Experimental studies of a seed disinfection device

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Abstract. This article deals with one of the most pressing problems at present - reducing seed germination loss during storage in grain bins. The quality of the grain determines the germination rate of the seed and its maturity. However, anyone involved in agriculture can say with certainty that seed treatment before planting - "seed disinfection" - is just as important. Seed disinfection is a targeted procedure that aims to protect the seed economically and ecologically. Special preparations (pesticides) and their combinations are used for this purpose. The equipment used for seed disinfection in many plants does not always meet modern agrotechnical requirements of treatment quality, consequently it is necessary to develop technology and design of technical means with justification of its design and technological parameters. During the work, experimental methods such as simulation, observation, experiment were used. On the basis of this, the technological scheme and design of the unit for disinfection of grain in the flow when putting in storage was obtained and the optimal parameters of the proposed device were determined.

1. Introduction
One of the major global problems of humanity is the food problem.

In the world economic system, it is characterised by food shortages in certain regions of the world, primarily in developing countries. Grain farming plays a major role in the food stock of states. Grain is also the main food exchange commodity; the prices of most food products are to some extent shaped by grain prices. Annual grain losses from pests account for 5-7% of the harvest. Stock pests live and develop both in the place where the grain grows and in the storage place - in the elevator or in the warehouse. The most harmful pests of bread stocks include: corn borer, corn weevil, grass moths, meal beetles, food mites. As a result of the activity of pests not only decreases the weight of the products, but also significantly reduces their quality. They acquire poisonous properties because infested grains produce a large amount of uric acid which may cause a number of diseases.

To protect the grain from pests, it is important to carry out a set of measures in a timely manner that will preserve not only the yield but also the quality of the product.

2. Methods and Materials
One of the effective preventive measures against diseases and pests of grain stocks is seed disinfection. Seed disinfection is a chemical treatment of seed material not only from fungal and bacterial diseases, but also from insects, rodents and other pests.[1]

Today such domestic seed dressers as PS-10AM and PS-22 (Gatchinselmash Ltd.), PS-20K-4 (Agrohimnash Ltd., Stavropol), as well as foreign PSK-15, PS-20D (Republic of Belarus), PK-20-02 "Super" (JSC Lvovagromashproekt) are the most popular in the market. Despite the technical...
characteristics, this equipment does not meet modern agricultural requirements, so the department "Mechanization of technological processes in agro-industrial complex" of Penza SAU developed the design of the device for disinfection of grain with different concentrations of working solutions.

The convenience of this design is that it can be mounted almost anywhere where there is grain flow (such as the elevator head or discharge carriage). Thanks to the digital control equipment, the instantaneous flow rate and the concentration of the spray agent can be controlled with ease, enabling the treatment of 20-500 tonnes of grain per hour. [2] The unit also features:
- automatic pressure control, which simplifies the work of the operating staff;
- sprayer clogging check modes.

The laboratory unit for grain disinfection (figure 1) consists of a supporting base (1) with a belt conveyor (4), which is driven by an electric motor (3). Above the conveyor belt there is a seed hopper (5) and a ramp (7) with nozzles (8). At one end of the ramp is a pressure gauge (10) to control pressure and a bypass valve (9), which discharges excess solution into a pesticide tank (12). At the other end of the ramp, a pressure line (6) is attached. The pressure in the pressure line is generated by a pump (15) driven by an electric motor (16). Valves (13,14) enable to close the liquid flow from the pump (15) into the pesticide tank and into the pressure line. The dressed seeds arrive in a receiving hopper (11). All processes are controlled from a control panel (2) by an operator.

![Figure 1. Technological scheme of the unit for disinfecting grain in the flow at putting into storage: 1 - base; 2 - control panel; 3 - electric motor; 4 - conveyor belt; 5 - seed hopper; 6 - pressure line; 7 - ramp; 8 - nozzles; 9 - bypass valve; 10 - pressure gauge; 11 - receiving hopper; 12 - tank; 13,14 - valves; 15 - pump; 16 - electric motor.](image)

The sequential mode of operation is used, which is the basic one. In this regard, sprayers are working in turns, providing a continuous flow of preparation to the grain mass.

At the moment the following variants of installation are available:
1. With spray rate control by computer;
2. With spray rate control on the control panel.

