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FIELD TEST, RESEARCH AND RESULTS OF A FLEXIBLE MACHINE WITH A ROTOR

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Abstract: Science-based farming systems have proven that the soil layer after plowing contains 100–200 million to 2–3 billion weed seeds per hectare, 70–90% of which can be destroyed by harrowing before and after emergence. Pre-sowing cultivation with rotor trowels leads to the development of seeds in the soil and the creation of an aeration process for the root system during the growing season, which improves plant development and productivity. A flexible trowel with a rotor was developed in our laboratory. Constructive and technological parameters were analyzed using the experimental planning method and optimal results were obtained, considering the diameter of the rotor and the speed of the unit as the main influencing factors. The “percentage of lump crushing” was the output parameter, and the “soil moisture” was the input parameter. The regression equation and diagrams were obtained from the mathematical analysis. Optimally, based on 4 experiments, the unit speed V=15 km/h, the cultivation depth 5–10 cm, and the rotor diameter D=380 mm were selected. The technological operations carried out using a flexible trowel with a rotor made 81.28% of the lump crushing in the soil, which had a significant effect of 95% on the development of the sown seeds. In the field test, the degree of “lump crushing” was studied in the soil with a moisture content of 18–24%. It was found that the fraction of soil with a size of less than 10 mm amounted to 51%.The size of the lumps was 10–25, those of 25–50 and 50–100 mm made up 18%, 13% and 14% of the soil, respectively. The size of lumps above 100 mm made up 4% of the soil.

Key words: machine, lump crushing, soil, rotor, flexible trowel.

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Introduction

In modern times, one of the most global problems of humanity is providing the population with food products, and the most important issue is paying for this provision. At present, the countries of the world, international organizations, especially the Food and Agriculture Organization of the United Nations (FAO), the World Bank, the International Fund for Agricultural Development (IFAD), the International Monetary Fund and other organizations are committed to reducing the number of people suffering from hunger, ensuring minimum food requirements, addressing other aspects of food security, etc. Extensive work is being done considering the problems. According to FAO recommendations, investments in agriculture should be increased by 50 percent.

In our country, it is important to achieve a reliable supply of food products so that the population does not face such a problem in the future. Cereal farming is of special importance in the food supply of the country's population. This is because grain farming is of great importance in meeting the population's demand for bread and bakery products, as well as in meeting the demand for strong and coarse fodder in animal husbandry (Borisenko, 2015; Maslov, 2017; Kambulov, 2008).

In recent years, the State Programs adopted in order to improve the food supply of the country's population have given a strong impetus to the development of grain farming. The goal in grain farming is to increase productivity per hectare. In order to achieve a successful solution to these issues, it is necessary to use advanced technologies and the latest achievements of science in the production of grain products in order to obtain high-quality products from a single cultivated area and increase the annual grain production to 5.0 million tons. There are real opportunities for this in our republic. The decrees signed by the President of the Republic of Azerbaijan on the development of grain farming require further attention to this field. It should be noted that 1,058,398.9 hectares of grain fields were planted in the country this year, of which 658,383.7 hectares include wheat and 400,015.2 hectares comprise barley. By keeping the cultivated area for grain growing in our republic around 1,395 thousand hectares, it is possible to increase the yield per hectare to 4.0–4.5 tons, and the annual grain production to 5 million tons. It is possible to achieve high productivity every year by implementing important technological measures in the cultivation of grain crops in a complex manner and by following agrotechnical measures correctly. The territory of the Republic of Azerbaijan, distinguished by the diversity of its natural geographical features, is characterized by the presence of all soil-climate zones spread across the globe, except for tropical and forest-savanna-type landscapes. Our republic has rich climatic resources due to favorable physical and geographical conditions. All this creates a favorable opportunity for the cultivation of many agricultural plants in Azerbaijan. Azerbaijan is an ancient agricultural land. Favorable natural-geographical conditions of the area where the country is located have created the basis for the comprehensive development of agriculture since ancient times.

The purpose of pre-sowing soil cultivation is to make the structure of the soil granular, clear the field of weeds, apply the remains of culms, organic and mineral fertilizers to the subsoil, and destroy the eggs and larvae of pests by uncovering them (Zhukova, 2010; Malyuga, 2014).

