The machine for the preparation of the soil in sowing of plow crops under film

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Abstract. In the world much attention is paid to the development and application of machines that perform all technological processes of soil cultivation and preparation of soil for sowing crops in one pass on the field. The aim of the research is to substantiate the constructive scheme and mutual arrangement of the working elements of the machine for preparing the soil for sowing melon crops under the tunnel-type film. The authors proposed new technology for preparing the soil for sowing melon crops under the film of the tunnel type in one pass of the machine, including the surface loosening of the covered soil, milling-free loosening and formation of irrigation furrow along the axis of symmetry of the sowing zone, preparing the strip of soil for sowing melon crops under the film of the tunnel type. The design of the developed combined machine for the realization of the offered technology is resulted. The basic principles and methods of classical mechanics, mathematical analysis, and statistics were used in this study. It is established that the most optimal design scheme of the machine is considered to be a scheme with a sequential installation of a lancet leg, pairs of deep loosening machines, furrow cutters, and rotary working elements inclined to each other. It is theoretically proved that qualitative preparation of the field for sowing melons with minimum energy consumption is provided with the longitudinal distance between the deep loosened and the lancet leg of 40 cm, the transverse distance between the deep loosened and the support wheel of 10 cm, the longitudinal distance between the deep loosened and the furrow cutter of 50,6 cm, the longitudinal distance between the furrow cutter and the rotary working device of 123 cm.

1. Introduction
Timely and high-quality preparation of soil for the cultivation of agricultural crops is an urgent task in agriculture. Existing technologies of soil preparation for sowing are carried out by single-operating machines in several passes, which leads to excessive compaction of soil, reduction of labor productivity, increase in labor and resource consumption, delaying of terms of soil preparation, intensive drying of soil, which leads to a reduction of crop yields [1-8].

Problems of cultivation and preparation of soils for sowing crops have been considered in many scientific papers [1-18].
Researches on the perfection of technologies of preparation of soil for sowing of melon crops, creation of machines for melon cultivation, substantiation of designs and parameters of their working bodies were carried out F.Mamatov, B.Mirzaev [2-7], D.Chuyanov [8, 11], U.Kodirov [1], H.Ravshanov [7], I.Ergashev [5, 6, 7], V.I.Malyukov [20], V.G.Abezin [21], A.D.Em, V.N.Zhukov [22] and others.

V.G.Abezin [21] substantiated and developed working bodies for pre-sowing tillage and sowing of melon seeds. Studies by A.D.Em and V.N.Zhukov [22] are mainly aimed at the development of machines for inter-row cultivation of melon seeds.

All these studies are aimed at the improvement of technologies and technical means of cultivation to prepare the soil for sowing melon crops in open ground. These techniques cannot be used to prepare the soil for sowing melon crops under the tunnel-type film.

The purpose of the study is to justify the design of a combined machine for preparing the soil for sowing melon crops under the film and the mutual location of its working bodies based on the theory of their interaction with the soil layer.

2. Methods

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

The authors proposed the new technology for preparing the soil for sowing melon crops under the tunnel-type film, which provides for surface loosening of the soil in the middle part of the zone of melon crops sowing covered by the tunnel-type film, non-soldering deep loosening (Fig.1,a), the formation of irrigation furrow along the axis of symmetry of the sowing zone (Fig.1,b) and preparation of the soil strip for sowing melon crops (Fig.1,c).

Combined machine (Fig. 2), which carries out the proposed technology consists of frame 1, lancet leg 4, paired left and right deep loosening 5 and 6, furrow 7, and rotary working tools 9 (Fig. 2). The machine, based on the technology of sowing melon crops under the film of closed tunnel type should process and prepare a strip with a width of 1.4 m in one pass.

During the operation of the machine, the Lancet Foot 4 shallow cultivates a strip equal to the working width of the furrow 7, loosens the soil and cuts the roots of weeds. At first, the drill bit 6 enters the soil and loosens it up. Thus the formed cracks spread on a surface of the soil at an angle y=40-45°. And after that the following deep loosener 5 influences the soil in a similar way. As a result, the best soil crumbling is ensured in the sowing zone. The furrow former 7 then cuts the furrows in the middle of the sowing zone. The process of preparing the soil for sowing under the film of the closed tunnel type ends with the cultivation of the strip for sowing melon crops, rotary working tools 9.

