

Agricultural land plays an important role in ensuring food security and employment in rural areas. For many years, the planned economy has forced Uzbekistan to grow water-intensive crops, which has led to declining land productivity and increased crop yields. In a market economy, new innovative technologies are in high demand not only in agriculture but also in other sectors.

The purpose of the study was to substantiate the parameters of frontal plowing slope, which provides high-quality execution of the technological process in accordance with the agro-technical requirements with minimum energy consumption without furrow plowing, agrotechnical and energy performance of variable frontal forks.

The following results were achieved by performing the tasks identified in the study: a – humidity $V=16-17\%$ and load conditions with elastic rods of 3 mm, 4 mm, 5 mm; b – humidity $V=13-14\%$ and the diameter of elastic rods is 3 mm, 4 mm, 5 mm; c – humidity $V=9-10\%$ and the diameter of the elastic rods is 3 mm, 4 mm, 5 mm.

The experiments were performed on lumps with different humidity conditions: 9–10 %, 13–14 % and 16–17 %. The speed of the installation was 1.0 m/s.

The recommended technology was to destroy soil fragments with a moisture content of 16–17 % at a vertical load of 400 N with 3, 4 and 5 mm elastic rods at 86.6, 81.5, 75.1 %, respectively, and the vertical load equal to 1,000 N – 94.4, 89.2, 81.2 %, respectively

Keywords: tillage mechanics, support-lump-breaking coil, elastic rods, seedbed formation

OPTIMIZATION OF THE MAIN PARAMETERS OF THE SUPPORT-LUMP-BREAKING COIL

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1. Introduction

The development and application of basic tillage machines for energy-efficient and labor-intensive soils is a world leader. «Globally, the area under cultivation before planting is 1.6 billion hectares» [1], the development of machines and tools for high-quality and productive work and energy-efficient tillage is one of the most important tasks. At the same time, great attention is paid to the development and application of flat plows without open fields and borders of grain and secondary crops.

Research work is being carried out around the world to develop new scientific and technical bases of resource-saving technologies of basic processing of grain and secondary crops and the technical means of their implementation. In this regard, it is important to develop plows and justify the technological process of plowing flat and quality soils [2], to ensure resource efficiency in the process of interaction of working parts with the soil. In this regard, it is necessary to develop a flat plow frontal plow without an edge, equipped with a corner cutting body.

Agriculture of the Republic of Uzbekistan is an important sector of the economy. Extensive measures are being taken to

reduce labor and energy consumption in agricultural production, save resources, grow agricultural crops on the basis of advanced technologies and develop high-efficiency agricultural machinery. In particular, special attention is paid to the development of technical means that ensure the quality of all technological processes with low energy consumption in the preparation of fields for planting in one pass [3, 4].

The Strategy of Actions for the Further Development of the Republic of Uzbekistan for 2017–2021 states that «...for the modernization and accelerated development of agriculture, further improvement of the reclamation of irrigated lands, development of amelioration and irrigation networks, intensive approaches to agricultural production, primarily water and the introduction of modern resource-saving agro-technologies, the widespread use of high-yielding agricultural machinery» [5]. Based on these tasks, it is important to ensure high yields of agricultural crops through technical and technological improvements of frontal plows without tillage.

2. Literature review and problem statement

Research on the creation and use of plows for smooth plowing, the study of their performance and justification of parameters, as well as the study of the process of interaction of working bodies with the soil, were carried out. Plows based on the results of these studies have been used in agricultural production with some positive results. The authors [6, 7] noted that the bulk density depends on the type of soil, which was also clear in the present study, where the bulk density was significantly higher for sand (1.37 g/cm^3) than for clay (1.15 g/cm^3) and peat (0.95 g/cm^3) at $p \leq 0.05$. This indicates the need to separate the data by soil type when the degree of soil compaction is correlated with the bulk density. A visual assessment of the soil structure can indicate to the soil scientist where to take samples and which soil measurements may be appropriate. However, these studies have not sufficiently explored the issues of substantiation of the angle cutter parameters that provide high work quality with low energy consumption of the frontal plow.

Empirical analysis and the benefits of assessing the correlation between visual observations and standard field or laboratory measurements for contrasting soil types and understanding their reproducibility, VSE quality could be improved if a more quantitative approach is used. VSE is usually based on qualitative or semi-quantitative information, where visual observations are presented as scores rather than numerical quantitative observations. The studies [8, 9] demonstrated that improvements in soil and food fertility can be achieved by mitigating the effects of soil compaction caused by climate change through the adoption of appropriate conservation farming practices in the study area. However, quantification can provide a better insight into soil quality and allows the universal application of VSE methods [10]. The plows created as a result of these studies have been used with some positive results in agricultural production [11]. Moreover, in these studies, the issues of substantiating the parameters of the slope of the frontal plow for smooth without furrow plowing, providing high-quality work with minimal energy consumption, have not been sufficiently studied [12, 13].

However, comparative analyses have shown that tillage does not take into account the fact that processing is overturned within the boundaries of the tillage with low energy consumption to increase soil compaction and weed burial and reduce fuel consumption, labor and other costs.

The results of the study, according to the authors, technical characteristics of the machine used for mechanical shredding of soil are that the proposed machine is a process of mechanical shredding of soil without hardening the soil, rather, it performs the function of scattering hard soil in the air using spirals and scattering it on the ground [14]. The advantage of the machine used for mechanical shredding of the proposed soil over other similar machines is: first, prevents soil compaction, softens the soil; secondly, the oxygen saturation of the soil in the post-experimental state increases by 12 % compared to normal soil [15], which has a positive effect on soil fertility.

