Technology and machine parameters for preparing the soil for sowing cotton

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Abstract. The study aims to justify the design scheme and main parameters of the combined aggregate for soil preparation for cotton sowing on ridges. The authors have developed the technology of soil preparation for cotton sowing on ridges and the aggregate for its implementation. The technology and design scheme of the developed aggregate are presented. The unit consists of a mouldboard deep loosener with a sloping rack and a ridge maker. The basic principles and methods of classical mechanics, mathematical analysis, and statistics were used in this study. The optimum constructive scheme of combined aggregate is grounded. It was established that to provide formation of new ridges instead of existing ones on fields without stems of cotton with the required degree with minimum power consumption working surfaces of inclined deep looseners equipped with mouldboards and rippers should be turned to each other and shifted relative to each other in a longitudinal plane. The formation of ridges to the required degree with minimal energy input is ensured at a width and length of the subsoiler's chisel, respectively 5 and 20 cm, the width of the wing width 21 cm, wing length between 47 and 49 cm, minimum longitudinal spacing between subsoilers 35 cm.

1 Introduction

Research on creation and application of machines for tillage and preparation of soil for seeding on ridges, study of their performance and justification of parameters, as well as study of processes of interaction of working bodies with soil were carried out by F.Mamatov [1-16], [18-23], [28-29], B.Mirzaev [5-12], [14-21], [23], 28-29] U.Umurzakov [4, 19], N.Aldoshin [3, 10, 11, 19, 20, 24], D.Chuyanov [5, 27], U.Kodirov [6, 24], H.Ravshanov [4-6], [20], [25-26], H.Fayzullaev [25], I.Kurdyumov [31], E.S.Zykin [31-38] and others.

The technologies of preparation of fields without cotton stems for sowing on ridges, currently used in agricultural production of the Republic, have several drawbacks. In particular, the existing technology has a high material and energy intensity, as it consists of several agro-technical activities carried out by separate units. All this leads to lower productivity, excessive compaction of soil, intensive drying, and delayed soil preparation for sowing. Research analysis has shown that when preparing fields for sowing on ridges, improvement of tillage quality, as well as reduction of fuel, labour and other costs, can be

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achieved by applying combined aggregate, carrying out formation of new furrows instead of existing ridges, new ridges instead of existing furrows on fields without cotton stalks. The study aims to justify the design scheme and main parameters of the combined aggregate for soil preparation for sowing cotton on ridges.

2 Methods

The basic principles and methods of classical mechanics, mathematical analysis, and statistics were used in this study.

Based on the analysis of research works and conducted studies, the technology and constructive scheme of the unit for soil preparation for sowing on the ridges have been developed. Patent for invention № IAP 04832 and utility model № FAP 00672 of the Republic of Uzbekistan are protected.

The proposed technology is carried out in the following sequence (Fig. 1): simultaneously loosening soil of the side parts of the right ridge of the existing row spacing, deep linear loosening of the bottom layer of the right side of the ridge being formed to a depth of 25-30 cm, turning the top soil layer with 10-12 cm thickness of the existing right ridge to the left - to the right of the middle of the existing ridge and loosening the bottom of the top layer of the right ridge (Fig. 1a). Then in this sequence, loosening the soil on the sides of the left ridge of the existing row spacing, deep linear loosening of the bottom layer of the left side of the ridge being formed to a depth of 25-30 cm, turning the top layer of soil with 10-12 cm thickness of the existing left ridge to the right - to the left side of the middle of the existing ridge and loosening the bottom of the top layer of the left ridge (Fig. 1b) is done. Then the loosened bottom layer of the right and left ridge topsoil is moved to the middle of the existing inter-row on the previously displaced topsoil. As a result, a new ridge with a deeply loosened bottom layer is formed instead of the existing ridge, and a new furrow is formed instead of the existing ridge (Fig. 1d).

The working process of the designed unit for implementing the proposed technology is as follows: subsoiler 4 with a tilt leg loosens the soil at the sides of the right ridge, the existing row spacing and deep linear loosening of the bottom layer of the right side of the ridge being formed, its blade 6 cutting the top layer of soil turns it to the left - to the right of the middle of the existing ridge, and ripper 3 loosens the bottom part of the top layer of the right ridge [33-34].
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1. Simultaneously loosening soil of the side parts of the right ridge of the existing row spacing, deep linear loosening of the bottom layer of the right side of the ridge being formed to a depth of 25-30 cm, turning the top soil layer with 10-12 cm thickness of the existing right ridge to the left - to the right of the middle of the existing ridge and loosening the bottom of the top layer of the right ridge (Fig. 1a).