3. Results and discussion

We define the height of deep looseneders by the following expression [24].

\[ H = h_1 + h_2 + a, \] (1)

Where: \( h_1 \) is the distance from the lower frame surface to the surface of the swollen soil, m; \( h_2 \) is the maximum height of the swollen soil layer, m; \( a \) is the maximum depth of cultivation, m.
Figure 1. Scheme of technology for preparing the soil for sowing melon crops under the film: a is the cross-section of the field after the surface and deep loosening of the sowing zone; c is the cross-section of the field after the formation of the irrigation furrow; d is the cross-section of the field after the preparation of the sowing strip for sowing.

Figure 2. Structural diagram of the machine for preparing the soil for sowing gourds under the film of the closed tunnel type: 1 is frame; 2 is attachment; 3 is support wheel; 4 is lancet paw; 5, 6 are left and right deep looseners; 7 is furrow cutter; 8 is parallelogram mechanism; 9 is rotary ripper; 10 is ripper plate

At $h_1=30 \text{ cm}$ [23], $h_2=a/4=10 \text{ cm}$ [24], and $a_{\text{max}}=35 \text{ cm}$ in expression (1), the height of the deepener is $H=75 \text{ cm}$. Transverse distance between support wheel and deep loosener (Fig. 3) was determined from the condition that the soil deformed under the influence of the bit did not reach the support wheel, that is, the support wheel moved outside the deformed zone of soil and the following expression was obtained.

$$S \geq a \tan \psi_2 - b_k - t_T,$$

(2)

Where: $\psi_2$ is the angle of soil chipping in the pepper plane, degree; $b_k$ is the width of the inclined part of the deep-cutter stand, m; $t_T$ is the thickness of the deep-cutter stand, m.

Taking $\psi_2=45^\circ$, $B_i=0.22 \text{ m}$, $t_T=0.05 \text{ m}$, and $a=35 \text{ cm}$ in expression (2) we will obtain $S \geq 0.08 \text{ m}$.

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The longitudinal distance $l_1$ (Fig. 4) from the tine to the tine of the drill bit is determined from the condition that the soil deformation zone treated with the drill does not reach the tine structure. At the same time, we take into account the destruction of the upper part of the reservoir raised under the action of the bit.

Based on experiments the height of the destroyed part of the layer is determined by expression $h_e=(0.2-0.25)$.

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Based on experiments, the height of the destroyed part of the formation is determined by the expression

\[ h_c = (0.2 - 0.25) a. \]

From Fig. 4 we have

\[ l_i \geq l_n + S_b = l_n + (a - h_c) \tan \psi_1, \]

where \( l_n \) is the length of the lancet leg, m; \( S_b \) is the length of the deformed zone of the soil under the influence of the bit, m; \( h_c \) is the height of the soil layer lifting on the working surface of the drill bit, m; \( \psi_1 \) is the angle of the soil chipping in the longitudinal-vertical plane, degree;

The values of angle 1 are determined by V.P.Goryachkin formula [25, 26]

\[ \psi_1 = \frac{\pi}{2} - \frac{1}{2} (\alpha_i + \phi_1 + \phi_2), \]

Calculations made on the basis of expression (5) at \( a = 35 \text{ cm}, h_c = 8 \text{ cm}, h_u = 5.4 \text{ cm}, l_n = 12.5 \text{ cm}, \alpha_i = 20^\circ, \phi_1 = 30^\circ, \) and \( \phi_2 = 40^\circ \) have shown that the longitudinal distance between the shallow paw and the deep loosener should be at least 39.5 cm.

The longitudinal distance \( L_2 \) (Fig. 5) from the nose of the deep loosener bit to the nose of the furrow cutter was determined from the condition that the soil deformation zone treated with the furrow cutter did not reach the standing structural elements of the deep looseners.
From Fig. 5 should
\[ L_2 \geq l_w + l_m + l_z = (a - H_T - h_u)\tan \beta_b + l_i \cos \alpha_i + a_i \tan \psi_1, \tag{6} \]

Where: \( H_T \) is the depth of immersion in the soil of the straight part of the drill stand, m; \( h_u \) and \( l_i \) are height and length of the drill bit, m; \( \beta_b \) is installation angle of the drill stand in the longitudinal plane, degree; \( a_i \) is the working depth of the furrow cutter, m.