3. Results
The process of dressing crops depends to a large extent on various factors, not least of which is the number of nozzles installed. In order to determine the optimum number of nozzles, a one-factor experiment was conducted and the results were obtained (Table 1).
Table 1. Data from the results of determining the completeness of seed dressing as a function of the number of nozzles.

| Indicator                  | Parameter |
|----------------------------|-----------|
| Number of nozzles, pcs     | 0  1  2  3  4  5  6  7 |
| Dressing completeness P, % | 0  1.3  3.2  4.1  95.9  96.5  6.9  7.1 |

The following shows the dependency of the dressing completeness, expressed as a percentage of the number of nozzles installed (Figure 2)

\[ Y = 88.9143 + 2.069 \times x - 0.1238 \times x^2 \]

Figure 2. Dependence of seed dressing completeness on the number of nozzles.

Based on the data presented, it can be concluded that to ensure the completeness of dressing in accordance with the standards, the optimal number of installed nozzles is 4. This allows to treat the seed material at 96.9%. If the number of nozzles is reduced, the pesticide will treat only part of the grain, and if they are increased, the unevenness of the process will increase.

The optimality criteria of the treatment process were taken as the completeness of seed treatment after leaving the seed disinfection unit (% of quality seeds). The basic factors which have been selected on the basis of the a priori ranking influencing quality indicators of the treatment process have been defined: h - nozzle installation height, mm; \( \alpha \) - spray angle, deg; \( V_t \) - conveyor speed, m/s; \( L_l \) - conveyor belt width, mm; \( P \) - nozzle pressure, MPa; \( \beta \) - nozzle installation angle, deg.; \( b \) - grain layer size, mm; \( \gamma \) - nozzle section installation angle, deg. (Table 2).

To conduct the screening experiment, a matrix was constructed, taking into account the factors initially identified (Table 3), by randomly mixing two half-replications of type \( 2^{+1} \). The experimental design was randomised using random number tables.
Table 2. Factors influencing the quality of the dressing process.

| Designation | Factor | Variation levels |
|-------------|--------|------------------|
| $X_1$       | $\alpha$ – spray angle, deg | -1 $X_1$, +1 $X_1$ |
| $X_2$       | $h$ – nozzle installation height, mm | 300 $X_2$, 0.1 $X_2$ |
| $X_3$       | $v_t$ – conveyor speed, m/s | 0.28 $X_3$, 200 $X_3$ |
| $X_4$       | $p$ – nozzle pressure, MPa | 10 $X_4$, 0 $X_4$ |
| $X_5$       | $l_d$ – conveyor belt width, mm | 0 $X_5$, 10 $X_5$ |
| $X_6$       | $\beta$ – nozzle installation angle, deg | 0 $X_6$, 10 $X_6$ |
| $X_7$       | $b$ – grain layer size, mm | 0 $X_7$, 10 $X_7$ |
| $X_8$       | $\gamma$ – nozzle section installation angle, deg. | 0 $X_8$, 10 $X_8$ |

Table 3. Matrix and results of the screening experiment.

| № of the experiment | Factors | Optimisation parameter $Y$ |
|----------------------|---------|---------------------------|
| $X_1$               | $X_2$   | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | $Y$   |
| 1                    | -       | -    | -    | -    | -    | -    | -    | 81.3  |
| 2                    | -       | -    | +    | +    | -    | -    | -    | 91.9  |
| 3                    | +       | +    | +    | -    | -    | -    | -    | 96.5  |
| 4                    | -       | -    | +    | -    | +    | -    | -    | 92.0  |
| 5                    | +       | +    | -    | +    | -    | +    | +    | 94.3  |
| 6                    | +       | -    | -    | +    | +    | +    | -    | 88.4  |
| 7                    | +       | +    | -    | +    | +    | -    | -    | 94.5  |
| 8                    | -       | +    | +    | +    | -    | -    | -    | 96.2  |
| 9                    | -       | +    | -    | +    | +    | -    | -    | 92.1  |
| 10                   | +       | -    | +    | -    | -    | +    | +    | 90.8  |

Table 4. Results of data processing of the screening experiment.

| Factor | $X_1$ | $X_2$ | $X_3$ | $X_4$ | $X_5$ | $X_6$ | $X_7$ | $X_8$ | Correlation coefficient | Factor significance |
|--------|-------|-------|-------|-------|-------|-------|-------|-------|--------------------------|---------------------|
|        | 0.26  | 0.69  | 0.40  | 0.47  | 0.20  | -0.51 | -0.18 | 0.15  |                          |                     |

An analytical expression for the response function used a second-order polynomial of the form:

$$ y = a_1x_1^2 + a_2x_2^2 + a_3x_3^2 + a_4x_1x_2 + a_5x_1x_3 + a_6x_2x_3 + a_7x_1 + a_8x_2 + a_9x_3 + a_{10} $$

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(1)

where $y$ – response function; $x$ – factors; $a$ – coefficients.