2. Then in this sequence, loosening the soil on the sides of the left ridge of the existing row spacing, deep linear loosening of the bottom layer of the left side of the ridge being formed to a depth of 25-30 cm, turning the top layer of soil with 10-12 cm thickness of the existing left ridge to the right - to the left side of the middle of the existing ridge and loosening the bottom of the top layer of the left ridge (Fig. 1b).

3. Then the loosened bottom layer of the right and left ridge topsoil is moved to the middle of the existing inter-row on the previously displaced topsoil. As a result, a new ridge with a deeply loosened bottom layer is formed instead of the existing ridge, and a new furrow is formed instead of the existing ridge (Fig. 1d).

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Then deep loosener 5 with tilt stand loosens the soil on the sides of the left ridge of the existing row, and deep linear loosening of the bottom layer on the left side of the ridge being formed, its blade 7 cutting off the top layer of soil turns it to the right - to the left side of the middle of the existing ridge, and loosener 3 loosens the bottom part of the top layer of the left ridge. After that, ridge maker 8 shifts the loosened soil layer of the ridges to form a new irrigation furrow and ridge (Fig. 2). The rest of the new ridges and furrows between the rows are formed in the same way [33-34].

To perform the processes of loosening the side of the ridge and the bottom layer of the irrigation furrow, turning the topsoil of the ridge, and loosening its bottom layer, we selected a deep loosener with a sloping stand equipped with a mouldboard and a ripper (Figure 3).

3 Results and Discussion

The main parameters influencing the qualitative and energy performance of a deep opener with a sloping machine leg are considered to be the following: 

- \( H_{thk} \) is height of deep opener, m;
- \( b_i \) is width of bit, cm;
- \( L_i \) is length of bit working surface, m;
- \( i_u \) is angle of bit blade sharpening, degree;
- \( i_n \) is angle of bit stand sharpening, degree;
- \( i_d \) is angle of blade sharpening, degree;
- \( t_y \) and \( b_u \) is thickness and width of stand, m.

Based on earlier researches, we accept angle of chisel blade sharpening \( i_i = 15^\circ \), angle of bit sharpening \( i_u = 30^\circ \), angle of chisel crushing \( 20^\circ \), chisel thickness and width \( t_y = 0,03 \) m, and \( b_u = 0,18 \) m accordingly.

![Fig. 1. Process flow diagrams for ridge forming technology in stemless fields](image)

![Fig. 2. Structural scheme of the combined machine (a) and arrangement of its working tools (b): 1 is frame; 2 is attachment; 3 is support wheel; 4 and 5 is deep loosener with tilt frame; 6 and 7 is left and right mouldboard; 8 is ridging tool](image)
The width of the deep loosener bit is determined based on the exclusion of the formation of growth in front of the bit according to the following expression proposed by V. Trufanov

\[ b_i \geq \frac{h_{cr}}{\mu}, \]  

(1)

where \( h_{cr} \) is the maximum working depth of the deep opener, m; \( \mu \) is the coefficient expressing the ratio of the critical depth of the bit stroke to its width.

According to expression (1), at \( h_{cr} = 30 \) cm and \( \mu = 7,0 \), bit width should be no less than \( 0,43 \) m. We accept \( b_i = 0,05 \) m.

According to expression (2), at \( h_{cr} = 30 \) cm and \( \mu = 7,0 \), bit width should be no less than \( 0,43 \) m. We accept \( b_i = 0,05 \) m.

Chisel length of subsoiler shall be determined considering the condition of smooth soil slide on chisel working surface and sufficient breaking under its action by the following formula

\[ l_i \leq \left( \frac{\sigma_v \sin^2 \left(\frac{\pi}{2} + \frac{\alpha_i - \varphi_1 - \varphi_2}{2}\right)}{\rho \sin \left(\frac{\pi}{2} - \frac{\alpha_i + \varphi_1 + \varphi_2}{2}\right) - \frac{V^2 \sin \alpha_i \left(\sin \left(\frac{\pi}{2} + \frac{\alpha_i - \varphi_1 - \varphi_2}{2}\right) \cos \alpha_i \cos \left(\frac{\pi}{2} + \frac{\alpha_i - \varphi_1 - \varphi_2}{2}\right) \cos \varphi_1 - \cos \left(\frac{\pi}{2} + \frac{\alpha_i - \varphi_1 - \varphi_2}{2}\right) \sin \varphi_1 \right)} \right), \]  

(2)

where \( \sigma_v \) is temporary resistance of soil to shear, Pa; \( \varphi_1 \) and \( \varphi_2 \) is angle of external and internal friction of soil, degrees; \( \rho \) is specific weight of soil, kg/m\(^3\); \( g \) is free-fall acceleration, m/s\(^2\); \( V \) is speed of movement, m/s.

