Assessment of the influence of key factors of the rapeseed drying process using electric radiant film heaters on germination ability and germination energy

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Abstract. Drying of any crop is a complex technological process, accompanied by a change in the content of not only the amount of moisture in them, but also useful substances and properties. The improvement of the drying technology of small-seeded crops should be aimed at preserving the sowing qualities of seeds (germination ability and germination energy), therefore, the assessment of the quality of rape plant seeds after the drying process in a conveyor-cascade type drying unit is an important and integral part of the work, and the use of modern mathematical methods is an integral part of the processing and interpretation of the results of field experiments. The experiment and analysis of the results of the work were carried out according to the methodology of the state variety testing of agricultural crops. The results were processed using two-factor analysis.

1. Introduction
One of the methods of preserving seed quality indicators is drying. All known drying methods are based on the principle of removing free moisture from the volume of seed material. [1-4] Evaporation of moisture excess for storage is achieved by creating conditions that promote and accelerate desorption processes. Appropriate conditions can be created in various ways, using a combination of methods, forming a control effect on the control object or, for example, correcting disturbing effects affecting the process of seed dehydration as a whole.

Electrical methods and means of dehydration are an environmentally sound approach to obtain functional seeds. Drying with heat supply is characterized by high productivity, nevertheless, the requirement to preserve seed quality indicators imposes significant restrictions not only on the maximum possible thermal load on the drying object, but also on the maximum possible speed of the process, since as a result of rapid drying, significant deformation of seed tissues is not excluded, for example, separation of the embryo from the central root of the seed [4-6].

The main criterion for evaluating all operations on seeds should be the condition of non-deterioration of the vital activity of the embryo. Nevertheless, the non-stationarity of the coefficients, the change in the volume, structure and weight of the seed sheaf, the lack of reliable concentrated data on the kinetics of drying and experimental data on the dynamic properties of dryers not only inhibits the development of the seed industry, but also the development and implementation of specialized drying devices.
2. Materials and methods
In the complex of agrotechnical measures carried out to obtain high and stable yields of agricultural crops, an important place belongs to the quality of the seed material and its preparation for sowing. Seeds of the best released plant varieties are quite an affordable reserve for increasing agricultural production.

The quality of seeds of cultivated plants intended for sowing is subject to laboratory testing according to the following indicators: color, gloss, smell (organoleptic indicators), the content of large impurities, purity, germination energy, germinating ability, viability, humidity, fungal and bacterial diseases and other indicators [5].

After checking the organoleptic properties, rape plant seeds are tested for sowing qualities (germination ability and germination energy).

Let us consider the processing of the results as a two-factor experiment to study the effect of infrared radiation from an electric film heater and an active substrate on the germination ability and germination energy of rape plant seeds. For drying, rape plant seeds were scattered on a surface equipped with an active substrate or without it; the electric film heater was placed on top [7-8].

3. Results and discussions
In this experiment, the following designations were adopted:
X₁ - factor of the presence or absence of electric film heater;
X₂ - factor of the presence or absence of active substrate;

The experiment was carried out in three repetitions. The plan and results of the experiment are presented in Table 1.

| No. | X₁ | X₂ | X₁*X₂ | Y₁₁, % | Y₁₂, % | Y₁₃, % | Y₂₁, % | Y₂₂, % | Y₂₃, % |
|-----|----|----|--------|--------|--------|--------|--------|--------|--------|
| 1   | +  | +  | +      | 97.6   | 97.1   | 99.4   | 96.5   | 94.4   | 95.6   |
| 2   | -  | +  | -      | 95.9   | 96.4   | 96.7   | 93.7   | 92.5   | 94.2   |
| 3   | -  | -  | +      | 95.8   | 95.3   | 95.6   | 91.3   | 92.5   | 90.6   |
| 4   | +  | -  | -      | 96.5   | 96.7   | 97.5   | 95.1   | 94.8   | 95.4   |

We process the results in the following sequence:
1. We find the arithmetic mean from m repetitions. In our case, m=3.

\[ Y_{av} = \frac{\sum_{n=1}^{m} Y_n}{m} \]  

2. We find the deviation squares:

\[ \Delta Y_{ln}^2 = (Y_{ln} - Y_{av})^2 \]  

3. We find the line-by-line variance:

\[ S_n^2 = \frac{1}{m-1} \sum_{l=1}^{m} \Delta Y_{ln}^2 \]  

4. We determine the calculated value of the Cochran's criterion:

\[ G_{max} = \frac{S_{n,max}^2}{\sum_{n=1}^{N} S_n^2} \]  

where N=4.

5. The resulting value of the Cochran's criterion is compared with the tabular value. If the experience is reproducible, then

\[ G_{max,calc} \leq G_{max,tabl} \]
If condition (5) is not fulfilled, then the experiment is not reproducible, and its results cannot be trusted [9].

