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INVESTIGATION OF THE GRAIN SEEDER OPENER OPERATION FOR ENVIRONMENTAL FRIENDLY TECHNOLOGIES OF CROPS PRODUCTION

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Abstract

Resource-saving technologies for sowing crops involve minimizing tillage with scientifically-based husbandry and rational use of resources. Such technologies include minimal and zero tillage based on mulched and direct sowing, with simultaneously applying fertilizers at different levels. The authors suggest the fundamental directions of an integrated farming system in relation to crops production, which, along with the use of all the positive environmental features of the organic, biological, biodynamic systems, allow using the chemical fertilizers within a limited framework. Consequently, it could lead to the dynamic development and increase rural sustainability as a whole. Based on these research materials, prototypes of seeders with experimental paws for different levels of fertilizing and sowing seeds were developed and manufactured. Field experiments with that grain seeder opener have shown steady work of combines in sowing grain crops.

***Key words**: grain seeder opener, environmental friendly technology, ecology, fertilizer.*

INTRODUCTION

Currently, the questions of technical support for high-quality sowing with minimal labor and production resources, as well as the rational use of mineral fertilizers remain relevant, this is due to increased intensification of production, as well as the development of an integrated approach to the cultivation of grain crops, all this would increase the environmental friendliness of products. The optimal conditions for the growth and development of plants depend on methods of sowing, in which a sufficient amount of nutrients, light, moisture, heat is provided, as well as providing the most favorable nutritional area and the lowest production costs. Therefore, the method of sowing is primarily chosen depending on climatic conditions, soil and the ratio of nutrients in it, the sowing qualities of seeds, as well as the needs of the cultivated crop in various nutrients. To achieve maximum yield when sowing, it is necessary to place the seeds at a given depth and observe the optimal area of their nutrition (Kalabushev et al., 2019).

MATERIALS AND METHODS

Laboratory studies were carried out with the aim of determining the optimal design parameters of a grain seeder opener at different levels in fertilizer application and sowing seeds, using multi-factorial design of the experiment, as well as conducting experiments according to the one-factor plan.

The basis of the research adopted methodology, Maintenance Standard (MS) AIST 5.6-2010. “Tests of agricultural machinery. Sowing and planting machines. Destination metrics. General requirements” and Interstate Standard (IS) R 52778-2007 “Testing of agricultural machinery. Operational and technological assessment methods”. The coefficient of variation was taken as a criterion for the uneven distribution of seeds over the sieving area.

Investigations of the grain seeder opener at different levels in fertilizing and sowing seeds were carried out with the laboratory equipment (Figures 1, 2). This equipment consists of a drive trolley (11), including a frame of the drive trolley (10), which are mounted on the soil channel (4). The tested grain seeder opener (15) is fixed on the drive trolley (11) and mounted the sowing system, consisting of a hopper for seeds (12), sowing apparatus (13) and seeds tube (14). The trolley (11) is driven through a cable using a gear motor (5). The motor gearbox (8) using chain gears drives the shaft (13) of the sowing coils. Management of the soil canal is carried out from the remote control (18).

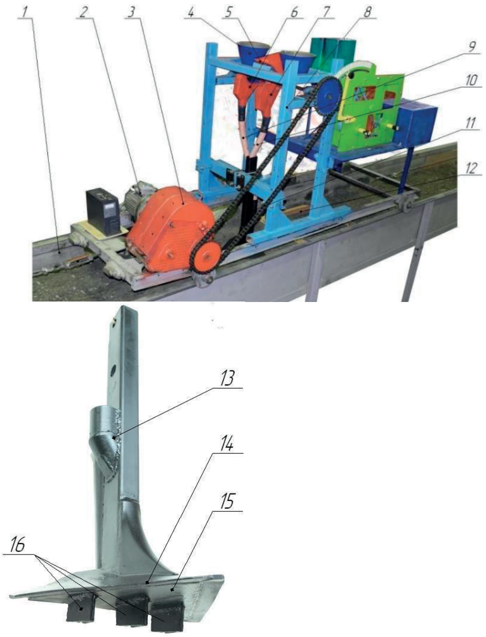

Figure 1. General view of the laboratory equipment and experimental grain seeder opener:
1 - soil channel; 2 - gear motor; 3 - chain gear; 4 - seed hopper; 5 - fertilizer hopper; 6 - seed sowing apparatus; 7 - fertilizer sowing apparatus; 8 - drive trolley; 9 - seeds tube; 10 - piping; 11 - grain seeder opener; 12 - screening surface; 13 - rack pipe line; 14 - lancet paw; 15 - sole; 16 - hollow wedges