3. The aim and objectives of the study

The aim of the study is to substantiate the parameters of the slope of the frontal plow, which ensure high-quality performance of the technological process according to agro-technical requirements with the lowest energy consumption for smooth, without furrow plowing.

To achieve this goal, the following objectives were set:

- development of an improved frontal plow based on the search and analysis of agro-technical indicators and ways to increase productivity and theoretical substantiation of the structural elements of the supporting spiral to reduce the energy consumption of existing flat plows;
- obtaining analytical links that reflect the processes of interaction of the working bodies with the ground and determining their parameters and resistance to gravity, as well as testing the improved angular front fork and determination of agro-technical energy performance of variable front forks.

4. Materials and methods

For the cultivation of any agricultural crop, first of all, it is necessary to prepare the soil, this is the primary task of any farmer. This motto has now become the basis of the support-lump-breaking coil of the developed structures in this direction. As we know, the ideal soil for cotton cultivation is considered to be such a soil in which the fractions of the formed lumps after processing met the agro-technical requirements. Based on these considerations, we have developed the design of the support-lump-breaking coil (Fig. 1).

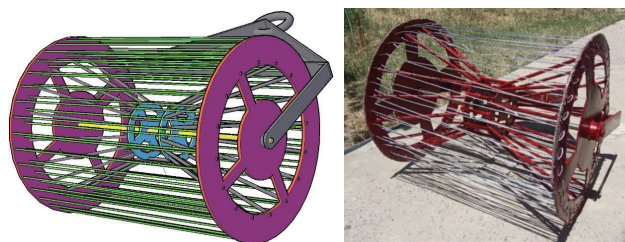


Fig. 1. Photo of the developed support-lump-breaking coil

The main purpose of experimental studies was to verify the results of theoretical studies, as well as to justify the rational values of the parameters of the support-lump-breaking coil. With this in mind, a program for the preparation and conduct of experimental studies was drawn up, which included: design and manufacture of experimental samples of the support-lump-breaking coil; design and manufacture of an experimental installation; determination of the in-

fluence of the design parameters (diameter and width of the support-lump-breaking device, diameter and number of elastic rods) and the speed of movement on the quality of the support-lump-breaking coil.

To conduct experimental studies, the developed support-lump-breaking roller is installed on the GC-4 (Fig. 2).

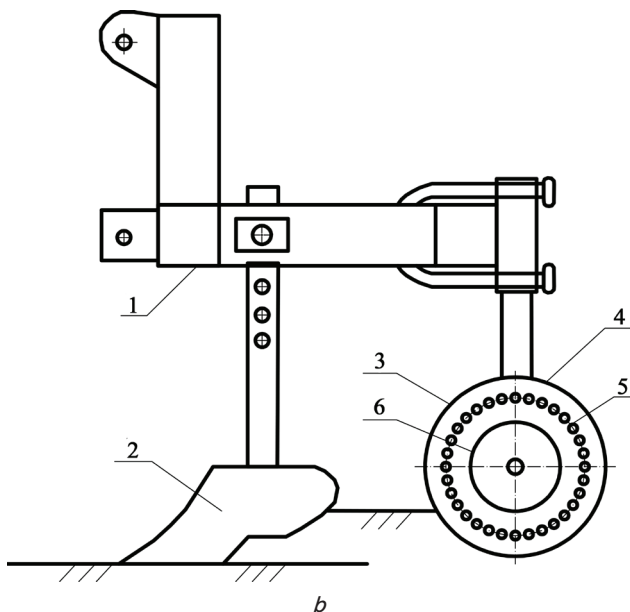
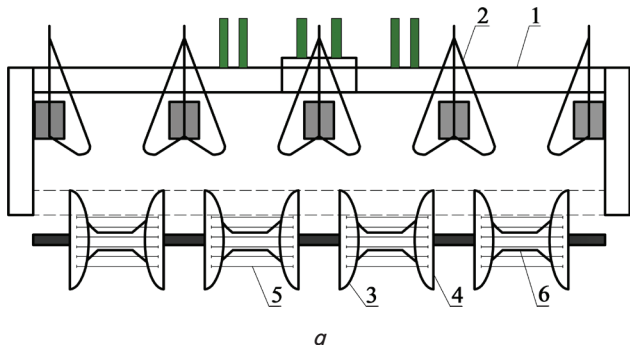


Fig. 2. Scheme of the hiller and devices for pre-sowing treatment of cotton beds: 1 – frame; 2 – spud; 3, 4 – discs; 5 – elastic rods; 6 – coil; *a* – top view (plan); *b* – side view (profile)

The use of elastic rods in the processing of beds is extremely effective. Its use makes it possible to effectively crush lumps when processing beds and get high-quality beds and reduce the energy consumption of the unit, as well as increase labor productivity [16].

It is obvious that the destruction of lumps occurs as a result of the action of the pressure force P on them from the elastic rods, while the destruction of lumps occurs under the condition:

$$P \geq P_k, \quad (1)$$

where P_k – the critical breaking force of the lump.

Lump destruction can be determined by the expression:

$$\varepsilon = \arccos \frac{D_{cp}}{D_c + (B_k - b_r) \operatorname{tg} \beta - \sqrt{(L_n - b_r)^2 - (B_k - b_r)^2}}, \quad (2)$$

where D_c – diameter of the middle part of the roller.

Let the distance from the axis of rotation of the device to the surface of the bed be $D_c/2$ (Fig. 3).

