The quality of loosening the soil with subsoilers of the combined machine

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Abstract. The aim of the study is to study the influence of the parameters of subsoilers on the quality of loosening of the soil when preparing the soil for sowing melons and gourds under a film with a combined machine. The authors have developed a combined machine for preparing the soil for sowing melons and gourds under a film. The structural diagram of the developed machine is presented. Theoretically, the completeness of loosening of the soil by subsoilers of the machine is determined from their parameters and relative position. Theoretical and experimental studies have established that the scheme of pair wise arrangement of subsoilers inclined to the right and left of the combined machine with working surfaces facing each other, as well as shifted relative to each other in the longitudinal plane, provides the required quality of work, while the longitudinal distance between the subsoilers should be 75 cm, and the transverse distance is 60 cm.

1. Introduction

High-quality soil preparation for cultivation of melons and gourds is an urgent task in agriculture. The existing technologies of soil preparation for sowing melons are carried out by single-operation machines in several passes, which leads to excessive soil compaction, a decrease in labor productivity, an increase in labor and funds consumption, a delay in soil preparation, intensive soil drying, which entails a decrease in yield [1-8; 20-28]. The problems of soil preparation for sowing melons and gourds are considered in many scientific works [1-5; 7-14; 18-27]. Research on improving soil preparation technologies for sowing melon crops, creating machines for melon growing, substantiating the structures and parameters of their working bodies were carried out by F.Mamatov, [1-16; 21-29; 33] B.Mirzaev [1-8; 12-14; 21-25; 28-29], D.Chuyanov [6; 20-22], U.Kodirov [4; 17], I.Ergashev [4-5], H.Ravshanov [18-19] V.I.Malyukov [30], V.G.Abezin [31], A.D.Em [32], V.N.Zhukov [32] and others. V.G.Abezin [32] substantiated and developed working bodies for pre-sowing soil cultivation and sowing melon seeds. All these studies are aimed at improving technologies and technical means of processing for preparing the soil for sowing melons in open ground. These technical means cannot be used to prepare the soil for sowing melons under a tunnel-type film.
The aim of the study is to study the influence of the parameters of subsoilers on the quality of loosening of the soil when preparing the soil for sowing melons and gourds under a film with a combined machine.

2. Methods

The authors have developed a combined machine (Fig.1) for preparing the soil for sowing melons and gourds under a film, which consists of a frame 1, a duckfoot paw 2, paired left 3 and 5 and right subsoilers 4 and 6, a furrow cutter 7 and rotary working bodies 8. The machine, based on the technology of sowing melons and gourds under a closed tunnel-type film, must process and prepare a strip with a width of 1.4 m in one pass. During the operation of the machine, the duck foot share 2 superficially processes a strip equal to the width of the furrow cutter 7, loosens the soil and cuts off the roots of weeds. First, the chisels of 9 subs oilers 4 and 5 with an inclined stand enter the soil and loosen it. Thus formed cracks spread to the soil surface at an angle \( \theta = 40-45^\circ \). After that, the subsequent subs oilers 3 and 6 in the same way affect the soil. The result is the best soil crumbling in the sowing area. Then the furrow cutter 7 cuts the furrows in the middle of the sowing zone. The process of soil preparation for sowing under a closed tunnel-type film ends with the processing of the strip for sowing melons and gourds with rotary working bodies 8.

![Figure 1. Schematic diagram of a combined machine for preparing soil for sowing melons and gourds under a film: a – top view; b – rear view](image)

The main quality indicator of the combined machine, which determines its efficiency, is the quality of soil loosening. The area of the loosened soil zone by subsoilers affects, on the one hand, the energy consumption of soil cultivation, on the other, the ability to retain and accumulate soil water. Therefore, when choosing a scheme for the location of subsoilers and their parameters, it is necessary to study the quality of soil loosening.

The quality of loosening is estimated by the completeness of loosening - the loosening coefficient \( \eta \). For subs oilers, the coefficient \( \eta \) is the ratio of the cross-sectional area of the loosened soil zone between the right and left subs oilers to the total area located in a plane perpendicular to the direction of movement of the machine and limited by the working width and maximum loosening depth, i.e.

\[
\eta = \frac{S_1 + S_2}{S},
\]

where \( S_1 \) and \( S_2 \) – respectively, the cross-sectional area of the loosened soil layer by the working bodies of the first and second rows, \( m^2 \); \( S \) – total cross-sectional area of the soil between the working bodies, \( m^2 \).