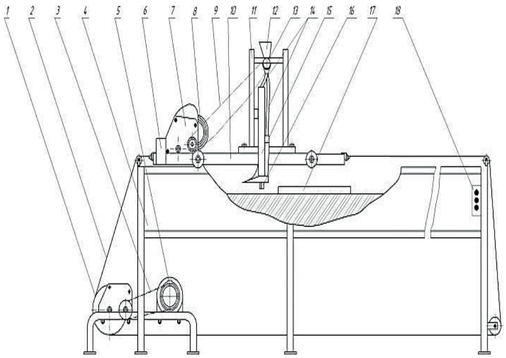

Figure 2. Scheme of the laboratory equipment:

1 - the system of pulley blocks; 2 - cable; 3, 9 - chain transmission; 4 - soil channel; 5, 8 - gear motor; 6 - frequency converter; 7 - gear; 10 - drive trolley; 11 - hitch; 12 - hopper; 13 - seed and fertilizer sowing machines; 14 - seeds tube; 15 - grain seeder opener; 16 - hollow wedges; 17 - screening surface; 18 - control panel

To bring the experimental conditions closer to the real ones, the grain seeder opener (15) was mounted on the drive carriage (11) so that the hollow wedges (16) of the fertilizer were deepened into the soil to the working depth, and the cutting plane of the grain seeder opener practically touched the soil surface. Seeds were poured into the hopper (12) (at least ¾ of its total volume) and the sowing apparatus was filled with seeds, starting it for a while. Next, the seeding rate was set using the frequency converter (6). From the control panel (18) the trolley and sowing apparatus (13) were turned on. When the grain seeder opener sole moved (15), the hollow wedges (16) were buried in the soil, forming lines for fertilizing 3 cm below the soil surface, then the sole sealed the lines and leveled the surface of the seed bed. In this case, the seeds passing through the sowing apparatus (13) and seeds tube (14), falling on the seed distributor, were distributed over the soil surface prepared by the grain seeder opener sole. Furthermore, a frame (17) with 5 x 5 cm cells was placed on the sieving surface

To get as close as possible to real conditions, the grain seeder opener (15) was mounted on the drive carriage (10) so that the plane of movement of the grain seeder opener (15) with hollow wedges (16) practically touched the sieving surface (box for collecting fertilizers) (17).

The drive carriage (11) is driven by a gear motor (5) by means of a chain hoist (1) and a chain gear (3). The shaft of the fertilizer metering device (13) of the reel and pin type, is driven by a gear motor (8) by means of chain gears (3), a multi-stage gearbox (7). Rotational speed of the drive shaft (13) is carried out using a frequency converter. The control panel (18) controls the equipment.

The experiments were carried out in the following sequence: they fill the hopper with granular fertilizers (at least ¾ of its total volume) and made the fertilizer metering machine to fill it with fertilizers. Then, in turn, the fertilizer distributors under study are installed in the fertilizer rack, and at the same time they include the drive of the cart and fertilizer sowing devices. Fertilizers moving from the hopper enter the fertilizer line through a fertilizer meter, passing through the fertilizer spreader and the hollow wedges (16) fall into the fertilizer container.

The variation coefficient of the seeds distribution over the sieving area with the grain seeder opener depends on many factors and their interaction with each other, which cannot be fully covered during the research.

When using grain seeders with reel sowing machines and grain seeder opener, the distribution of seeds over the sieving area can be described by Poisson's law:

$$Đ_m = \frac{\lambda^m}{m!} \cdot e^{-\lambda}$$

λ - the average number of seeds on the accounting row length; m - a random number of seeds (0 = 1); e - the base of the natural logarithms (e $\approx$2,718).

The uneven distribution of seeds over the sieving area is evaluated by choosing squares with the same number of seeds (W = 0, 1, 2, ..., n) and counting their number n_W.

The frequency of the squares is calculated by the formula:

$$\overline{P} = \frac{n_w}{n}$$

n_W - the number of seeds located in squares of 0, 1, 2 or more pieces; n - the total number of accounting squares (at least 300 pcs.) (Shumaev et al., 2016).

