INFLUENCE OF SEED DENSITY AND GEAR RATIO ON QUANTITY OF SOWED SEEDS

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Abstract. The study aims to establish the relationship between the density of sown seeds, the gear ratio in the transmission system of the Saxonia A200 seed drill and the amount of seeds sown. A laboratory experiment was performed at the Department of Mechanization of Agriculture at the Agricultural University of Plovdiv. The main variables were the density of the material to be sown and the gear ratio (rotation speed of the seed drill). Each of the two factors changes on three levels. The experiment was performed with grass mixture seeds with a density of 250 kg·m^{-3}, oats with a density of 537 kg·m^{-3}and wheat with a density of 825 kg·m^{-3}. Gear ratio changes as follows: at the lowest gear the gear ratio is 70.5, at the highest gear the gear ratio is 1.25 and at the average gear the gear ratio is 35, 0. It was found that the gear ratio has a stronger effect on the change in the amount of seed sown compared to the density of the seed. About 61.1% of this change is due to the gear ratio and 33.3% to seed density. It was found that 5.6% of the change in the amount of seeds sown was due to other factors not considered in the present study. To determine the functional relationship between the factors and the observed indicator the regression analysis was performed. The corrected multiple correlation coefficient was $R^2 = 0.937$, confirming the strong relationship between the selected factors and the observed variable. The level of significance in the obtained model was $p < 0.001$. An adequate regression model is obtained, which can be used for forecasting and solving optimization problems.

Keywords: sowing apparatus, gear ratio, seed density, seed quantity.

Introduction

In the cultivation of cereals, sowing is one of the most responsible operations, as the correctly chosen technology, the exact adjustment of the sowing rate depending on the specific soil and climatic conditions, determine future yields [1-2]. The main element in the drills is their sowing apparatus. They are different both in purpose and design [3-4]. Conditionally they can be divided into several groups: mechanical, hydraulic, electromechanical, pneumatic and electropneumatic. Currently, the most widely used are pneumatic and mechanical. Of the mechanical ones, brush seed meter is used for sowing different crops, as it universal. It has a relatively simple construction and it is easy to adjust the sowing rate. Brush sowing apparatus is characterized by good uniformity of sown seeds and is less affected by external factors [5]. The feeding of the seeds in the devices of this type is carried out under the action of the friction forces in the surface of the pins and indirectly depends on the physical and mechanical properties of the seeds. Those with a horizontal axis of rotation have very good technological indicators. They are small in size, reliable, durable, have good sowing qualities and are a good alternative to traditional sowing machines. Brush sowing apparatus [6] sows the seeds of crops with a wide range of their physical and mechanical characteristics. The most promising are those which working bodies actively separate the seeds connected from the hopper and feed them into the seed pipelines or into the pneumatic conveying system. As a disadvantage of this type of apparatus it can be pointed out that above the sowing opening a prism of the seed sliding is formed. This is the reason for the unevenly compacted flow and as a result – batch sowing.

Currently, one of the most common ways to change the speed of rotation of seed drills is the use of replaceable gears and reducers [7]. Unfortunately, this method has a number of disadvantages that affect sowing and ultimately the harvest. Thus, one of the main disadvantages is the difficulty in regulating the sowing rate due to the abrupt change in the gear ratio of the gearbox.

Some authors suggest replacing the mechanical gearbox for driving the shaft of seeders with electric drive [8]. Important indicators in the operation of these sowing machines are the gear ratio and seed density. The basis of the electric drive of the sowing machines and regulation of the sowing norm are mechatronic systems. Existing control systems of sowing machines are intricate and not reliable enough [9]. In these systems, devices are connected by a variety of signal and power wires. This leads to a "problem of interfaces" and a decrease in the efficiency of the control process. The solution to this problem is based on the mechatronic approach or combining elements and control units into mechatronic modules. They are characterized by reliability, compact design and lower cost. When sowing cereals,

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as wheat, barley, oats and etc., an important indicator for adjusting the drill is the seed density [10]. Studies [11] have shown that it varies widely for different cultures.

The aim of the present study was to establish the relationship between the seed density, the gear ratio in the transmission system of the Saxonia A200 seed drill and the amount of seed sown from one sowing apparatus.