The following main tasks are performed in pre-sowing soil cultivation:

1. Preventing the loss of moisture from the soil layer, strengthening microbiological processes and creating a soft soil layer with a smooth surface;

2. Destroying weeds and preventing their germination after sowing;

3. By burying the seed to any depth, carrying out quality sowing.

Flexible rotary trowels are widely used in developed countries (Marinina et al., 2017).

Flexible rotor trowels are designed to work in early spring frost plowed areas with a lot of plant residues, even after the use of soil conditioners and mulchers, as well as on no-till and rest soils (Alekseev, 2002; Kambulov, 2018). It is used in soil-saving and energy-saving technologies in horticulture. The cultivation of the soil with rotating tines placed on the rotor is particularly important for its moisture conservation, as it allows plant residues and weeds to be removed down to the soil surface, forming a mulch layer that breaks up the soil capillaries and improves moisture retention (Demshin and Vladimirov, 2010) .

The flexible rotor trowel has the following features (Ryazanov, 2010)

- softening the soil to a depth of 2–8 cm, regular distribution of plant residues and weeds on the soil;
- crushing and scrubbing of lumps;
- creating a mulch layer on its surface to keep moisture in the soil;
- dispersing the soil crust and capillaries to reduce water evaporation in the soil;
- reducing the costs incurred for the destruction of weeds and spraying of agrochemicals, including direct sowing (no till);
- reducing the costs of fuel and lubricants to achieve high productivity;
- regulating the force acting on the soil by pressing the working bodies to the soil;
- improving soil aeration (ventilation);
- favorable cultivation of irrigated lands;
- removing weeds by their roots without being cut off (plucked out) and placed on the ground;
- the presence of a flexible shaft and a large angle of attack prevents it from becoming clogged with sticky soil and moist plant residues.

Material and Methods

The following standards were used during the testing of the flexible cable trowel:

- GOST 33687-2015 Machines and tools for surface treatment of soil (Nagiyev et al., 2023)

The average speed of the machine, km/h, was calculated by the following formula:

$$V = \sum_{i=0}^{n} \frac{L_i}{t_i}\ 3.6 \quad (1)$$

where:

L_1 is the length of the distance in the i-repetition, m;

ti – i-repetition distance crossing time, sec.;

n – number of repetitions, times.

In order to determine the distance of the herd and the time to cover that distance, they divided the total distance equally, not less than 50 m, marked the time and recorded the time with a stopwatch.

This was repeated four times (twice when the unit moved in the straight direction and twice in the opposite direction), the measurement error was 1 second. The cultivation depth (softened layer) was measured with a ruler, by putting the line to the uncultivated depth of the soil. For this purpose, the measurements were repeated no less than 25 times.The measurements were made in the direction of movement of the machine at intervals of 1 m along the track of the working body. If the footprint of the working body is predetermined, then the measurement is taken at an equal distance to the entire working width of the machine. If there is a rough surface behind the working body, the measurement is made in the dash and in the furrow. The average number was determined from two measurements (Figure 1).

Figure 1. Wooden frame for taking the measurements.

The experiment was repeated four times (twice in the direction of movement and twice in the opposite direction).

The depth measurement error can be 1 cm. The measurement numbers were entered in the table and processed by statistical methods.The accuracy of the calculation was up to 1/10. The soil compaction was determined according to the sample taken.The sample was taken from 4 points of the field (two in the direction of the movement of the aggregate, and two in the opposite direction) at the depth of cultivation in the field of 0.25 m^2.

A set of 0.50 x 0.50 m frame and metal sieves was taken to determine soil crushing.Soil samples corresponding to the fractions passed through the sieves with the diameter of the sieve holes (10, 25, 50 and 100 mm) were taken. A digital scale was used. When analyzing the samples, large buckets were first selected, and then the soil was poured into buckets with a diameter corresponding to the gradation mentioned above.

A set of sieves was placed in decreasing order of the diameter of the holes on them.The soil fraction less than 10 mm was poured into the bottom of the set of sieves. By carefully shaking the sieves, it was ensured that the soil was poured in fractions. The mass of each lump was determined with an error of 50–100 g.The ratio of the mass norm of the lump and the mass share of the lump to the total mass was calculated (Figure 2).

The calculation was done with an accuracy of one lump of a percent. The mass measurement value of each lump was determined by dying 4 times, and its average mathematical value.

