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Article

Optimization of the Adjustable Screw Dosing Parameters of a Grain Seeder Designed for Agricultural Dryland

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Abstract: This study focuses on optimizing the parameters of a screw dosing system in grain seeders for dryland agriculture to improve seed sowing efficiency. While ensuring agronomic requirements for seed distribution remains a challenge, the study addresses this gap by conducting multi-factor experiments using the Hartley-3 design. The research examines the effects of funnel surface area, screw rotation speed, and aggregate movement speed on sowing performance. Results indicate that these factors significantly influence sowing rates and seed distribution. Optimal settings for screw rotation and funnel area were identified, which promote uniform seed distribution. These findings have important implications for enhancing agricultural efficiency in dryland farming.

Keywords: Screw, Grain, Seeder, Funnel, Hartley, Cochran, Regression, Student.

1. Introduction

According to statistical data, over 133,000 hectares of land in the republic are dedicated to wheat, and more than 86,000 hectares are used for barley cultivation. Therefore, the total grain area amounts to 219,000 hectares. From this figure, it can be seen that if the quality of seed sowing in irrigated areas is improved and the number of seeds is sufficiently ensured, it is possible to increase the yield by 1.5 centners per hectare in exchange for ensuring the completeness of seed sowing, resulting in an additional 32,850 kg of grain production. Based on this, a prototype of the seed sowing machine for irrigated fields was developed, and experiments were conducted with this seeder. The need for multi-factor experimental results arose to determine the acceptability of the parameters obtained from one-factor experiments [1, 2, 3, 4].

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2. Materials and Methods

The mathematical planning method of multi-factor experiments was used to determine the parameters of the screw volumetric feeder that ensures seed sowing at the level of agronomic requirements [3, 4]. In this case, it was considered that the second-degree polynomial would fully reflect the influence of factors on the assessment criteria, and the experiments were conducted according to the Hartley-3 design [4, 5, 6].

Based on the results of the theoretical research and one-factor experiments, the following parameters were accepted as the factors having the greatest influence on the sowing rate:

1. Surface area of the funnel at the bottom of the bunker;
2. Speed of screw rotations;

3. Speed of the aggregate movement.

The factors are conditionally designated as follows: X1– surface area of the funnel at the bottom of the bunker, X2 – speed of screw rotations, X3 – speed of the aggregate movement. Table 1 presents the factors, their designations, ranges of variation, and levels.

Table 1. Factors, their designations, ranges of variation, and levels

Factors and Their Units of Measurement	Conditional Designation	Range of Variation	Levels		
			Low (–1)	Basic (0)	High (+1)
Bunker bottom funnel surface area, mm^2	X_1	20	280	300	320
Screw rotation speed, r/min	X_2	10	50	60	70
Aggregate movement speed, km/h	X_3	1	5	6	7

In conducting multi-factor experiments, the assessment criteria were accepted as the sowing rate of seeds Y1 (kg/ha) and the uneven distribution of seeds according to the seeder coverage width Y2 (%). To minimize the influence of uncontrolled factors on the assessment criteria, the sequence of the experiments was determined using a random number table [7, 8].

The data obtained from the experiments were processed according to the "PLANEX" program developed by the Experimental Testing Department of the Scientific Research Institute of Agricultural Mechanization. In this process, Cochran's criteria were used to assess the homogeneity of variance, Student's criteria for evaluating the regression coefficients, and Fisher's criteria for assessing the adequacy of regression models.

The data obtained from the experiments were processed in the specified order, leading to the following regression equations that adequately describe the sowing rate of seeds Y1:

$$Y1 = 101{,}5 + 53{,}4\,X1 + 40{,}350X2 - 35{,}883X3 - 3{,}533X12 + 28{,}717X1X2 -$$
$$-21{,}6\,X1X3 - 0{,}417\,X22 - 28{,}683X2X3 + 3{,}050\,X3\,2 \quad (1)$$

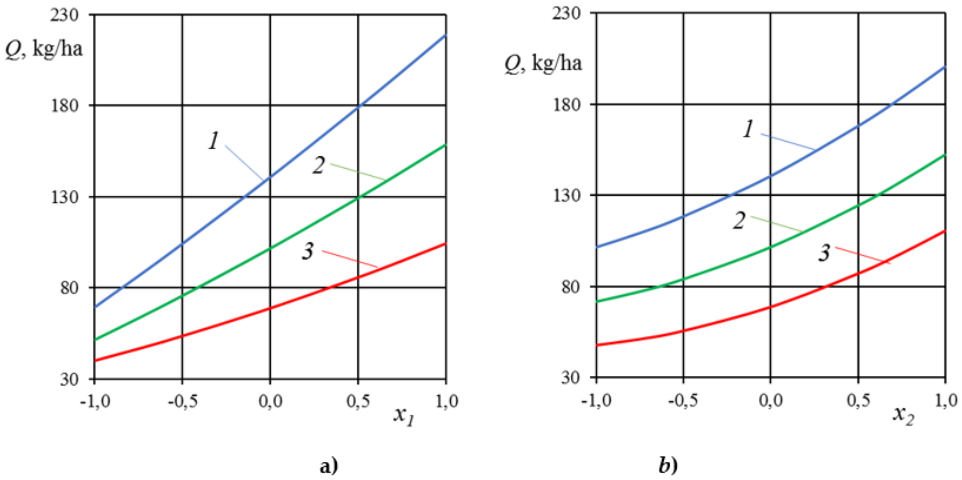
uneven distribution of seeds (Y2),

$$Y2 = 2{,}264 + 0{,}029X1 - 0{,}321X2 - 0{,}041X3 - 0{,}023\,X12 + 0{,}043\,X1X2 +$$
$$+0{,}014\,X1X3 + 0{,}471X22 + 0{,}012\,X2X3 + 0{,}013\,X32 \quad (2)$$

The obtained regression equations (1-2) and the analysis of the graphs constructed based on them (Figures 1-2) indicate that all factors significantly affect the assessment criteria.