Performed calculations by expression (6) at \( a=35 \text{ cm}, H_T=10 \text{ cm}, h_u=5.4 \text{ cm}, l_u=15 \text{ cm}, \alpha_i=20 \text{ degrees}, \theta_i=30^\circ \) and \( \beta_b=45^\circ \) showed that the longitudinal distance between the deep loosener and the furrow should be at least 50.6 cm.

The longitudinal distance \( L_3 \) between the furrow cutter and the rotary cultivator (Fig. 6) is determined from the condition to exclude soil particles coming from the wings of the furrow cutter on the teeth of the rotary cultivator, ie.
\[ L_3 \geq l_x + \frac{D_p}{2}, \tag{7} \]

Where: \( l_x \) is the distance from the toe of the bore-cutter to its wing, m; \( L_{x1} \) is the distance of soil particles ejection in the direction of the machine movement, after the furrow-cutter separating from the wing, m; \( D_p \) is the diameter of the rotary working device, m.

The minimum longitudinal distance between the deep loosening bits was determined from the condition that the ripper bits would affect the soil particle coming off the deep loosening bits after they fell to the bottom of the furrow (Fig. 7).

Based on Fig. 7.
\[ L \geq \frac{V_i}{g \cos \varphi} \left[ 1 - \frac{\sin \alpha_u \sin (\alpha_u + \varphi)}{\cos \varphi} \right] \times \left[ V_i \sin \alpha_u \cos (\alpha_u + \varphi) + \sqrt{V_i^2 \sin^2 \alpha_u \cos^2 (\alpha_u + \varphi) + 2gh u \cos^2 \varphi} \right] + l_i \cos \alpha_i, \tag{8} \]

Where: \( V_i \) is the forward speed of the machine, m/s; \( h_u \) is the height of the soil layer lifting on the working surface of the deep loosener bit, m.
Fig.7. Scheme for determining the minimum longitudinal distance between deep looseners

The minimum longitudinal distance between the deep cultivators at \( h_i = 0.054 \) m, \( \alpha = 20^\circ \), \( \varphi = 30^\circ \), \( g = 9.81 \) m/s\(^2\) and \( l_i = 0.5 \) m and \( V = 2.5 \) m/s in expression (8) is equal to \( L \geq 0.444 \) m. We accept 0.5 m.

We determine the width of the drill bit using the following formula [26].

\[
b \geq \frac{a(m + ctg \alpha_n)}{0.1 \left[ \frac{\sigma_x}{\tau_k} \right] (1 + 3tg \zeta) - n}
\]  

(9)

Where: \( \sigma_x \) is specific resistance of the soil to buckling, Pa; \( \tau_k \) is temporary specific resistance of the soil to buckling, Pa; \( \zeta \) is the angle of slope to the horizon of the resulting forces acting on the deepening bit from the soil side, degree; m and n are dimensionless coefficients depending on physical and mechanical properties of the soil.

As expression (9) shows, the width of the bit in the first turn depends on the depth of cultivation, physical and mechanical properties of the soil, and the angle of crushing the bit. Taking \( a_{\text{max}} = 35 \) cm, \( \alpha_u = 20^\circ \), \( m = 4.2 \); \( [\sigma_x] = 1.44 \cdot 10^6 \) Pa and \( [\tau_k] = 2 \cdot 10^4 \) Pa, \( n = 2.5 \) on expression (9) it is determined that when cultivating to the depth of 35 cm, the width of the bit should be less than 50 mm.

4. Conclusions

1. The most optimal design scheme of the machine for adjusting the soil for sowing under the film of the tunnel type is considered to be the scheme with a sequential installation of a lancet tine, pairs placed, and inclined to each other deep loosener, furrow cutters, and rotary working tools.

2. According to the results of theoretical studies, it was found that qualitative preparation of the field for sowing melons under the film at minimum energy consumption is provided with a longitudinal distance between the deep loosener and the lancet leg 40 cm, the transverse distance between the deep loosener and the supporting wheel 10 cm, the longitudinal distance between the deep loosener and furrow former 50,6 cm, the longitudinal distance between the furrow former and the rotary working device 123 cm.

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