

The results of the study of uneven seed dispersion by the centrifugal distribution system of a pneumatic grain seeder

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Abstract. There were determined the parameters and operating modes of the centrifugal dispersion system of a grain pneumatic seeder, which ensured the minimum unevenness of the seed dispersion between the seed lines.

1 Relevance of research

Currently, pneumatic grain seeders with centralized dispersion systems are widely used, their changeable productivity in 30 percent or more with an equal working width exceeds the productivity of units with mechanical seeders. The increase in productivity is mainly due to the reduction of unproductive time costs associated with filling the hoppers with seed material, movements and technological maintenance of the machine. However, the analysis of research papers on the problem and the results of search experiments revealed a significant drawback of their work - a high unevenness of the seed dispersion between seed lines, due to the imperfection of the technological process of seed dispersion by centralized dispersion systems. The uneven seed dispersion along seed lines undoubtedly has a negative impact on the yield of grain crops and significantly reduces the efficiency of the use of seeders with dispersion systems.

Improving the quality of seed dispersion through seed lines by justifying the parameters and operating modes of the dispersion system of a pneumatic grain seeder based on modeling the movement of seeds in a centrifugal disperser is relevant. In recent years, pneumatic grain seeders have become widely used, allowing to increase the productivity of sowing units, as well as to reduce operating costs. [2, 3, 9]. The main disadvantage of existing designs of pneumatic grain seeders is the uneven seed dispersion between the seed lines, which leads to overspending of seeds [4]. Kuban State Agrarian University has proposed a design of a centrifugal seed disperser, which reduces the unevenness of seed dispersion along the seed lines [1, 10].

The design scheme of the disperser requires a theoretical justification of the design and operating parameters based on the equation of motion in the disperser's chamber.

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2 Investigation of uneven seed dispersion by a centrifugal disperser

A multi-factor experiment was implemented in accordance with the program of laboratory and production studies of the centrifugal disperser. The experiments were carried out in three-fold repetition [5, 11].

Experimental studies of the transverse unevenness of the dispersion by the centrifugal dispersion system of a pneumatic grain seeder were carried out according to the Bock plan B3 (Table 1).

Table 1. Results of experimental studies of the uneven dispersion of the centrifugal dispersion system

№ experiment	Values of factors									Y_1	Y_2	Y_3	Y_{cp}
	x_1	x_2	x_3	x_1x_2	x_1x_3	x_2x_3	x_1^2	x_2^2	x_3^2				
1	1	1	1	1	1	1	1	1	1	4,92	5,54	5,47	5,31
2	-1	1	1	-1	-1	1	1	1	1	6,3	6,72	5,98	6,33
3	1	-1	1	-1	1	-1	1	1	1	4,75	5,38	5,62	5,25
4	-1	-1	1	1	-1	-1	1	1	1	6,25	5,68	5,23	5,72
5	1	1	-1	1	-1	-1	1	1	1	5,9	5,41	6,47	5,93
6	-1	1	-1	-1	1	-1	1	1	1	8,15	7,44	7,75	7,78
7	1	-1	-1	-1	-1	1	1	1	1	5,13	5,97	5,71	5,6
8	-1	-1	-1	1	1	1	1	1	1	7,39	7,48	7,95	7,61
9	1	0	0	0	0	0	1	0	0	4,84	5,36	5,22	5,14
10	-1	0	0	0	0	0	1	0	0	5,83	5,11	5,69	5,54
11	0	1	0	0	0	0	0	1	0	6,28	6,72	6,35	6,45
12	0	-1	0	0	0	0	0	1	0	5,18	4,89	5,62	5,23
13	0	0	1	0	0	0	0	0	1	5,74	5,24	5,05	5,34
14	0	0	-1	0	0	0	0	0	1	5,29	5,88	5,14	5,44

We checked the variance for the reproducibility of the experiment and tested the hypothesis of uniformity of the variance according to the Cochran criterion, the calculated value of which was 0.1305 and 0.3924 with a table value for our experiment. The hypothesis of uniformity of experience was accepted based on the condition of uniformity of the variances of the experimental results ($G_{cal.} \leq G_{tabl.}$). The hypothesis of the normality of the dispersion was tested using the Pearson agreement criterion.