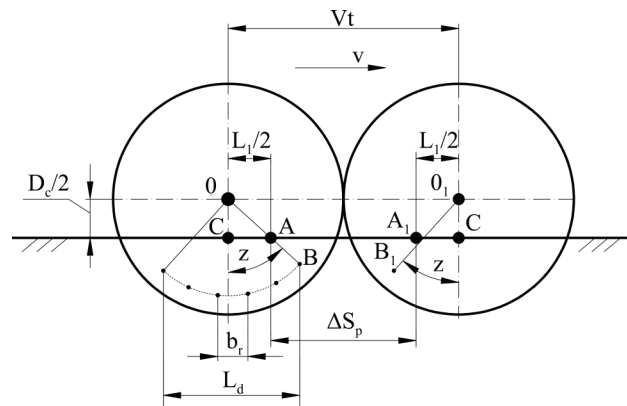


Fig. 3. Diagram of the effect of elastic rods on the bed

Determine the path ΔS^1 along the bed, traversed by an elastic rod, at which the destruction of the lump occurs:

$$\Delta S^1 = Vt - L_i, \quad (3)$$

From the diagram in Fig. 2:

$$L_i = 2AC = 2 \sqrt{\left[\frac{D_c + (B_k - b_r) \operatorname{tg} \beta}{2} - \frac{1}{2} \sqrt{(L_n - b_r)^2 - (B_k - b_r)^2} \right]^2 - D_c^2/2}. \quad (4)$$

Taking into account (3), the expression (4) has the following form:

$$\Delta S_p = Vt - 2 \sqrt{\left[\frac{D_c + (B_k - b_r) \operatorname{tg} \beta}{2} - \frac{1}{2} \sqrt{(L_n - b_r)^2 - (B_k - b_r)^2} \right]^2 - D_c^2/2}. \quad (5)$$

Taking into account the expressions (4) and (5), the number of acting elastic rods with the surfaces of the bed in a stationary position, the device has the following form:

$$n_0 = L_d / b_r, \quad (6)$$

where L_d – the length of the arc of the device, along which the elastic rods are located to a fixed position on the bed, m ; b_r – distance between elastic rods along the perimeter of the disc.

$$L_d = \frac{D_c + (B_k - b_r) \operatorname{tg} \beta}{2} \times \arccos \frac{D_c}{D_{ok} - \sqrt{(L_n - b_r)^2 - (B_k - b_r)^2}} \cdot \frac{\pi}{180^\circ}. \quad (7)$$

The distance between the elastic rods along the perimeter of the disc is determined from the following condition:

$$b_r \leq d_{kr}, \quad (8)$$

where d_{kr} – diameter of the minimum permissible lump, m .

Taking into account the expressions (7), the number of acting elastic rods with the surfaces of the bed is determined by the following expression:

$$n_0 = \frac{(D_c + (B_k - b_r) \operatorname{tg} \beta)}{2} \times \arccos \frac{2D_c}{D_{ok} - \sqrt{(L_n - b_r)^2 - (B_k - b_r)^2}} \cdot \frac{\pi}{180^\circ} / b_r. \quad (9)$$

Taking into account the diameter of the disc circumference along which the elastic rods are located and the distance between the elastic rods along the perimeter of the disc, we determine the total number of elastic rods:

$$n = \pi D_{ok} / b_r. \quad (10)$$

Substituting the values $D_{ok}=0.63-0.65$ m, $D_c=0.204$ m, $L_p=0.81$ m, $b_r=0.16$ m, $B_k=0.66$ m in (8) and (9), we get that the number of elastic rods is $n_0=6-8$ and $n=80-82$ pcs.

From the analysis of these calculations, it can be seen that with an increase in the radius of the circle on which the elastic rods are located, and the number of additional effects of elastic rods, their number increases in direct proportion [17–19].

To determine the quality of grinding in the treated layer of the formed bed, soil samples were taken with an area of one linear meter and deep to the depth of processing.

To study the fractional composition of soil lumps of cotton beds from one linear meter of its surface in the fiftieth multiplicity, all soil lumps with a thickness of more than 25 mm were collected and divided into four fractions: 25–50, 50–75, 75–100 and more than 100 mm.

The samples were weighed after screening, and the degree of destruction of soil lumps was determined by the content of fractions with dimensions less than 25 mm:

$$C = \frac{m_i}{m} \cdot 100, \%, \quad (11)$$

where m_i – fraction weight with dimensions less than 25 mm; m – total mass of the sample, kg.

The average values of the experimental results are presented in Table 1.

Table 1

Fractional composition of soil lumps of cotton beds

No.	Number of soil lumps (pcs) with dimensions, mm				Total, pcs
	25–50	50–75	75–100	≥100	
1	37	6	2	1	46

The data of Table 1 indicate that the number of soil lumps collected from 1 linear meter of the surface of a cotton bed is on average 47.6 pcs, and their standard deviation is 2.7 pcs.

The percentage of soil lumps with a size of 25–50 mm from the total number of soil lumps is 81.0 %, soil lumps with a size of 50–75 mm – 14.4 %, soil lumps with a size of 75–100 mm – 2.6 %.

The percentage of soil lumps with dimensions over 100 mm is about 2.0 % of the total number of soil lumps.

The entire program of experimental studies of the support-lump-breaking coil was carried out in two stages:

- study of the influence of the design parameters of the support-lump-breaking device on its qualitative performance indicators;

- determination of the effect of the speed of movement and vertical load on the support-lump-breaking coil on its traction resistance.

Each experience in the accounting plot consisted of the following elements:

- preparation of background;
- setting for a given mode of operation of the installation and the support-lump-breaking coil (speed of movement, load on the working body);
- conducting an experiment;
- recording readings and making a report.

Before conducting experiments according GOST 20915-75 «Agricultural machinery. Methods for determining test conditions», soil moisture and hardness were determined.