To determine the tabular value of the Cochran's criterion, we first find the number of degrees of freedom:

\[ \gamma_1 = m - 1 ; \gamma_2 = N \]  

In our case, the calculated and tabular value of the Cochran's criterion is:

A) for germination ability:

\[ G_{\text{max calc}} = 0.742809; \quad G_{\text{max tabl}} = 0.7679 \]

B) for germination energy:

\[ G_{\text{max calc}} = 0.384527; \quad G_{\text{max tabl}} = 0.7679 \]

Since the result of the experiment turned out to be reproducible, it is possible to start processing of experimental data.

Our two-factor linear model has the following form:

\[ y = A_0 + A_1 \times X_1 + A_2 \times X_2 + A_{12} \times X_1 \times X_2 \]  

6. The coefficient \( A_0 \) is determined by the expression:

\[ A_0 = \frac{\sum_{n=1}^{N} y_n}{N} \]  

7. The coefficient \( A_1 \) is determined by the expression:

\[ A_1 = \frac{\sum_{n=1}^{N} y_n \times X_{1n}}{N} \]  

8. The coefficient \( A_2 \) is determined by the expression:

\[ A_2 = \frac{\sum_{n=1}^{N} y_n \times X_{2n}}{N} \]  

9. The coefficient \( A_{12} \) is determined by the expression:

\[ A_{12} = \frac{\sum_{n=1}^{N} y_n \times X_{1n} \times X_{2n}}{N} \]  

In our case, the values of the regression coefficients are:

A) for germination ability:

\[ A_0 = 96.70833; \quad A_1 = 0.758333; \quad A_2 = 0.475; \quad A_{12} = 0.091667; \]

B) for germination energy:

\[ A_0 = 93.88333; \quad A_1 = 1.416667; \quad A_2 = 0.6; \quad A_{12} = -0.4; \]

After the regression coefficients are determined, it is necessary to identify their significance.

10. To do this, we find an estimate of the general variance:

\[ S^2 = \frac{\sum_{n=1}^{N} s_n^2}{N} \]  

11. Variance of determining regression coefficients:

\[ S_A^2 = \frac{S^2}{N+m} \]  

12. The regression coefficient \( A \) is significant if

\[ A > S_A \times t \] 

where \( t \) is the Student's criterion, depending on the number of degrees of freedom

\[ \gamma = N \times (m - 1) \]
and the level of significance, which for engineering calculations is assumed to be equal to 5%.

In our case, the values $S_A * t$ are:

A) for germination ability:
$$S_A * t = 0.467167;$$

B) for germination energy:
$$S_A * t = 0.565506;$$

Comparing the obtained values of the regression coefficients with the parameters $S_A * t$, we conclude that only the coefficients $A_0, A_1, A_2$ are significant in both cases.

The last stage of processing the results of the experiment is to assess the adequacy of the obtained mathematical model. To do this, it is necessary to calculate the values of the Fisher coefficient for both series of experiment.

The Fisher's criteria are calculated in the following sequence:

13. The theoretical values of germination ability and germination energy are calculated without considering insignificant coefficients by the expression:
$$y_n = A_0 + A_1 * X_{1n} + A_2 * X_{2n}$$

14. The variance of inadequacy is determined by the formula:
$$\sigma_{v.a.d}^2 = \frac{m}{N-C} \sum_{n=1}^N (y_{av} - y_n)^2$$

15. Fisher’s criterion:
$$F = \frac{\sigma_{v.a.d}^2}{s^2}$$

For our example:
A) Germination ability:
$$F_{calc} = 0.204738;$$

B) Germination energy:
$$F_{calc} = 2.663973;$$

The obtained value of the Fisher's criterion is compared with the tabular value obtained depending on the number of degrees of freedom:
$$y_1 = N - C$$
$$y_2 = N * (m - 1)$$

If $F_{calc} \leq F_{tabl}$, then the resulting mathematical model describes the process adequately.

In our case, when $y_1$ and $y_2$, $F_{tabl} = 5.32$, therefore, $F_{calc} < F_{tabl}$ in both series of experiments, mathematical models for germination ability and germination energy describe these processes adequately.

4. Conclusions

1) Metrological error plays a huge role in the deviation of test results in reproducibility conditions.

2) Calculations and analysis of the Cochran's criteria for germination ability and germination energy indicate the reproducibility of the experiments;

3) Calculations and analysis of regression coefficients indicate the maximum contribution to the value of germination ability and germination energy of the factor of application of electric film heaters, the second most important is the factor of active substrate application;

4) Calculations and analysis of the Fisher's coefficients for both series of experiments indicate the adequacy of the constructed mathematical model.
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