The values of coefficients of the experimental model were calculated (Table 4.4). We checked the significance of coefficients according to the Student's t -test at 5% significance level of regression equations, and also determined their confidence intervals:

Table 2. Values of regression coefficients of the mathematical model equation

Coefficient	b_0	b_1	b_2	b_3	b_{12}	b_{13}	b_{23}	b_{11}	b_{22}	b_{33}
Calculated	4,92	-0,57	0,23	-0,44	-0,04	0,29	0,02	0,3	0,8	0,35
Accepted	4,92	-0,57	0,23	-0,44	0	0,29	0	0,3	0,8	0,35
t_{005}^{pacu}	50,25	5,87	2,44	4,50	0,49	3,02	0,21	3,06	8,172	3,57
t_{005}^{mab1}	2,04	2,04	2,04	2,04	2,04	2,04	2,04	2,04	2,04	2,04

The calculated factors, the criterion of which t_{005}^{pacu} is greater than the tabular one t_{005}^{mab1} , are considered significant. Factors b_{12}, b_{23} are insignificant.

Excluding factors b_{12}, b_{23} , we obtained a regression equation describing the dependence of parameters and operating modes of the dispersion system of a pneumatic grain seeder. After determining and substituting the coefficients of the regression equation in a polyno-

mial of the second degree, the regression equation was obtained in encoded form:

Equation of the mathematical model of the uneven seed distribution between seed lines in encoded form:

$$Y = 4,92 - 0,57X_1 + 0,239X_2 - 0,44X_3 + 0,296X_1X_3 + 0,3X_1^2 + 0,8X_2^2 + 0,35X_3^2. \quad (1)$$

To check the adequacy of the model, the variance of the adequacy was determined and the value of the F-criterion was calculated: $S_{ao}^2 = 0,3349$; $F_{pacv} = 2,3299$.

The calculated value of the F-criterion at 5% significance level and with our number of degrees of freedom is 3.7. We can accept the hypothesis about the adequacy of the model based on the condition $F_{cal} \leq F_{tabl}$. A mathematical model with 95% accuracy describes the nature of the influence of factors on the response.

The influence of factors on the optimization parameter can be estimated using the diagram (Figure 1). The greatest influence on the coefficient of variation is exerted by the radius of the disperser and the speed of rotation of the fan impeller, which indirectly confirms the results of theoretical studies.

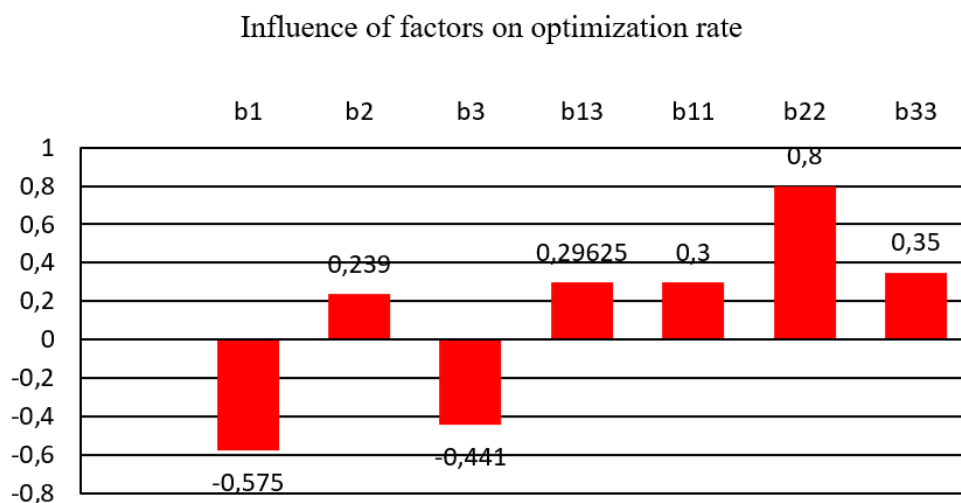


Fig. 1. Influence of factors on optimization rate

The regression equation in canonical form is the following:

$$Y - Y_s = B_1X_1^2 + B_2X_2^2 + B_3X_3^2. \quad (2)$$

Optimal values of factors $X_1 = 0,818$; $X_2 = -0,149$; $X_3 = 0,284$.

The resulting model (2) is three-dimensional. We can only analyze two-dimensional models. A two-dimensional model is obtained by differentiating the model (2) in partial derivatives. Therefore, we apply the following method for the convenience of its analysis. We will fix each of factors at its optimal value in turn. The other two will vary. Thus, when fixing one of the factors at the optimal value, we will get the range of variation of the other two factors and, based on its analysis, we will choose the intervals of variation of variable factors, at which the required degree of unevenness of the seed dispersion between the seed lines of the pneumatic grain seeder is provided. The graphical dependences of the disperser's radius, the minute seed supply, and the fan speed are shown in Figures 2-4.

In Figure 2, the fan speed $X_3=0,284$ is taken as a fixed factor.

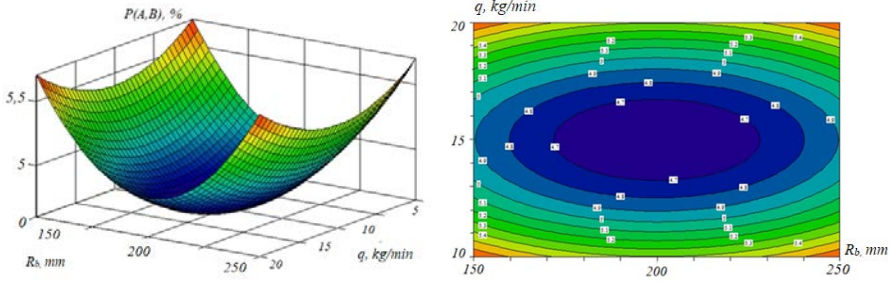


Fig. 2. Surface and cross-section of the response of dependence of the unevenness of seed disperser $P(A,B)$ on the radius of the disperser R_b and the minute seed supply q at a fixed speed of the fan impeller N_v .

The transformed equation of the mathematical model in the canonical form (1) will take the form, taking into account the fixed factor X_3 :

$$Y - Y_s = B_1 X_1^2 + B_2 X_2^2 \tag{3}$$

In Figure 3, the minute supply of seed material is taken as a fixed factor $X_2 = -0,149$.

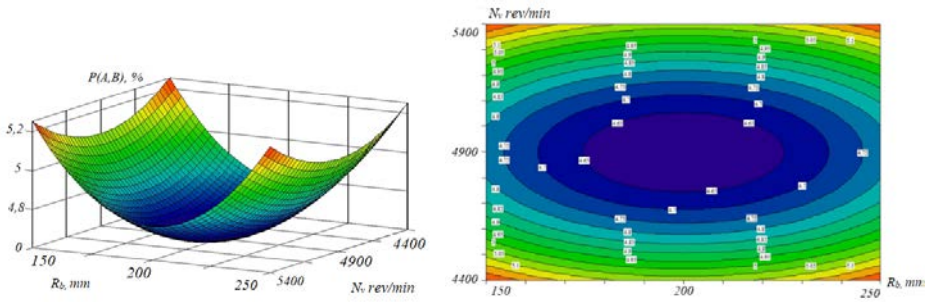


Fig. 3. Surface and cross-section of the response of dependence of the unevenness of seed disperser $P(A,B)$ on the radius of the disperser R_b and the speed of rotation of the fan impeller N_v at a fixed minute seed supply q .