Based on the results of using a screening experiment, factors of little significance were eliminated, which reduced the scope for further research. As a result, the most significant factors $X_1$ ($h$ - nozzle installation height, mm), $X_2$ ($v_t$ - conveyor speed, m/s) and $X_4$ ($p$ - pressure in the nozzle, MPa) were identified. (Table 5). Plans and methods of conducting experiments and processing the results are described in detail in many sources [4,5]. The natural values of factor levels were converted into coded dimensionless values (to construct a standard matrix for the experiment) using the formula:

$$ x_i = \frac{X_i - X_{0i}}{\varepsilon} $$

(2)

where $x_i$ – the coded factor value (dimensionless value), the upper level is denoted by +1 and the lower level by -1 (the centre of the experiment is zero); $X_i$ – the natural value of the factor; $X_{0i}$ – the natural value of the factor at the zero level; $\varepsilon$ – the natural value of the interval of variation of the factor [6];
Table 5. Factors affecting the dressing process with the dressing device under investigation.

| Designation and name of factors | Levels of factors | Variation interval |
|---------------------------------|-------------------|-------------------|
| X₁ – H – nozzle installation height, mm | 350 | Upper 400 | Lower 300 | 50 |
| X₂ – Vt – conveyor speed, m/s | 0.3 | Upper 0.5 | Lower 0.1 | 0.2 |
| X₃ – Pкр – pressure in the nozzle, MPa | 0.32 | Upper 0.36 | Lower 0.28 | 0.04 |

In order to obtain a mathematical model of the seed dressing process in the form of a second-degree polynomial, an orthogonal composite plan was used. Its planning matrix and experimental results are presented below (Table 6).

Table 6. Matrix of planning experiments and results of experiments.

| №  | x₁  | x₂  | x₃  | Y, % of quality seeds |
|----|-----|-----|-----|-----------------------|
| 1  | -1  | 1   | 1   | 90.2                  |
| 2  | 1   | 1   | -1  | 92.91                 |
| 3  | 1   | -1  | 1   | 89.49                 |
| 4  | 1   | -1  | -1  | 87.2                  |
| 5  | -1  | 1   | 1   | 88.3                  |
| 6  | -1  | 1   | -1  | 92.16                 |
| 7  | -1  | -1  | 1   | 89.4                  |
| 8  | -1  | -1  | -1  | 91.8                  |
| 9  | 1   | 0   | 0   | 93.94                 |
| 10 | -1  | 0   | 0   | 91.25                 |
| 11 | 0   | 1   | 0   | 93.95                 |
| 12 | 0   | -1  | 0   | 91.58                 |
| 13 | 0   | 0   | 1   | 92.47                 |
| 14 | 0   | 0   | -1  | 94.83                 |
| 15 | 0   | 0   | 0   | 97                    |

In the right part (Table 6), the arithmetic average (for three repetitions) values of the optimization parameter are recorded for each individual experiment. Dependent on the total number of factors k the number of experiments N can be determined by the dependence N=2^k+2k+n.

During the multifactor experiment the values of certain parameters were set in the optimal range. [6] After conducting the multifactorial experiment, the results were processed on a PC and allowed to obtain an adequate mathematical model of the second order, described in coded form by the dependence Y=f(H, Vт, Pкр):

\[
Y = 96,16089 - 0,39900 x₁ + 0,80500 x₂ - 0,42200 x₃ - 2,10611 x₁² - 1,93611 x₂² - 1,05111 x₃² - 0,80750 x₁ x₂ - 0,73000 x₁ x₃ - 0,89500 x₂ x₃
\]  (4)

4. Conclusions

There are many methods of pre-sowing seed treatment, but the purpose of all of them is the same - to improve the seeding properties of seeds. The proposed design of seed dressing unit will allow to achieve the value of seed dressing quality P = 96% of the total amount of seeds. The made calculations of technical and economic estimation show that payback period will make up 0.72 years. All this indicates economic feasibility of the seed dressing unit implementation.
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