Average density $\overline{m}$ (average number of seeds) is found from the expression:

$$\overline{m} = \frac{n_c}{n}$$

n_c - total number of seeds squared.

We calculate the variation indicators: uneven distribution (coefficient of variation) (ν); standard deviation (σ), accuracy indicator (P) and the main mistake (ε).

Analyzing the uneven distribution of seeds, it is necessary to find out if there are any coincidences of the optimal, experimental frequencies of empty squares and squares with one plant.

Frequency Probability Dependencies P_0 and P_1 from the seeding rate, taking into account the field germination $R_{вс}$ are presented in the form of nomograms. Optimal values P_0 and P_1 is determined after implementation of the R coefficient based on the seeding density $\overline{m}$ in pieces per square 5x5 cm.

To determine the dependence of the design of the grain seeder opener at different levels in fertilizer application and sowing of seeds on the uneven distribution of seeds over the sieving area, conclusions are drawn by comparing the calculated frequency values with the experimental ones.

The studies were carried out at a seeding rate of 240 kg/ha, the grain seeder opener was moved at a speed of 2.5 m/s, while the sowing unit was installed at a height of 0.95 m.

The optimization criterion was the non-uniformity (coefficient of variation) of the distribution (ν) seeds and fertilizers according to the sifting area. Since it is impossible to take into account the influence of all factors when studying the process of seed distribution over the sieving area, therefore, 14 factors that most affect the grain seeder opener work were initially identified. Then, based on the specific tasks of the study, as well as a priori information, more significant factors were identified: the length of the wedges, the angle of inclination of the wedges in the longitudinal-vertical plane, the distance between the rows of wedges in the longitudinal-vertical plane, the width of the wedges, the width of the working part of the sole of the grain seeder opener necessary for closing grooves of wedges, the height of the sole relative to the cutting edge of the paw, the height of the seed distributor relative to the cutting edge of the paw, the speed of the grain seeder opener. To identify more significant factors, a screening experiment was carried out, which made it possible to reduce the number of further experiments by screening further insignificant factors. Further, the basis of a three-factor experiment was laid D-optimal plan, as a result of which regression equations were obtained for the process of sowing seeds of grain crops with simultaneous multi-level fertilizer application. The research results were processed on a personal computer using computer programs: Statistica 6.0 RUS, MathCAD 15, Microsoft Office and etc.

RESULTS AND DISCUSSIONS

To solve the problem, a grain seeder opener of different levels of fertilizer application and seed distribution was developed, manufactured and tested.

When determining the effect of the installation of hollow wedges (Figure 3) on the sowing quality, the coefficient of distribution of seeds variation over the sifting area was taken as an optimization criterion (ν, %). This parameter depends on many factors. In this regard, laboratory studies were carried out using the methodology for planning a multifactor experiment in a laboratory setting.

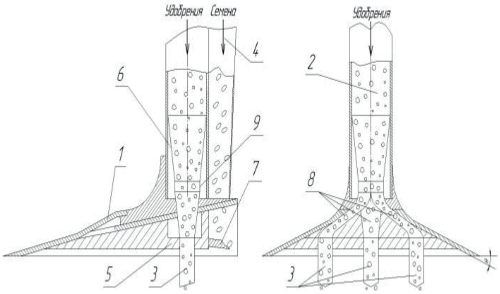

Figure 3. Grain seeder opener at different levels in fertilizer application and seed distribution:
1 - lancet paw; 2 - rack-pipe line; 3 - hollow wedges (knives); 4 - seeds tube; 5 - sole; 6 - guide funnel; 7 - seed distributor; 8 - supply channels; 9 - fat stream divider

After processing the results of a multivariate PC experiment in the Statistika 6.0 program, we obtained an adequate second-order mathematical model describing the dependence $\nu = f(\psi, \gamma, b)$ in encoded form:

$$Y = 46{,}635 - 0{,}129x_1 + 0{,}324x_2 + 0{,}257x_3 - 1{,}069x_1^2 - 1{,}639x_2^2 + \\ + 0{,}949x_3^2 + 0{,}355x_1x_2 - 1{,}797x_1x_3 - 0{,}099x_2x_3$$