The transformed equation of the mathematical model (1) in the canonical form (2) will take the following form, taking into account the fixed factor X_2 :

$$Y - Y_s = B_1 X_1^2 + B_3 X_3^2 \tag{4}$$

In Figure 4, the radius of the disperser’s chamber is taken as a fixed factor $X_1 = 0,818$.

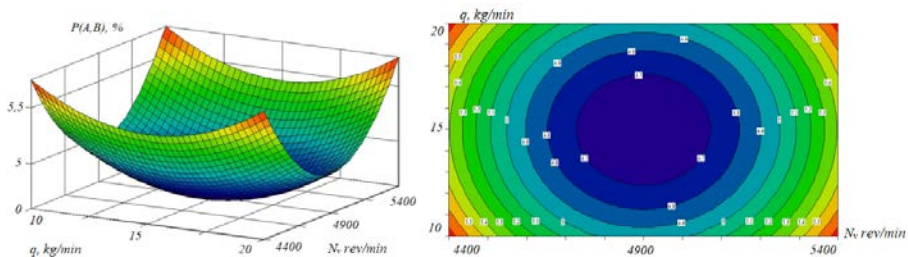


Fig. 4. Surface and cross-section of the response of dependence of the uneven seed disperser $P(A,B)$ on the minute seed supply q and the speed of rotation of the fan impeller N_v at a fixed radius of the disperser’s chamber R_b .

The transformed equation of the mathematical model in the canonical form (4.1) will take

the following form, taking into account the fixed factor X_1 :

$$Y - Y_s = B_2 X_2^2 + B_3 X_3^2 . \quad (5)$$

The cross sections of the response surfaces shown in Figures 4.6 - 4.8 are ellipsoids, and the centers of the response cross sections are the extremum at which the minimum unevenness of the dispersion is achieved.

Coordinates of the extremum point, at which the minimum non-uniform seed dispersion between the seed lines is achieved $Y = 4,6 \%$: $X_1 = 0,818$; $X_2 = -0,149$; $X_3 = 0,284$.

or in natural units:

- radius of the chamber of the seed dispenser $R_b = 241$ mm.
- minute seed supply $q = 14,26$ kg/min;
- frequency of rotation of the fan impeller $N_v = 5042$ rev/min.

The regression equation (2) can be represented in decoded form as follows:

$$y = 68,052 - 0,059x_1 - 0,912x_2 - 0,017x_3 + 5,92 \cdot 10^{-6} x_1 x_3 + 3 \cdot 10^{-5} x_1^2 + 0,032x_2^2 + 1,4 \cdot 10^{-6} x_3^2 . (6)$$

The obtained values lie in the region of the factor space of the experiment. Therefore, the intervals and levels of variation of factors were chosen correctly.

An increase in the uneven distribution between seed lines occurs with an increase in the minute supply of seeds q to the dispenser, as well as with a decrease in the speed of the fan impeller N_v . It is impossible to optimize the minute seed supply q as a factor, since it is determined in each specific case, depending on the established seeding rate. The negative impact of the minute feed q on uneven seed dispersion can be minimized by increasing the number of dispensers on the seeder.

After analyzing the surfaces and cross-sections in Figures 2 and 3, it can be concluded that the radius of the dispenser R_b had a greater influence on the transverse unevenness of the dispersion of the seeder than the minute seed supply q and the speed of the fan impeller N_v . Also, the speed of rotation of the fan impeller N_v has a greater effect on the unevenness than the minute seed supply q (Figure 4).

The obtained data allow us to form the following recommended ranges of changes in the levels of independent factors: for the radius of the seed dispenser $R_b \in [170; 230]$ mm, for minute seed supply $q \in [12; 18]$ kg/min, for the speed of rotation of the fan impeller $N_v \in [4700; 5100]$ rev/min, it corresponds to the range of speeds $u \in [13; 17]$.