To determine soil moisture using a cutting cylinder with a volume of 601.4 cm³ along the bed (rut) in six places, samples were taken in layers of 0–10, 10–20, 20–30 cm. The cylinder was immersed in the soil with a special guide and ramrod, then the excess soil was carefully separated from the cylinder with a knife and after that all the soil was poured out on a sheet of paper, thoroughly mixed and without delay samples were taken from it into aluminum soil cups to determine soil moisture. The selected samples were recorded in a field log, then packed in a special box and sent to the agrochemical laboratory for weighing [20]. The cups of soil were weighed and placed with the lid open in the drying cabinet. In the drying cabinet, the soil sample was dried at a temperature of 1050 °C for 8 hours. The cups with dried soil (in closed form) were placed in the desiccator and after cooling after 15–20 minutes were weighed. According to the difference in the mass of the cup with the soil before drying and after drying, the amount of water contained in the soil suspension, i. e. the mass of evaporated moisture, was determined.

According to the difference in the mass of the cup with dried soil and the empty one, the mass of absolute dry soil was determined, and then its moisture content was determined by the formula:

$$W = \frac{m_b - m_c}{m_c} \cdot 100, \%, \quad (12)$$

where m_b – mass of wet soil; m_c – mass of dry soil.

In places where soil moisture was determined, the soil hardness was determined in layers 0–10, 10–20 and 20–30 cm using a high hardness tester with a conical plunger.

Before the experiment, the hardness tester was calibrated on the stand and the calibration coefficient was determined.

By rotating the handle through a conical gear, a conical tip with a base diameter of 11.3 mm, an angle at the top of 22°30' and an area of 1 cm² is introduced into the soil.

The device allows determining the resistance force that occurs when the plunger of the hardness tester is vertically immersed in it. The soil resistance force causes the spring to deform, which is fixed by a pin on the diagram tape. The movement is transmitted to the drive drum of the recording device automatically by means of a screw mechanism that ensures the movement of the tape only when the plunger is immersed in the soil [21].

Soil hardness (P) was determined by the formula:

$$P = \frac{H_{cp} \cdot q}{S}, \quad (13)$$

where H_{cp} – the value of the average ordinate of the hardness diagrams, cm; q – the scale of the spring, N/cm; s – the cross-sectional area of the plunger, cm².

The degree of destruction of soil lumps was determined directly in the field with the separation of the sample into fractions with a particle diameter of more than 50; 50–25 and less than 25 mm using a special set of sieves with a hole diameter of 50; 25 mm. The sieves in the set were arranged in order of decreasing hole diameter.

Soil samples for analysis were taken after the passage of a lump-breaking device at five points in each version of the experiments using a metal box without a bottom measuring 50–50 cm across, 20 cm high, which was embedded vertically in the treated soil layer. The samples were weighed after screening, and the degree of destruction of soil lumps was determined by the content of fractions with dimensions less than 25 mm:

$$C = \frac{m_i}{m} \cdot 100, \% \tag{14}$$

where m_i – fraction weight with dimensions less than 25 mm; m – total mass of the sample, kg.

The characteristics of the field on which the experiments were conducted are given in Table 2.

Characteristics of experimental conditions

Name of indicators	Value of indicators
Test time	March-April 2020
Test location	Experimental farm of Usmai
Type and mechanical composition of soil	Serozem, medium-heavy loamy
Soil moisture (%) in layers, cm:	
0–10	8–10
10–20	11–12
20–30	13–14.6
Hardness of the soil (MPa) layer, cm:	
0–10	1.7–1.8
10–20	1.8–1.98
20–30	2.0–2.2
relief	smooth
microrelief	slightly pronounced

Field experiments have shown a higher efficiency (moisture preservation in the soil, soil crumbling) of this design in comparison with analogues.

The task of the research was to determine the rational values of the parameters of the support-lump-breaking working body, which provide the required degree of destruction of soil lumps in a cotton bed. Given the complexity of the process, in which many factors participate and interact, the experiments were carried out using the method of mathematical planning of the experiment [21], the essence of which is to obtain a response function under the action of a number of factors:

$$Z = f(X_1, X_2, X_3, \dots, X_n), \tag{15}$$

where Z – criterion (response) for evaluating the studied processes; $X_1, X_2, X_3, \dots, X_n$ – independent factors that can be varied.

The response function can be approximated by a polynomial of the form:

$$Z = \beta_0 + \sum_{i=1}^n \beta_i X_i + \sum_{i=1}^n \beta_{ij} X_i X_j + \sum_{i=1}^n \beta_{ii} X_i^2, \tag{16}$$

where $\beta_0, \beta_i, \beta_{ij}, \beta_{ii}$ – theoretical regression coefficients, the value of which can be used to judge the degree of influence of factors on the response criterion.

Based on the results of the experiment, regression coefficients are calculated, which are used to estimate the theoretical regression coefficients. In this case, equation (16) takes the form:

$$Y = \beta_0 + \sum_{i=1}^n \beta_i X_i + \sum_{i=1}^n \beta_{ij} X_i X_j + \sum_{i=1}^n \beta_{ii} X_i^2, \tag{17}$$

where Y – calculated value of the criterion.

The response criterion is the degree of destruction of soil clumps of the support-clump-breaking material.

Based on the theoretical analysis of the process and preliminary experiments, the levels and intervals of variation of factors are selected. The plan of the Hartley-4 multivariate experiment was chosen for the experiments.

