentration in the ozone-air mixture equaled to 4.21, 2.57, 1.45, respectively. 1.87 mg/m$^3$ showed that laboratory germination obeys a 3rd degree polynomial dependence on the treatment time, i.e.

\[
G_{\text{w.wheat}} = 0.00003 \cdot t^3 - 0.0073 \cdot t^2 + 0.3698 \cdot t + 72.566, \quad R^2 = 0.9443, \quad (1)
\]
\[
G_{\text{s.barley}} = 0.00005 \cdot t^3 - 0.0143 \cdot t^2 + 0.9318 \cdot t + 79.854, \quad R^2 = 0.9658, \quad (2)
\]
\[
G_{\text{oats}} = 0.00006 \cdot t^3 - 0.0041 \cdot t^2 + 0.3633 \cdot t + 72.28, \quad R^2 = 0.9737, \quad (3)
\]
\[
G_{\text{maize}} = 0.00008 \cdot t^3 - 0.0018 \cdot t^2 + 0.0858 \cdot t + 97.57, \quad R^2 = 0.9373, \quad (4)
\]
where $G_{l\text{,cropper}}$ is laboratory germination of seeds of a given cropper, %;

t is time of ozone treatment, min;

$R^2$ is approximation confidence value.

Dependencies 1-4 are shown in Figure 1.

**Figure 1.** Dependence of laboratory germination of seeds (Gl) of grain crops on the time (t) of treatment during pre-sowing ozonation at the following average concentration of ozone in the ozone-air mixture: 1 – 4.21 mg/m³; 2 – 2.57 mg/m³; 3 – 1.45 mg/m³; 4 – 1.87 mg/m³

Analysis of Figure 1 shows that the optimal time for pre-sowing ozone treatment of the seeds of winter wheat, spring barley, oats and maize with an average ozone concentration in the ozone-air mixture is equal to 4.21 mg/m³, 2.57 mg/m³, 1.45 mg/m³, 1.87 mg/m³ is 31 min, 42 min, 50 min and 30 min, respectively. The calculated laboratory germination of winter wheat seeds in the range from 23 to 41 minutes, barley in the range from 32 to 52 minutes, oats in the range from 40 to 60 minutes, maize in the range from 17 to 45 minutes with ozonation falls within an error of ±1%.

The dependences of the laboratory germination of wheat, barley, oats and maize seeds on the ozone dose comply with the dependencies 5-8 and are shown in Figure 2. The dose was determined as the product of the treatment time and the average gas concentration within a given period of the experiment.

\[
G_{l\text{,wheat}} = 0.0000001 \cdot d_c^3 - 0.0002 \cdot d_c^2 + 0.0573 \cdot d_c + 72.771, \quad R^2 = 0.9776, \quad (5) \\
G_{l\text{,sprbarley}} = 0.000003 \cdot d_c^3 - 0.0022 \cdot d_c^2 + 0.3485 \cdot d_c + 80.003, \quad R^2 = 0.803, \quad (6) \\
G_{l\text{,oats}} = 0.000004 \cdot d_c^3 - 0.0024 \cdot d_c^2 + 0.2605 \cdot d_c + 72.304, \quad R^2 = 0.8947, \quad (7) \\
G_{l\text{,maize}} = 0.000001 \cdot d_c^3 - 0.0005 \cdot d_c^2 + 0.0442 \cdot d_c + 97.578, \quad R^2 = 0.929. \quad (8)
\]

where $G_{l\text{,cropper}}$ is laboratory germination of seeds of a given cropper, %;

$d_c$ is dose of ozone treatment, min mg/m³;

$R^2$ is approximation confidence value.
According to Figure 2, we will analyze the effect of the ozone treatment dose on the laboratory germination of various crops. The acceptable dose of ozone treatment of winter wheat is 163 min mg/m³. At the same time, a change in this parameter in the range from 96 to 234 min mg/m³ gives the same calculated value of the laboratory germination of the seeds when rounded off to the nearest whole number. Consequently, with ozone treatment of winter wheat seeds with an ozone concentration in the ozone-air mixture of 4.21 mg/m³, the ozonation time should be 23 ... 41 minutes. The optimal dose of ozone treatment of spring barley is 99 min mg/m³.

At the same time, a change in this parameter in the range from 84 to 116 min mg/m³ gives the same calculated value of laboratory germination of seeds when rounded off to the nearest whole number. Consequently, with ozone treatment of spring barley seeds with an ozone concentration in the ozone-air mixture of 2.57 mg/m³, the ozonation time should be 32 ... 52 minutes. The acceptable dose of ozone treatment of oats is 65 minutes mg/m³.

At the same time, a change in this parameter in the range from 45 to 86 min mg/m³ gives the same calculated value of laboratory germination of seeds when rounded off to the nearest whole number. Consequently, with ozone treatment of oat seeds with an ozone concentration in the ozone-air mixture of 1.45 mg/m³, the ozonation time should be 40 ... 60 minutes. The optimal dose of ozone treatment of maize is 52 minutes mg/m³. At the same time, a change in this parameter in the range from 32 to 75 min mg/m³ gives the same calculated value of laboratory germination of seeds when rounded off to the nearest whole number. Consequently, with ozone treatment of maize seeds with an ozone concentration in the ozone-air mixture of 1.87 mg/m³, the ozonation time should be 17 ... 45 minutes.

If the ozonizer is not able to maintain a specified mode, then it is recommended to focus on the dose of ozone treatment in the range from 96 to 234 min mg/m³ for winter wheat, from 84 to 116 min mg/m³ for barley, from 45 to 86 min mg/m³ for oats and 32 to 75 minutes mg/m³ for maize. In this
case, it will be necessary to calculate the ozonation time as the ratio of the ozone treatment dose to the actual ozone concentration in the ozone-air mixture.

4. Conclusion
When pre-sowing the seeds of winter wheat, spring barley, oats and maize with an average concentration of ozone in the ozone-air mixture equal to 4.20, 2.60, 1.45 and 1.88 mg/m³, the operation time should be in the range of 23 ... 41, 32 ... 52, 40 ... 60 and 17 ... 45 minutes, respectively.

If the ozone generator is unable to maintain the specified operating modes, it is necessary to observe the doses during ozone treatment. The doses may be different depending on the crop. Thus, for winter wheat it varies in the range of 110 ... 200 min mg/m³, for spring barley – 84 ... 114 min mg/m³, for oats – 40 ... 60 min mg/m³, for maize – 32 ... 74 min mg/m³. In this case, it is necessary to calculate the ozonation time depending on the actual concentration of ozone in the ozone-air mixture. The average optimal duration of pre-sowing ozone treatment of grain crops is 38 minutes. It corresponds with the rational period of time for ozonation of any of the studied crops at an ozone concentration in the ozone-air mixture of up to 5 mg/m³. The average optimal dose for ozone treatment of grain crops is about 95 min mg/m³.

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