Materials and methods

To achieve this goal, during 2021 in the laboratory of the Department of Agricultural Mechanization at the University of Plovdiv, a stationary laboratory experiment was conducted. The experimental set-up consisted of a sowing machine and auxiliary elements of the Saxonia A200 seeder, widely used by agricultural producers in Bulgaria. The following independent variables changed during the experiment: the density of the seeds (Y) and the gear ratio of the seed-drill (X). Each of the two factors changes on three levels. Grass seeds with $Y = 250$ kg·m^{-3}; oats $Y = 537$ kg·m^{-3} and wheat $Y = 825$ kg·m^{-3} were selected. For the other factor, the variables were $X = 70.5$; $X = 1.25$ and $X = 35.0$. With each new experiment, the seeder is filled with a new amount of tested seeds. To emptying the seed box from the seeds of the previous experiment, the seed drill was manually driven by means of a crank with 2094 s^{-1} revolutions. To simulate the process of sowing the seeds from the sowing machine, it was rotated by 4397 s^{-1} revolutions, which corresponded to 1/10 of the sowing rate. The sown seeds were collected and weighed on an FR-H 6000 scale to within ± 0.1 g.

To facilitate the experiment, the amount of sown seeds was first determined for grass mixtures at different X, then for oats and wheat. Measurements were performed for each point of the experimental plan in 5-fold repeatability.

The obtained data were averaged and factorial and regression analyzes were performed with them. The factor analysis (by the method of the main diagonal) established the influence of each of the factors on the change of the sown quantity of seeds.

Regression analysis determined the functional relationship between the factors and the observed indicator. The obtained regression equation is graphically illustrated with a regression surface using the software product Statistics v.7.

The plan of the experiment is shown in Table 1.

Table 1

Plan of the experiment – independent variables

Gear ratio of the seed drill (X)	Density of the seeds (Y) kg·m^{-3}
70.50	825.00
70.50	250.00
1.25	825.00
1.25	250.00
35.00	825.00
35.00	250.00
70.50	532.00
1.25	532.00

Results and discussion

The results shown in Table 2 were obtained from the operation of only one sowing apparatus. To determine the amount of seed sown from the whole drill, it is necessary to multiply the amount of the seed sown from one sowing machine by the number of sowing machines of the observed seed drill.

From Table 2 it can be seen that with increasing Y, the sown amount of seeds increases linearly. This is logical, because at the same number of revolutions the sowing machine exports the same volume of seeds. The higher the density multiplied by this volume, the greater the amount (weight) of the seeds.

On the other hand, as X decreases, the output shaft of the gear unit starts to rotate faster (at a higher speed), respectively the shaft of the seed drill. This leads to the removal of more seeds at the same speed of the drive wheel.

Table 2

Averaged data from the conducted experiments

Independent variables		Sown seed quantity for 42 turns, g (*Z*)
Gear ratio of the seed drill (*X*)	Density of the seeds (*Y*), kg·m^{-3}	
70.50	825.00	9.6
70.50	250.00	3
1.25	825.00	502.4
1.25	250.00	151.4
35.00	825.00	17.6
35.00	250.00	5.6
70.50	532.00	6
1.25	532.00	322

The factor analysis performed in Table 3 gives grounds to claim that *X* has a stronger effect on the change of *Z* compared to *Y*. About 61.1% of this change is due to *X* and 33.3% are under the influence of *Y*. In conclusion, 94.4% of the change in *Z* is due to both factors. Only 5.6% of this change is due to other factors not reported in the current study. According to [12], this is a prerequisite to conduct a regression analysis with only these two factors (*Y*; *X*), shown in Table 4.

Table 3

Factor analysis, Eigenvalues (*Y*; *X*), extraction: principal components

Variable	Eigenvalue	% Total	Cumulative, Eigenvalue	Cumulative, %
X	1.83	61.09	1.83	61.09
Y	0.99	33.33	2.83	94.42

Table 4

Results of regression analysis

Variable	Beta	Std. Err.	*B*	Std. Err.	*t*(4)	*p*-level
X	-1.711	0.554	**-8.000**	2.591	-3.086	0.037
Y	1.670	0.152	**0.616**	0.056	11.009	0.0004
X^2	1.797	0.521	**0.126**	0.036	3.445	0.026
X.Y	-1.288	0.247	**-0.010**	0.002	-5.214	0.006

X **–** gear ratio of the seed drill**,** ***Y*** **–** density of the seeds**,** kg·m^{-3}

The corrected multiple correlation coefficient $R^2 = 0.937$ shows a strong relationship between the selected factors and the observed variable, as 94% of the change in *Z* is due to *X* and *Y*. On this basis, it is assumed that the resulting regression model is sufficiently consistent of the experiments performed at a significance level $p < 0.0029$. According to the authors [12], this is a prerequisite to use to predict and solve optimization problems.