Table 2

After the implementation of the planning matrix, the results of the experiment were processed according to the well-known method on an IBM Pentium IV PC using the PLANEXP-2 program for multiple regression analysis. The hypothesis of uniformity of variance with the same number of repetitions of experiments is tested using the Cochran criterion, and the significance of regression coefficients is tested by the Student's criterion with a confidence probability of 95%. The adequacy of the process model, i.e. the suitability of the regression equation for describing the optimization parameter, was checked by the Fisher-F criterion. The model is considered adequate when $F_{calc} < F_{tab}$.

5. Results of experimental studies

5.1. Theoretical justification of structural elements of support-lump-breaking coil

The longitudinal distance between the angle cutter and the body is determined on the condition that the deformation zone of the plate does not reach the angle cutter, and the height of it is determined taking into account its machining depth and coverage width, agro-technical and energy performance of the angled frontal plow, which prepares the soil for planting without forming open ridges and boundaries in one pass through the field, the laws of variation depending on the parameters and the speed of aggregate were determined.

In the course of research, the question of the influence of the load on the support-lump-breaking coil on the degree of destruction of soil clumps of cotton beds was studied. The results of the research are shown in Fig. 4.

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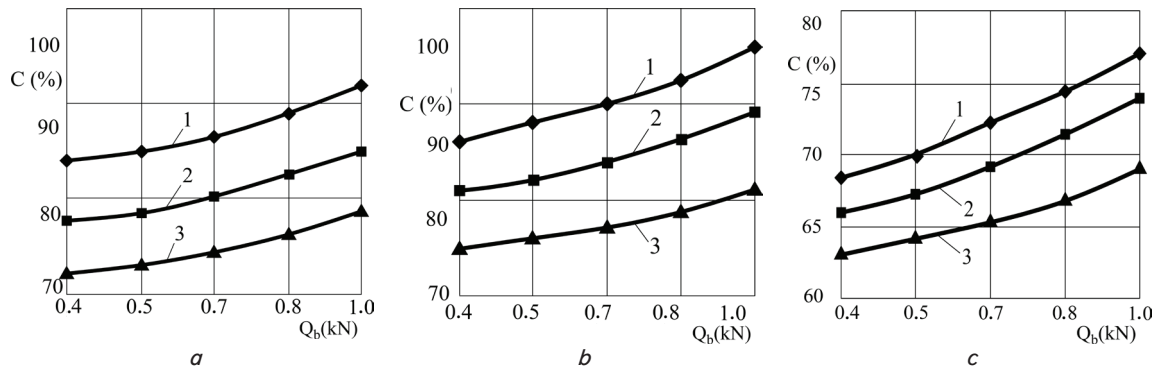


Fig. 4. Dependence of the degree of destruction of soil lumps on the vertical load on the support-lumps-breaking coil and the diameter of elastic rods: 1, 2, 3 – accordingly, the diameter of the elastic rods is 3, 4 and 5 mm; *a* – at humidity $W=16-17\%$ and diameter of elastic rods of 3 mm, 4 mm, 5 mm; *b* – at humidity $W=13-14\%$ and diameter of elastic rods of 3 mm, 4 mm, 5 mm; *c* – at humidity $W=9-10\%$ and diameter of elastic rods of 3 mm, 4 mm, 5 mm

As an elastic rod, we adopted a steel rope of the spiral type TC with a diameter of 3, 4 and 5 mm, made of high-carbon cold-drawn wire with a tensile strength of 170–220 MPa.

The experiments were carried out at different humidity of lumps: 9–10 %, 13–14 % and 16–17 %. The speed of movement of the installation is 1.0 m/s.

Analysis of the data shows that with increasing the vertical load on the working body, the degree of destruction of soil lumps increases with increasing diameter of the elastic rods and a decrease in moisture of soil lumps, the degree of destruction decreases. Thus, at a vertical load of 400 N, the degree of destruction of soil lumps with a moisture content of 16–17 % by elastic rods of 3, 4 and 5 mm, respectively, was 86.6, 81.5, 75.1 %, and at a vertical load of 1000 N – 94.4, 89.2, 81.2 %, respectively. At the same loads, the degree of destruction of lumps with a humidity of 13–14 %, respectively, was 84.1, 77.6, 72.3, 91.8, 85, 78.7 %, and with a humidity of 9–10 %, respectively 68.2, 66.4, 63.1, 77.0, 73.8, 68.9 %.

The influence of the load on the degree of destruction of soil lumps can be expressed by the following empirical formulas:

– at humidity $W=16-17\%$ and diameter of elastic rods of 3 mm, 4 mm, 5 mm:

$$C = 0.002Q_b^2 + 0.03Q_b + 84.08, \quad R^2 = 0.9894; \quad (18)$$

$$C = 0.002Q_b^2 - 0.1063Q_b + 81.15, \quad R^2 = 0.9855; \quad (19)$$

$$C = 0.002Q_b^2 - 0.099Q_b + 75.73, \quad R^2 = 0.9985; \quad (20)$$

– at humidity $W=13-14\%$ and diameter of elastic rods of 3 mm, 4 mm, 5 mm:

$$C = 0.003Q_b^2 - 0.165Q_b + 85.76, \quad R^2 = 0.9901; \quad (21)$$

$$C = 0.003Q_b^2 - 0.142Q_b + 78.83, \quad R^2 = 0.9913; \quad (22)$$

$$C = 0.002Q_b^2 - 0.101Q_b + 72.59, \quad R^2 = 0.9980; \quad (23)$$

– at humidity $W=9-10\%$ and diameter of elastic rods of 3 mm, 4 mm, 5 mm:

$$C = 0.001Q_b^2 + 0.058Q_b + 64.55, \quad R^2 = 0.9907; \quad (24)$$

$$C = 0.001Q_b^2 - 0.013Q_b + 64.02, \quad R^2 = 0.9984; \quad (25)$$

$$C = 0.001Q_b^2 - 0.042Q_b + 62.47, \quad R^2 = 0.997. \quad (26)$$

The obtained data show that the greatest degree of destruction of soil lumps is provided by elastic rods with a diameter of 3.0–4.0 mm and it is about 80–95 %.