To describe the response surface by a second-order equation, the theory of planning a multifactor experiment of uniform-uniform table design was used. After processing the results, an adequate model of the coefficient of variation of seed distribution (ν, %) was obtained, which in decoded form will be written as:

$$\nu = 44{,}2256 + 0{,}047 \cdot \psi + 10{,}3378 \cdot \gamma - \\ - 0{,}0888 \cdot b - 0{,}0005 \cdot \psi^2 - 11{,}1983 \cdot \gamma^2 + \\ + 0{,}0014 \cdot b^2 - 0{,}0008 \cdot \psi \cdot \gamma - 0{,}0021 \cdot \psi \cdot b + \\ + 0{,}0676 \cdot \gamma \cdot b \quad .$$

To study the response surface, two-dimensional sections with contour lines were constructed (Figure 4).

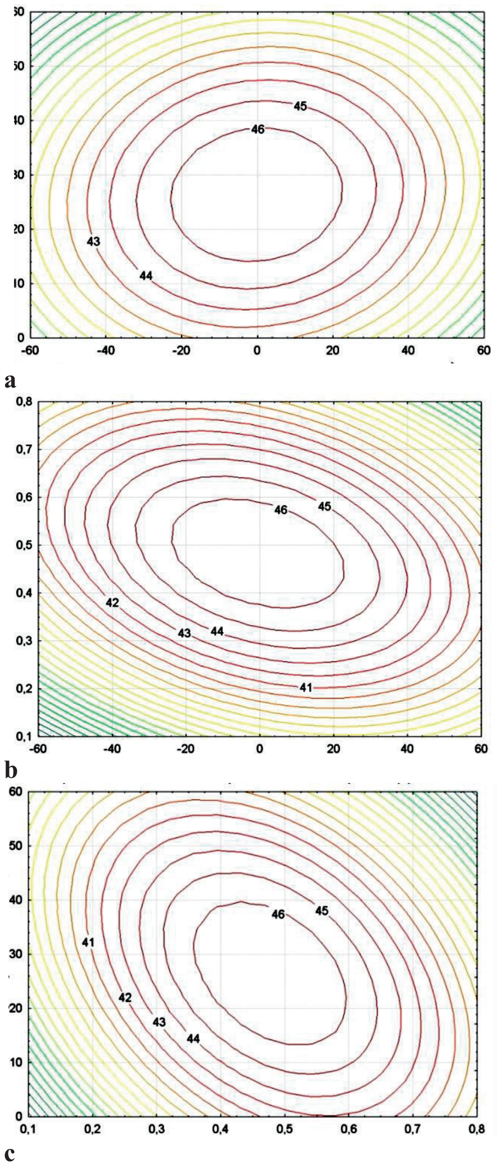

Figure 4. Two-dimensional cross-section of the response surface, characterizing the dependence of the coefficient of variation of the distribution of seeds over the sieving area (ν):
a) from the angle of inclination of the hollow wedges in the longitudinal vertical plane (ψ) and the width of the working part of the sole of the opener necessary for sealing furrows of hollow wedges (b); b) from the angle of inclination of the hollow wedges in the longitudinal vertical plane (ψ) and the tangent of the half angle of the solution of hollow wedges (γ); c) from the tangent of half the angle of the solution of hollow wedges (γ) and the width of the working part of the sole of the opener necessary for sealing furrows of hollow wedges (b)