In the course of the laboratory experiment, the probability of the seed dispersion through seed lines in the interval equal to 5 % of specified seeding rate was investigated, the results of which are shown in Figure 5 [6]. The studies were carried out with a minute seed supply of 10, 15 and 20 kg /min, the radius of the centrifugal dispenser R_b was 0.2 m, and its height $h = 0.8$ m, the speed of the fan impeller N_v was assumed to be 5042 rev/min, which corresponds to the air flow velocity u equal to 16.42 m/s.

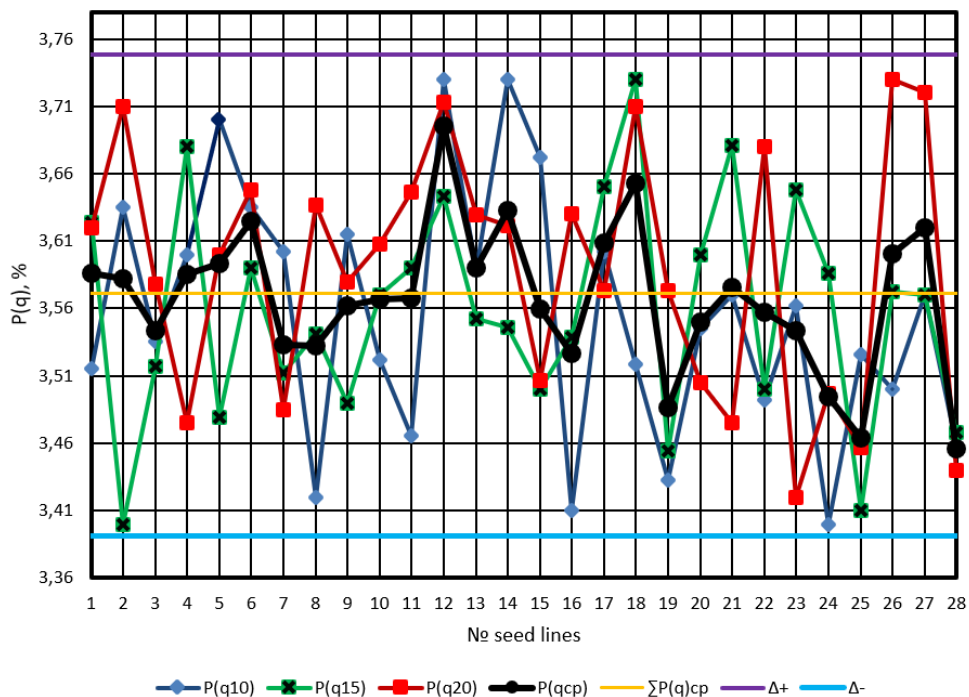


Fig. 5. Probability of seed dispersion in seed lines at different minute seed supply q

The results of studies of the probability of seed dispersion were processed by statistical methods using the Laplace function [7, 8]. The probability of the random value of seed entering the one of the 28 seed lines at various minute seed supply was 94.3% at 10 kg / min, 96.83% at 15 kg/min, and 94.26% at 20 kg/min, which indicates the normal distribution of the random seed dispersion by the centrifugal dispersion system of the pneumatic grain seeder.

3 Conclusion

A mathematical model of uneven seed dispersion by a centrifugal dispersion system has been developed in order to confirm experimentally the parameters and operating modes of the pneumatic grain seeder. Based on the analysis, which determined that with the height of the disperser's chamber $h=0.8$ m, the radius of the disperser $R_b=0.241$ m and the speed of the seed movement $u=14.26$ m/s, the unevenness of the seed dispersion is $P(A,B) = 4.6\%$, which is 8.3% less than that of the serial dispersion system of the pneumatic grain seeder. The relative error in the results of experimental studies of uneven seed dispersion between the seed lines is no more than 5% of the results obtained in the course of theoretical studies.

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