During the experiments, the number of elastic rods was 60 pcs, the diameter of the discs $R=0.6$ m, the width of the device – 0.70 m. (Fig. 5).

From the graphs, it can be seen that with an increase in the speed of movement, with all the humidity of the soil lumps, the degree of their destruction decreases. Thus, at a speed of 0.4 m/s and soil humidity of 7–8, 10–12, 15–17 %, the degree of destruction of soil lumps by the support-lump-breaking device was 72.4, 79.2, 86 %, respectively, and at a speed of 1.6 m/s it is 67.1, 75.6, 82.3 %, respectively.

This is mainly due to the reduction of the time of impact of elastic rods on soil lumps.

The degree of destruction of soil lumps at different speeds of movement of the experimental support-lump-breaking roller ranges within 67–86 %. The main parameters of the support-lump-breaking coil are (Fig. 6):

- B – width, m;
- t – disc thickness, m;
- γ – sharpening angle of the discs, deg;
- D_c – diameter of the middle part, m;
- D_o – diameter of the disc circumference along which the elastic rods are located, m;
- D_d – disc diameter, m;
- L – length of elastic rods, m;
- n – number of elastic rods, pcs;
- d_c – diameter of elastic rods, m.

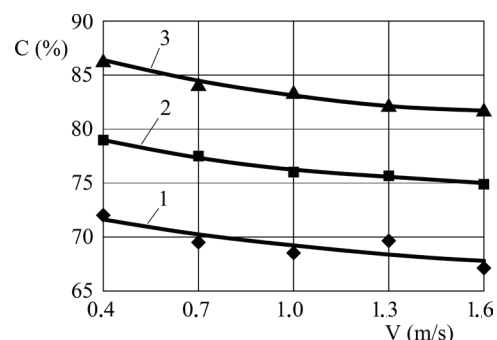


Fig. 5. Dependence of the degree of destruction of soil clumps on the speed of movement of the support-clump-breaking device: 1 – $W=7-8\%$, 2 – $W=10-12\%$, 3 – $W=15-17\%$

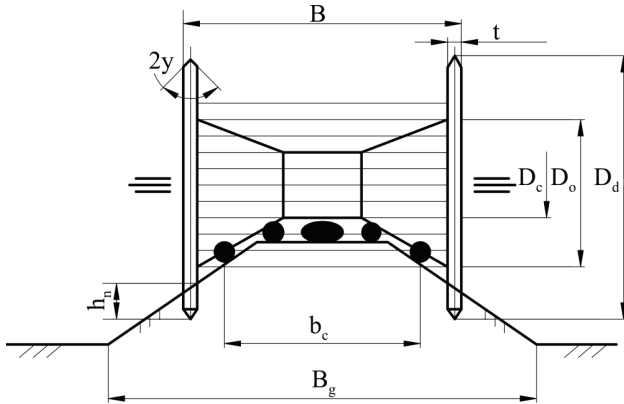


Fig. 6. Scheme for determining the geometric parameters of the support-lump-breaking coil

The width B (Fig. 6) of the support-lump-breaking coil is calculated from the condition:

$$B \geq b_{cp} + 3\sigma + 2c + t, \quad B \geq b_c + 3\sigma + 2c + t, \quad (27)$$

where b_c – average value of the width of the spatial layer for the development of the root system of cotton; σ – standard deviation of the spatial layer width for the development of the cotton root system; c – tolerance for horizontal vibrations of the machine; t – disc thickness.

Thus, it was found that the width of the support-lump-breaking coil should be at least 60 cm [22].

According to the scheme shown in Fig. 7, the length L of the elastic rods of the support-lump-breaking coil is determined by the following formula:

$$L = AB + BC + DC, \quad (28)$$

where

$$AB = DC = \frac{0.5(B - b_c)}{\cos \varphi_r},$$

$BC = b_c$ – width of ridges at the top; φ_r – angle of slope of the ridges to the horizon.

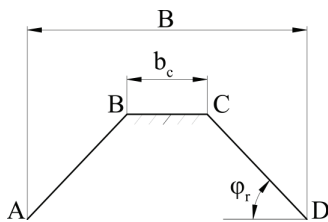


Fig. 7. Scheme for determining the length of elastic rods

From the analysis of this expression, it follows that the length of elastic rods should be 81 cm and depends on the width of the spatial layer for the development of the cotton root system, its standard deviation, the angle of slope of the slopes and the width of the top of the ridges [23].

The support-lump-breaking coil is characterized by the following diameters (Fig. 6): the diameter of the middle part D_c , the discs D_d and the circle D_o on the disc, on which the elastic rods are located.

The support-lump-breaking coil is characterized by the following parameters (Fig. 8): the diameter of the middle part D_c , the discs D_d and the circle D_o on the disc, on which the elastic rods are located.

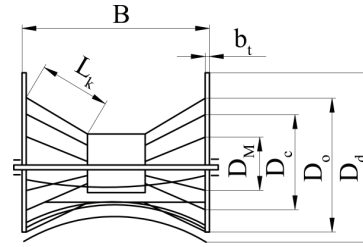


Fig. 8. Scheme for determining the design diameters of the support-lump-breaking coil

First, we determine the diameter of the middle part of the support-lump-breaking coil interacting with the top of the cotton bed. We determine this diameter from the condition that the elastic rods of the device easily roll over the lumps that are on it, i. e. the pressure of the rods is concentrated on the lumps and as a result they are destroyed. Otherwise, the elastic rods will push the soil lumps forward. As a result, they are not destroyed, but they are unloaded in front of the support-lump-breaking coil and showered into the furrows.