The crushing of lump clods in the field depends on the structural parameters of the flexible rotor trowel, the structural parameters of the soil and the speed of the unit. Since the study and testing of a flexible rotor trowel for soil tillage required several application periods and the process itself was limited by agrotechnical conditions, it was appropriate to combine field research and testing with process simulation.For the optimization of the factors in the implementation of the technological process, the crushing percentage of the pulp was taken as the output parameter, and the moisture of the soil was taken as the input parameter. It is related to the following factors that have a greater effect on the output parameters (Gurbanov et al., 2015).

Controlling factors were as follows:

X1 (D) – rotor diameter;

X2 (V) – machine speed.

Figure 2. A set of sieves for determining the fractional composition of the soil.

We can use a 4-centered, orthogonal, first-order composite planar to construct a mathematical model in which the output parameters vary in three levels, for each of which a base level and a change step have been set.

The factors themselves were coded according to the expression:

$$X_i = \frac{K_i - K_{oi}}{E} \quad (2)$$

where:
X_i is the encoding of the value of the factor;
K_i is the true value of the factor;
K_{oi} is the true value of the factor at the zero level;
E – change interval.

In the next step, we moved on to coded variables, X_1 and X_2:

$$X_1^{min} = \frac{p^{min} - p^0}{\Delta p} = -1; \quad X_1^{max} = \frac{p^{max} - p^0}{\Delta p} = +1 \quad (3)$$

$$X_2^{min} = \frac{w^{min} - w^0}{\Delta p} = -1\,; \quad X_2^{max} = \frac{w^{max} - w^0}{\Delta w} = +1 \qquad ....(4)$$

where:
p – rotor diameter variable values ;
w – variable speed of the agregate.

To determine the dependence, we drew up a matrix for planning experiments:

$$y = f\,(x_1, x_2); \quad ....(5)$$

For simplicity, we denoted here:

$$y = \frac{p}{p_0}; \quad ....(6)$$

The first experiment was carried out (table in the first line) when p = m, correspondingly w = m_1 and the second experiment, when p = n, correspondingly w = m_1 and so on. The "output" column shows the average (taking into account the repetition of the experiments): p/p_0.

The matrix (in Table 1) was thus constructed in such a way that each variable X_j only took on two values in the experiments (+ or -), that is, it only changed at two levels (at the upper and lower limits).

Table 1. Planning the experiment.

Variant number	To be planned			The result	Output parameters
	X_0	X_1	X_2	X_1X_2	Y
1	+1	-1	-1	+1	80,6
2	+1	+1	-1	-1	83,3
3	+1	-1	+1	-1	81,4
4	+1	+1	+1	+1	81,3

X_1(D) is the diameter of the rotor in the rotor trowel, X_2 (V) is the speed of the rotor trowel, Y is the percentage of crushing.

In this case, all possible combinations of X_j variables were involved in a full factorial experiment (TFT).

The coefficients were calculated and the adequacy of the response equation was analyzed.

The Bj coefficients were calculated according to formula (5).

It follows from the orthogonality property of the plan that if we take any two columns in the completed matrix and multiply the indices in the same rows in pairs, then all the columns obtained in this way – in the results 2^{k2} of all four numbers in the plan or 2^{k3} in eight numbers – are equal to zero.

This feature was sometimes used to plot missing columns, for example, when studying the interaction of factors (Table 2).

It should be noted that for large values, TFT involves more experience than is necessary to calculate the coefficients of the linear equations (without taking into account interactions) (Mammadov and Ibrahimov, 2007):

if $k = n$ factors, then $N = i^n$ experiments.

Table 2. Controllable factors and their change interval.

Input parameter	Level of coded variables	Factors	
		The speed of the unit, km/h X_1	Rotor diameter, mm X_2
Soil moisture	Down (+)	10	360
	Basis (+)	15	380
	Up (+)	20	400
	Variation interval, ε	5	20

Depending on the selected factors, a regression equation was obtained for the splitting of the top layer of the soil by the rotating working body and the crushing of the lumps:

$$y=81,28+0,52X_1-0,17X_2-0,53X_1X_2 \quad (7)$$

where: y – crushing of the soil with the rotor teeth.

Figure 3. The general view of a flexible trowel with a rotor.

Figure 4. Testing of a flexible rotor trowel.

Results and Discussion

An overview of the proposed flexible trowel with a rotor is given in Figures 3 and 4. At that time, the working speed of the unit was 14–16 km/h, the width was 3.5 m, and the cultivation depth was 5–10 cm.