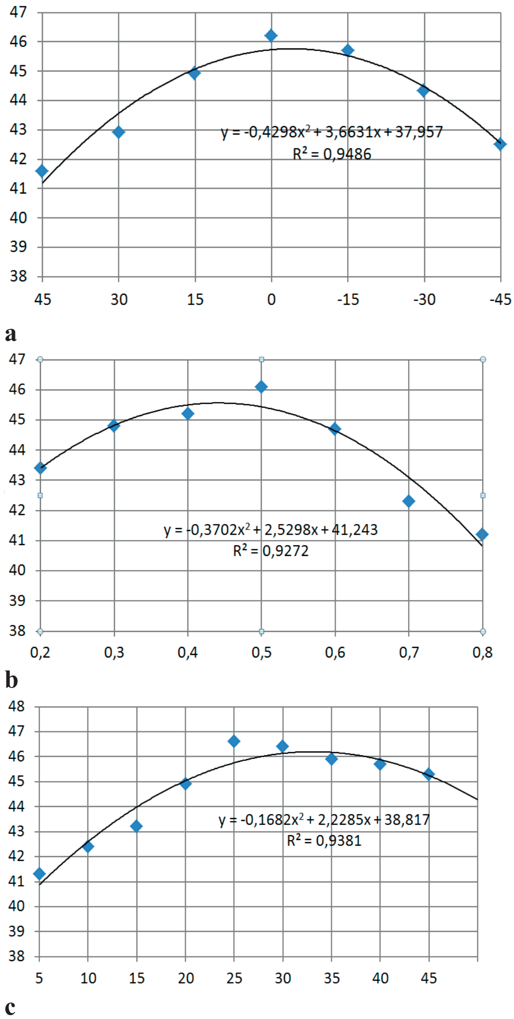

Figure 5. Dependence of the uniform distribution of seeds over the sieving area on the angle of inclination of hollow wedges in a longitudinally vertical plane (a), the tangent of the half angle of the solution of the hollow wedges (b), the width of the sole of the opener necessary for filling the grooves of the hollow wedges (c)

Analyzing the graphic image of two-dimensional sections (Figure 4), we could conclude that the optimal values of the studied factors are in the intervals:

$$\psi = -22.7 - 21.5 \text{ deg}$$

$$\gamma = 0.37 - 0.59$$

$$b = 14.2 - 38.3 \text{ mm}$$

in this case, the optimization parameter (ν is the coefficient of variation of the seeds distribution over the sieving area) would accordingly be equal to 46%.

Based on the results of the field experiment, the dependences of the uniform distribution of seeds on the angle ψ of the inclination of the hollow wedges in the longitudinal-vertical plane, the tangent γ of the half angle of the solution of the hollow wedges, the width b of the working part of the sole of the opener necessary for filling the grooves of the hollow wedges were plotted and presented in Figure 5 (Larushin et al., 2016).

According to studies, the optimal uniformity of the distribution of seeds over the sifting area was obtained with an angle of installation of hollow wedges in the longitudinally vertical plane (forward-backward) ψ = -7-10 deg, the tangent of half the angle of the solution of hollow wedges γ = 0.39-0.47, the width of the sole necessary for filling the furrows behind the hollow wedges - b = 27-39 mm, with a distribution variation coefficient of at least 45.5%.

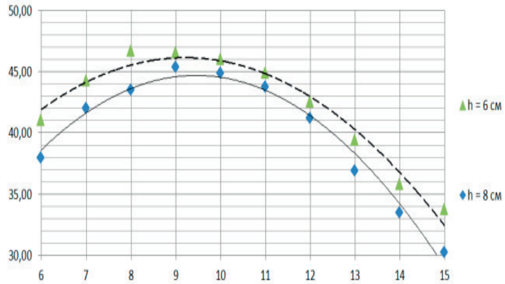

Figure 6. Effect of aggregate speed and sowing depth on the value of the coefficient of the seeds distribution variation over sifting area

It was also determined the influence of the speed of movement and the depth of tillage on the coefficient of the seeds distribution variation over the sowing area of the grain seeder opener (Figure 6). As a result of research, it was found that the optimal speed of the experimental grain seeder opener with a sowing depth of 6 cm should be 8.4-9.7 km/h with a coefficient of variation in the distribution of seeds of at least 45.5%.

Industrial studies have shown that the experimental grain seeder opener at different levels of fertilizer application and seed distribution compared with the base seeder provides an increase in spring wheat productivity to 0.27 t/ha.

At the same time, it ensures the introduction of the starting dose of fertilizers together with the seeds and the main dose of fertilizers below the sowing bed with a soil layer of 21.5-25.3 mm. The uniform distribution of seeds by an experimental grain seeder opener will be at least 45.5% (uniform distribution of seeds by a basic seeder is 40%).

CONCLUSIONS

In the course of studies the developed grain seeder openers, it was found that the use of an experimental grain seeder opener provides an increase in spring wheat productivity to 0.27 t/ha.

Economic calculations confirm that the use of the grain seeder opener with coulters at different levels of fertilizer application and seed distribution is economically feasible. The annual economic effect at a standard annual load of 160 hours amounted to 412824.55 rubles. on one seeder, with a payback period of 1.43 years.

It was found that due to the use of the proposed design, the dose required for applying mineral fertilizers is reduced to 40%, which would undoubtedly have a beneficial effect on reducing the environmental load on the soil.

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