5. 2. Agro-technical and energy performance of the changing frontal plugs

It is known from literature sources [24] that in order to ensure the rolling of elastic rods through the encountered lumps, the diameter of the middle part of the support-lump-breaking coil must satisfy the following condition:

$$D_c \geq m \text{ctg}^2 \frac{\varphi_1 + \varphi_2}{2}, \quad (29)$$

where h – largest size (height) of the lump; φ_1, φ_2 – friction angles of the lump, respectively, on the rod and the soil.

From the diagram shown in Fig. 6:

$$D_o = D_c + (B - b_c) \text{tg} \varphi_r, \quad (30)$$

or taking into account:

$$D_o \geq m \text{ctg}^2 \frac{\varphi_1 + \varphi_2}{2} + (B - b_c) \text{tg} \varphi_r. \quad (31)$$

The diameter of the disc:

$$D_d = D_o + 2h_n, \quad (32)$$

where h_n – depth of disc immersion in the soil.

According to the diagram shown in Fig. 6:

$$h_n = h_g - 0.5(B - b_c) \text{tg} \varphi_r, \quad (33)$$

where h_g – height of the cotton bed.

Taking into account the last expression and expression (32), expression (33) has the following form:

$$D_o \geq m \text{ctg}^2 \frac{\varphi_1 + \varphi_2}{2} + 2h_g. \quad (34)$$

From the analysis of the expressions (28), (30) and (33), it follows that the diameters D_c, D_o and D_d depend on the width of the support-lump-breaking coil, sizes of lumps on

the surface of the beds, their external and internal angles of friction, the width of the tops of the cotton patch and the angle of its slopes to the horizon.

Accepting $\varphi_1=30^\circ$, $\varphi_2=40^\circ$, $m=100$ mm, $b_c=90$ mm, $h_g=210$ mm and $\varphi_2=40^\circ$ and also substituting the above found value in expressions (29), (31) and (34), we get that $D_c \geq 204$ mm, $D_e \geq 480.9$ mm and $D_d \geq 480.9$ mm.

Thus, the calculations found that the diameter of the middle part of the support-lump-breaking coil should be at least 176 mm, the diameter of the circle along which the elastic rods are located (fixed) – at least 510 mm and the diameter of the support disc of the support-lump-breaking coil – at least 680 mm.

As can be seen from the analysis of the geometric parameters of the support-lump-breaking coil, to a greater extent, the density of the soil in the ridge is influenced by such components as: the diameter of the discs and elastic rods, the number of rods and the depth of their immersion in the soil, as well as rigid rods installed at an angle of slope and horizontally. However, the impact of a large number of factors and the complexity of the processes taking place during soil compaction due to the constantly changing physical and mechanical properties of the soil do not allow finding the optimal geometric parameters of the support-lump-breaking coil, only with the help of theoretical relations, only an experimental study is needed.

6. Discussion of experimental results

Based on the results, the longitudinal distance between the angle cutter and the body is determined to provide appropriate measurement. The measurement showed that the deformation zone of the plate does not reach the angle cutter, and its height is determined taking into account its machining depth and coating width, agro-technical and energy performance. The laws of variation depending on the parameters of the angular frontal plow and the speed of the aggregate were evaluated based on rigorous calculations, which a condition of the soil for planting without forming open ridges and boundaries in a single pass through the field, were determined.

Through precise experimental conditions, the effect of the load on the base-disintegrating spiral on the rate of soil destruction of cotton beds was studied.

The results of the question on the influence of the load on the device are depicted in Fig. 4. The conditions for the load influence where humidity is $W=16-17\%$ and the diameter of the elastic rods is 3 mm, 4 mm, 5 mm; b is the humidity $W=13-14\%$ and the diameter of the elastic rods is 3 mm, 4 mm, 5 mm; c is the humidity $W=9-10\%$ and the diameter of the elastic rods is 3 mm, 4 mm, 5 mm were studied.

The experiments were performed on lumps of different humidity conditions: 9–10 %, 13–14 % and 16–17 %. The speed of movement of the installation was 1.0 m/s.

The authors [25] found that soil depth was a very important factor influencing soil microbiological structure and activity. Soil conservation practices improved the physicochemical and microbiological properties of the soil. It was found that this technology, developed by the authors, does not affect the microbiological and physicochemical properties of the soil. Their findings support our work and the results are aligned with our findings. Other researchers [26] emphasized that as the vertical load on the working body increases, the rate of soil particle destruction increases, as the diameter of the elastic rods and the humidity of the soil

particles decrease. Their work also supports our findings. The recommended technology was to destroy soil fragments with a humidity of 16–17 % at a vertical load of 400 N with 3, 4 and 5 mm elastic rods, respectively, 86.6, 81.5, 75.1 %, and the vertical load was 1,000 N – 94.4, 89.2, 81.2 % respectively. At the same loads, the rate of extinction of lumps with a humidity of 13–14 % was 84.1, 77.6, 72.3, 91.8, 85, 78.7 %, respectively, and with a humidity of 9–10 %, respectively, 68.2, 66.4, 63.1, 77.0, 73.8, 68.9 %.

Based on the fact that the effect of the load on the degree of destruction of soil particles can be expressed by the following empirical formulas, the humidity is $W=16-17\%$ and the diameter of the elastic rods is 3 mm, 4 mm, 5 mm.