According to expression (2), at \( \alpha_i = 20^\circ \); \( v_r = 2104 \) Pa; \( \varphi_1 = 30^\circ \); \( \varphi_2 = 40^\circ \); \( \rho = 1450 \) kg/m\(^3\) and \( V = 2 \) m/s, length of chisel working surface should be \( l_i = 0,196 \) m. We take \( l_i = 0,2 \) m.

The height of the deep opener is determined by the following expression

\[ N_n = a_p - \frac{N_p - h_{nm}}{2} - a_a + \frac{l_i \sin \alpha_i}{2} + 1,2 \sqrt{a_a^2 + b_a^2}, \]  

(5)

where \( a_a \) is thickness of loosened soil layer relative to top of formed ridge, m; \( H_n \) is height of new ridge, m; \( h_{nm} \) is height of existing ridge, m; \( a_i \) is depth of moldboard tillage, m.

By expression (9) at \( a_p = 0,45 \) m, \( h_{nm} = 0,15 \) m, \( a_a = 0,12 \) m, \( b_a = 0,21 \) m, \( l_i = 0,2 \) m, \( \alpha_i = 30^\circ \), \( l_u = 0,26 \) m and \( a_{p_{max}} = 0,5 \) m height of subsoiler should be no less than \( N = 0,72 \) m. We assume
The longitudinal distance between adjacent subsoilers is determined based on the conditions of avoiding overlapping of the zone of soil deformation by rear subsoiler chisel with the zone of soil deformation by front subsoiler chisel

\[ L_c \geq (a_p - N_p + \frac{1}{2} h_n) \cot \psi. \] (7)

At \( a_p = 0.45 \text{ m}, h_n = 0.15 \text{ m}, l_n = 0.26 \text{ m}, \) and \( \psi = 40^\circ \) by expression (7), the longitudinal distance between subsoilers should be no less than 0.375 m.

The longitudinal distance from the deep loosener's chisel to the ridge loosener's chisel toe is determined based on the conditions of avoiding overlapping of the soil deformation zone by the chisel and the ridge loosener to each other

\[ L_{sw} \geq l \cos \alpha_a + N_{ab} \tan \beta_b + b_a \cot \gamma_a + a_r \cot \psi. \] (8)

According to expression (8) at \( l = 0.2 \text{ m}, \alpha_a = 20^\circ, N_{ab} = 0.3 \text{ m}, ba = 0.21 \text{ m}, \gamma = 40^\circ, \) and \( \psi = 45^\circ \) longitudinal distance from deep loosener chisel to ridge former's nose should be no less than 0.63 m.

Experimental researches on the justification of design of working elements of the developed unit and scheme of their mutual arrangement, scheme of arrangement of mouldboard deep loosener with sloping legs on the frame, length of wing and width of capture, width of capture, angle of crumbling and angle of installation of ripper blade to the direction of movement were carried out.

Experimental studies were conducted in two stages. At the first stage, the influence of the construction of working tools with a tilt stand and their mutual location, type of working tools for tillage of inter-row and ridge forming and their mutual location, the longitudinal distance between the mouldboard deep rippers with a tilt stand, number and width of ripper and also speed of their movement on their agricultural and energy performance were studied; at the second stage, the multi-factor experiments with the application of mathematical planning of experiments were carried out.

To conduct experimental research on the justification of the design of working tools with tilt legs and scheme of their mutual arrangement, four variants of experimental samples of working tools were developed and manufactured. The results of experimental studies showed that at speeds of 7-9 km / h to ensure the required quality of crumbling the soil with minimal energy consumption is advisable to use in the unit working bodies with a tilted leg facing each other with their working surfaces and offset relative to each other in the longitudinal plane.

To conduct experimental research on the substantiation of the type of working elements for tilling between the rows and the forming of ridges and their relative positioning, the device consisting of different working elements was made of three variants. According to the research results, it was established that the device consisting of mouldboard deep loosening tools with angle legs and ridging tools ensures the formation of ridges with required height and minimum energy consumption.

According to the data of the one-factor experiments, it is established that the length of the wing of the subsoiler should be within 0.47-0.49 m, and the width of the ripper should be within 0.1-0.14 m to provide the required quality of work with minimum power consumption at speeds of 7-9 km/hour and the longitudinal distance between them should be no less than 0.375 m.
Conclusions

1. The most optimal constructive scheme of combined aggregate is the scheme with consecutive installation of tilted subsoilers equipped with right- and left-turning mouldboards and ridge breakers.
2. It was established that to ensure the formation of new ridges instead of existing ones on fields without cotton stalks of required degree with minimum energy consumption working surfaces of inclined subsoilers equipped with mouldboards and rippers should face each other and shift relatively from each other in the longitudinal plane.
3. The formation of ridges to the required degree with minimum energy input is ensured when the width and length of the chisel respectively 5 and 20 cm, width of the wing share 21 cm, wing length between 47-49 cm, the minimum longitudinal distance between subsoilers 35 cm.

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