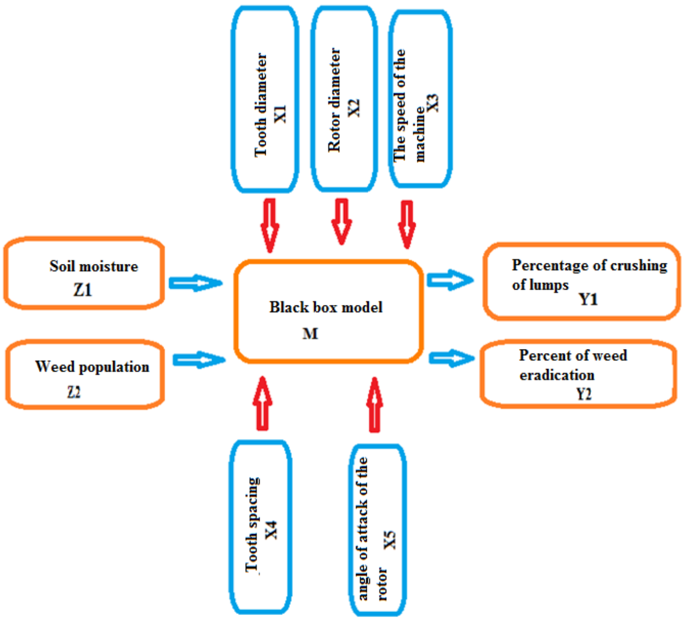

Figure 5. The mathematical model of the influencing factors of a flexible rotor trowel.

Depending on the diameter of the rotor, the effect of the speed characterizes the lump crushing phases, with the outside numbers indicating the speed of the unit, and the numbers written outwards from the center indicating the diameter of the rotor (Figure 7).

A mathematical structural model of a flexible trowel with a rotor was built, in which the influencing factors, input and output parameters, are shown (Figure 5).

From the 3-dimensional graph obtained from the regression equation, it is clear that with a diameter of the rotor of 380 mm and a speed of the unit of 15 km/h, the maximum crushing was 81.28%. The peak limit was considered optimal (Figure 6). Two main factors affecting crushing were analyzed and graphed using the Excel software according to the mathematical theory.

Soil moisture was determined during the test. It was found that the moisture in the 0–5, 5–10 and 10–15-cm layers of the soil was 18%, 21% and 24%. The average density of the soil was 0.986 g/cm^3. After the machine went through the test, the percentage of crushing of the lumps was studied. It was found that the soil fraction less than 10 mm accounted for 51% (Table 3).

The size of the lump fractions of 10–25, 25–50 and 50–100 mm constituted 18%, 13% and 14%, respectively. The size of lumps above 100 mm accounted for 4% of the soil.

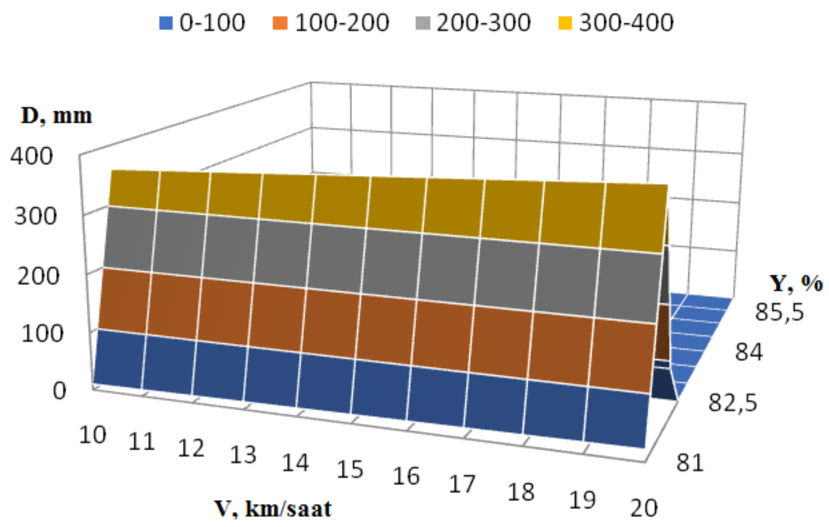

Figure 6. The dependence of the soil crushing percentage on the influencing factors.