According to the results, the rate of maximum destruction of soil fragments is provided by elastic rods with a diameter of 3.0–4.0 mm, and it is about 80–95 %.

During the experiments, the number of elastic rods was 60, the diameter of the discs was $R=0.6$ m, and the width of the tool was 0.70 m (Fig. 5) and the degree of soil erosion was found to depend on the speed of movement of the support-collection device.

As can be seen from the graphs, as the speed of movement increases, the rate of their extinction decreases with all the moisture in the soil. Thus, at a speed of 0.4 m/s and soil humidity between 7–8, 10–12, 15–17 %, the rate of destruction of soil fragments by the support-breaking device is 72.4, 79.2, 86 %, respectively, at a speed of 1.6 m/s, respectively, 67.1, 75.6, 82.3 %, respectively, which is mainly due to the reduction of the exposure time of the flexible rods to the soil surface.

The rate of destruction of soil fragments at different speeds of movement of the experimental support-softening roll is up to 67–86 %.

Thus, it was determined that the width of the base-splitting roll should be at least 60 cm. According to the scheme shown in Fig. 7, the length L of the elastic lines of the roll-to-be-broken fracture was determined by the following formula.

From the analysis of this expression, it follows that the length of the elastic rods should be 81 cm and the width of the spatial layer for the development of the cotton root system, its standard deviation, slope angle and slope angle is the width of the ridge top.

The supporting spray spiral is characterized by the following diameters (Fig. 6): the diameter of the middle part D_s , the discs D_d and the circle D_o on the disc, on which the elastic rods are located.

Thus, the calculations showed that the diameter of the middle part of the support should be at least 176 mm, the diameter of the circle where the elastic rods are located (fastened) should be at least 510 mm and the diameter of the support disc support – disposable spool at least 680 mm.

An analysis of the geometric parameters of the soil splitting spiral shows that the following components affect the soil density to a greater extent: the diameter of the discs and elastic rods, the number of branches and the depth of their immersion into the soil, as well as rigid rods mounted at a slope angle and horizontally. However, due to the influence of many factors and the constantly changing physical and mechanical properties of the soil, the complexity of the soil compaction processes does not allow finding the optimal geometric parameters of the reference – spiral, only an experimental study is needed.

There are 12 regions in the Republic of Uzbekistan, and the methods of tillage in each region require an approach based on the characteristics of the land. The construction and operation of plows with discs, i.e. working bodies in the

form of spherical discs in the leveling of lands were analyzed, a review of research on their creation and substantiation of parameters was formed and other well-known scientists were engaged in the creation of machines with disc working bodies and substantiation of their parameters. However, it should be noted that in the context of the Republic, no separate research has been conducted on the experimental study, application and justification of the parameters of the spiral, which combines the assistance in the basic tillage of lands.

Many factors were involved in this process, and mutual experiments were carried out using 5 mathematical planning methods as an experiment, the effect of 13 factors was studied taking into account the complexity of the process.

Based on the theoretical analysis of the process and initial experiments, the degree of variability and intervals of the factors were selected, and the Hartley-4 multi-variable experimental plan was selected for the experiments.

The experimental results were processed in a reliable manner on an IBM Pentium IV computer using PLANEXP-2 software for specific regression analysis, and the proportionality of the variance hypothesis with a similar number of iterations of the experimental results was tested using the Cochran criterion. The adequacy of the model, i. e., the suitability of the regression equation to describe the optimization parameter, was checked by the Fisher-F criterion. The model was considered adequate when $F_{calc} < F_{tab}$.

It is not possible to introduce the proposed technology in all regions of the country, because the deformative nature of land in each region is different. This technology is offered in areas with high mechanical sand content of the soil. In addition, the use of soil moisture is limited in Namangan, Andijan, Fergana, Tashkent regions, as the technology increases the weight of sticky clay equipment in the process of breaking down wet lumps, which in turn accelerates the compaction properties of the soil, negatively affecting soil fertility.

7. Conclusions

1. The method of determining the quality of grinding in the treated layer of the formed seedbed, in which soil samples

were taken with an area of one linear meter and in depth to the depth of processing, is disclosed. The program of experimental study of the support-lump-breaking coil, which was carried out in two stages, is described. The method for determining soil moisture using a cutting cylinder with a volume of 601.4 cm³ along the bed (rut) in six places is also described. The following is a method for optimizing the main parameters of the support-lump-breaking coil, while the solution of the research problem is given, which consisted in determining the rational values of the parameters of the support-lump-breaking working body, providing the required degree of destruction of soil lumps in a cotton bed. The results of experimental studies on the dependence of the degree of destruction of soil lumps on the vertical load on the support-lump-breaking coil and the diameter of elastic rods were verified in practical application. The substantiation of the parameters of the support-lump-breaking coil was tested successfully in the experimental study.

2. The results of the empirical analysis show that the maximum degree of destruction of soil particles is provided by elastic rods with a diameter of 3.0–4.0 mm, and it is about 80–95 %. During the experiments, the number of elastic rods was 60, the diameter of the discs was $R=0.6$ m, and the width of the tool was 0.70 m. Based on the experimental results, the efficiency of the proposed technology is 4–5 times higher in the Republic of Uzbekistan than in traditional earth crushers. It is recommended to introduce this new technology in the Republic of Uzbekistan in Kashkadarya, Surkhandarya, Jizzakh, Syrdarya, Bukhara, Samarkand, Navoi, Karakalpakstan, as the nature and conditions of land use are the same.

One of our future plans is to produce the proposed technology not only in 8 regions of the country, but also in all regions of the country with innovative land crusher equipment that adapts to the characteristics of the land and serves to increase land efficiency.

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