3. Results and Discussion

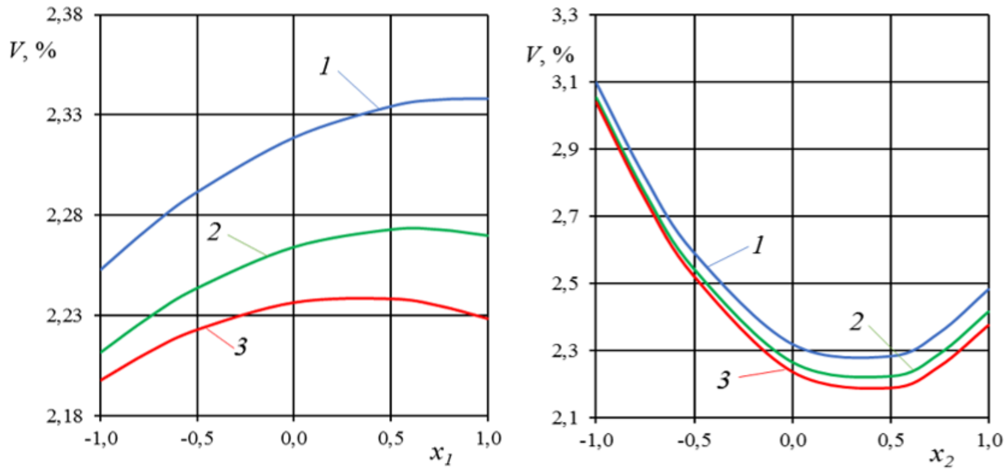
1a – The analysis of the graphs presented in the figure shows the following: at different speeds of the aggregate, an increase in the sowing rate is observed as the surface area of the funnel increases. It can be seen that the sowing rate is linearly correlated with the surface area of the funnel.



When the factor X3 is at levels -1, 0, and 1,

Figure 1. Graphs of the variation in sowing rate as a function of factors X1 (a) and X2 (b).

1b – The analysis of the graphs presented in the figure shows the following: for the specified quantity of seeds, an increase in the sowing rate is observed as the speed of the screw rotations increases at different speeds of the aggregate. It can be seen that the sowing rate is related to the speed of the screw rotations according to a quadratic parabolic relationship. 2a – The analysis of the graphs presented in the figure shows the following: at different speeds of the aggregate,



When the factor X3 is at levels -1, 0, and 1,

Figure 2. Variation of seed unevenness as a function of factors X1 (a) and X2 (b).

As the surface area of the funnel increases, the uneven distribution of seeds initially shows a sharp increase, continuing until the surface reaches 300 mm². When the surface area is in the range of 300-320 mm², the unevenness does not change significantly. It can be seen that the uneven distribution of seeds according to the seeder coverage width is related to the surface area of the funnel by a cubic parabolic relationship.

2b – The analysis of the graphs presented in the figure shows the following: at different speeds of the aggregate, as the speed of the screw rotations increases, the distribution of seeds sharply decreases, reaching the smallest value at 60-62 r/min. As the number of screw rotations increases towards 70 r/min, the unevenness also increases. When the number of screw rotations is 70 r/min, the amount of seeds falling into the bags attached to the twelve volumetric feeders is at the specified level, while the excess seeds are observed to fall into the additional container. This situation indicates that the screw rotates at a speed of 1.16 revolutions per second, meaning it makes 1.16 revolutions instead of a complete single revolution. This results in the screw delivering wheat to the second volumetric feeder 16% faster than intended.

However, during this time interval, the volumetric feeders operate as usual, continuing to deliver wheat into the hoppers while collecting the excess into the additional container. As a result, the amount of seeds falling into the additional container increases, which leads to a shortage of wheat in the bunker at the specified area.

The regression equations (1) and (2) establish the following values, which ensure that the assessment criteria Y1 for the sowing rate is 110 kg/ha, and Y2 for the uneven distribution of seeds according to the seeder coverage width is less than ±3% (see Table 2).

Table 2. Optimal values of the screw volumetric feeder

X_3		X_1		X_2	
code.	result, km/h	code.	result, mm²	code.	result, r/min
1	7	0,831	316,63	0,313	63,13
0	6	0,098	301,96	0,074	60,74
-1	5	-0,242	295,17	-0,213	57,87

4. Conclusion

The study successfully identified the optimal parameters for the screw volumetric feeder in a grain seeder designed for dryland agricultural conditions, demonstrating that the surface area of the funnel, screw rotation speed, and aggregate movement speed significantly influence both seed sowing rates and distribution. The findings suggest that for optimal performance, the screw should rotate at speeds between 58-63 r/min with a funnel surface area of 295-316 mm² to ensure an even seed distribution with minimal deviation. These results imply that precise control of these variables can enhance agricultural productivity in dryland environments by improving sowing accuracy. Further research should explore the application of these findings across varying soil conditions and seed types to refine the feeder's adaptability and efficiency in diverse agricultural scenarios.

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