The resulting regression model is described by:

$$Z = -8X + 0.616Y + 0.126XX - 0.010XY \quad (1)$$

The regression surface $Z = f(X, Y)$, graphically reflecting the relationship between the gear ratio, seed density and the sown quantity is presented in Fig. 1.

From the figure it was found that with increasing *Y* and decreasing *X*, the sown amount of seeds *Z* increases. The obtained results confirm the research [1] that at gear ratios over 30 the dependence between the speeds of rotation of the wheels and the sown amount of seeds is nonlinear.

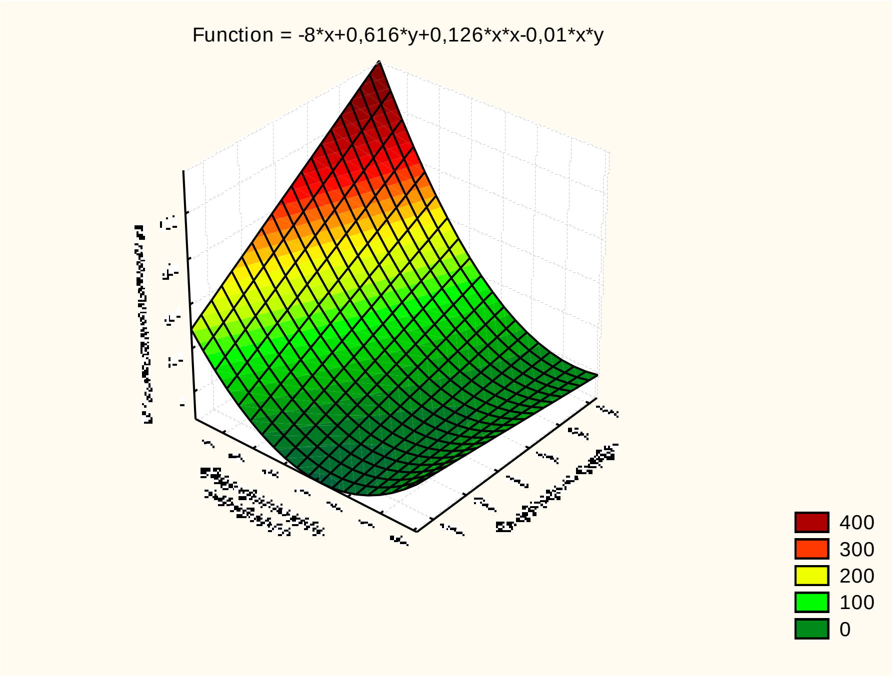

Fig. 1. **Regression surface for relationship between gear ratio, seed density and sown amount *Z* = f (*X*, *Y*)**

Conclusions

1. The change in the amount of seed sown *Z* is due in 94% of the cases to the gear ratio in the drive system *X* of the sowing apparatus and the seed density *Y*. 61% of this change is due to the gear ratio and 33% to the seed density.
2. A regression model with the multiple correlation coefficient $R^2 = 0.937$ was obtained. This shows a strong relationship between the selected factors and the observed variable. The model is adequate with the experimental data at a significance level $p < 0.0029$ and from a statistical point of view can be used to solve practical problems.

Author contributions:

Conceptualization, D.K.; methodology, D.K. and I.B.; software, D.K., I.B. and I.Z.; validation, D.K. and A.A.; formal analysis, D.K. and A.A. investigation, D.K., I.B. and I.Z.; data curation, D.K.; writing – original draft preparation, D.K..; writing – review and editing, A.A.; visualization, D.K., A.A.; project administration, D.K.; funding acquisition, D.K. All authors have read and agreed to the published version of the manuscript.

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