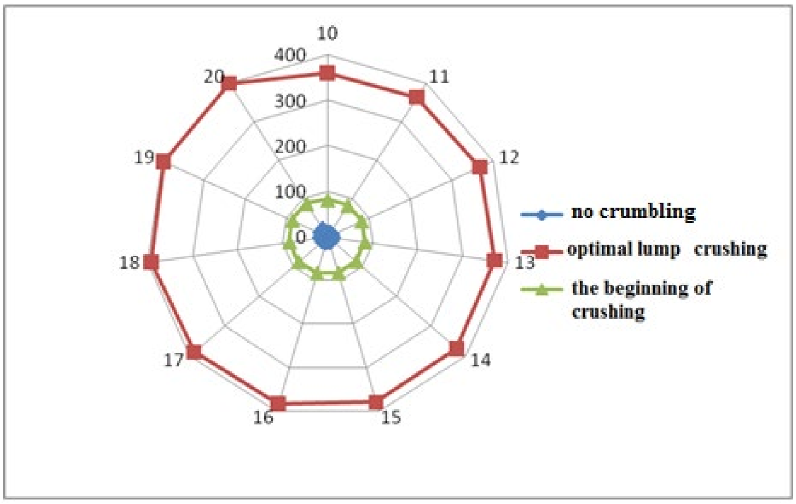

Figure 7. Phases of soil crushing depending on the diameter of the rotor.

Table 3. Determining the soil crushing quality.

Repetition	Lump sizes , mm						Total sample weight	
	10 down	10–25	25–50	50–100	100 up	10 down		
	kq	%	kq	%	kq	kq	kq	%
1	4.8	49.2	1.8	18.4	1.25	4.8	9.75	100
2	4.9	51.1	1.7	17.8	1.3	4.9	9.50	100
3	5	52.01	1.6	16.6	1.2	5	9.60	100
4	4.7	48.9	1.9	19.7	1.2	4.7	9.60	100
Total	19.4	201.6	7	72.5	4.95	19.4	38.45	400
Middle	4.85	51	1.75	18	1.23	4.85	9.6	100

Conclusion

During the experimental test, the working speed of the machine was 14–16 km/h, the width was 3.5 m, and the cultivation depth was 5–10 cm.

According to the agrotechnical conditions, the degree of crushing of the lumps was 81.28% on average.The diameter of the rotor trowel was D=380 mm, and the technological operation speed was optimally chosen as V=15 km/h.

The size of the lump fractions of 10–25; 25–50 and 50–100 mm constituted 18%, 13% and 14%, respectively.The size of lumps above 100 mm accounted for 4% of the soil.

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TERENSKO ISPITIVANJE, ISTRAŽIVANJE I REZULTATI ISPITIVANJA KOMBINOVANE MAŠINE SA ROTOROM

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R e z i m e

Naučno zasnovani poljoprivredni sistemi su dokazali da sloj zemljišta nakon oranja sadrži od 100–200 miliona do 2–3 milijarde semena korova po hektaru, od kojih se 70–90% može uništiti drljanjem pre i posle nicanja. Predsetvena obrada rotacionom drljačom sa motičicama dovodi do razvoja semena u zemljištu i stvaranja aeracije za korenov sistem tokom vegetacione sezone, što poboljšava razvoj i produktivnost biljaka. U našoj laboratoriji razvijena je kombinovana drljača sa motičicima. Konstruktivni i tehnološki parametri su analizirani metodom planiranja eksperimenta i postignuti su optimalni rezultati, uzimajući u obzir prečnik rotora i brzinu jedinice kao glavne faktore uticaja. „Procenat sitnjenja grudvi" bio je izlazni parametar, dok je „vlažnost zemljišta" bio ulazni parametar. Regresiona jednačina i dijagrami su dobijeni matematičkom analizom. Optimalno, na osnovu 4 ponavljanja, odabrana je brzina jedinice V=15 km/h, dubina obrade 5–10 cm i prečnik rotora D=380 mm. Tehnološke operacije sprovedene korišćenjem kombinovane drljače sa motičicima sa rotorom postigle su 81,28% sitnjenja grudvi u zemljištu, što je imalo značajan uticaj od 95% na razvoj posejanog semena. U poljskom ispitivanju, proučavan je stepen „sitnjenja grudvi" u zemljištu sa sadržajem vlage od 18% do 24%. Utvrđeno je da je frakcija zemljišta veličine manje od 10 mm iznosila 51%. Grudve veličine 10–25 mm, 25–50 mm i 50–100 mm činile su 18%, 13% odnosno 14% zemljišta. Grudve veće od 100 mm činile su 4% zemljišta.

Ključne reči: mašina, sitnjenje grudvi, zemljište, rotor, kombinovana drljača sa motičicama.

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