When determining the completeness of loosening the soil, we assume that the width of the chisels and the height of the inclined part of both working bodies are the same. Fig.2 shows that when...
loosening the soil in the zones of soil cultivation with chisels of the right and left subsoilers, the zones of propagation of soil deformation intersect with each other. In this case, a ridge with a height of $h_y$. Then the cross-sectional area of the loosened soil layer by the working bodies of the first row (Fig. 2).

\[ S_1 = F_1 + 2F_2 + F_3 \]  \hspace{1cm} (2)

Cross-sectional area of the loosened soil layer by the working body of the second row

\[ S_2 = F_2 + F_3 + F_4 + F_5 + F_6 + F_7 \]  \hspace{1cm} (3)

From Fig. 2 we have

\[ F_1 = [2(a - h_c)\tan \psi_2 + b_i]h_c; \]  \hspace{1cm} (4)

\[ F_2 = \frac{1}{2}(a - h_c)^2 \tan \psi_2; \]  \hspace{1cm} (5)

\[ F_3 = b_i(a - h_c); \]  \hspace{1cm} (6)

\[ F_4 = h_i^2 \tan \psi_2; \]  \hspace{1cm} (7)

\[ F_5 = \frac{1}{2}[(a - h_c) - h_y]^2 \tan \psi_2; \]  \hspace{1cm} (8)

\[ F_6 = [2h_y \tan \psi_2 - (a - h_c) \tan \psi_2](a - h_c - h_y); \]  \hspace{1cm} (9)

where $M$ – is the distance between the tracks of the working bodies.

From rice

\[ M = B_k - 2H_k \tan \beta_k - b_i, \]  \hspace{1cm} (10)

where $\beta_k$ – angle of inclination of the subsoiler rack in the transverse plane, degree.

**Figure 2.** Scheme for determining the completeness of loosening the soil with subsoilers:

1 and 2 – right and left subsoilers; 3 – chisels

Substituting the values $F_1, F_2, F_3, F_4, F_5, F_6$ and $F_7$ according to (3) – (9) in (2) and (3) we get

\[ S_1 = (a^2 - h_c^2)\tan \psi_2 + ab_i, \]  \hspace{1cm} (11)
\[ S_z = (a - h_z)^2 \cot \psi_2 + b_n(a - h_z) + \frac{3}{2} h_z^2 \cot \psi_2 - (a - h_z)h_z \cot \psi_2 + \]
\[ + (2h_y - a + h_z)(a - h_z - h_y) \cot \psi_2 + (B_k + 2H_k \cot \beta_k - b_i)h_z. \]  

(12)

The total cross-sectional area of the soil between the working bodies is

\[ S = B_i a_i. \]  

(13)

where \( B_i \) – width of capture of subsoilers, m.

From Fig.2 we have

\[ B_i = 2(a - h_z) \cot \psi_2 + b_i + M. \]  

(14)

Substituting the value of \( M \) according to (10) into (13) and (14), we obtain

\[ B_i = 2(a - h_z) \cot \psi_2 + B_k - 2H_k \cot \psi_2. \]  

(15)

\[ S = [2(a - h_z) \cot \psi_2 + B_k - 2H_k \cot \psi_2]a. \]  

(16)

Substituting the values of \( S_1, S_2 \) and \( S \) in (1), we obtain the following expression to determine the coefficient of loosening completeness \( \eta \)

\[ \eta = \frac{(a^2 - h_z^2) \cot \psi_2 + ab_i}{a[2(a - h_z) \cot \psi_2 + B_k - 2H_k \cot \psi_2]} + \frac{(a - h_z)^2 \cot \psi_2 + b_n(a - h_z) + \frac{3}{2} h_z^2 \cot \psi_2 - (a - h_z)h_z \cot \psi_2}{a[2(a - h_z) \cot \psi_2 + B_k - 2H_k \cot \psi_2]} + \]
\[ + \frac{(2h_y - a + h_z)(a - h_z - h_y) \cot \psi_2 + (B_k + 2H_k \cot \beta_k - b_i)h_z}{a[2(a - h_z) \cot \psi_2 + B_k - 2H_k \cot \psi_2]} . \]

(17)

It can be seen from (17) that the coefficient of loosening completeness \( \eta \) depends on the parameters of subsoilers, the transverse distance between them, the depth of soil cultivation, and the physical and mechanical properties of the soil.

Fig.3 shows the graphs of the dependence of the soil loosening coefficient on the depth of cultivation of the soil of sub oilers at \( \beta_i = 45^\circ, \psi_2 = 45^\circ \) and \( b_i = 5 \) cm.

Fig.3 shows the graphs of the dependence of the soil loosening coefficient on the depth of soil cultivation of subsoilers at and from the graphs it can be seen that with an increase in the lateral distance between the subsoilers and the depth of soil cultivation, the coefficient of loosening increases. In this regard, the transverse distance between the subsoilers and the depth of tillage must be selected based on agro technical requirements.

The height of the ridges at the bottom of the furrow is also one of the main agricultural indicators. From Fig.2 we have

\[ h_y = \frac{M - b_i}{2} \cot \psi_2. \]  

(18)

Substituting the value of \( M \) according to (10) into (18), we have

\[ h_y = \frac{B_k - 2H_k \cot \beta_k - 2b_i}{2} \cot \psi_2. \]  

(19)

It is known that during soil cultivation, the upper part of the ridge collapses, in this regard, the height of the ridge decreases, then the actual height of the ridge is determined by the following formula [34]

\[ h_{y_2} = K h_y, \]  

(20)
Figure 3. Graphs of the dependence of the coefficient of soil loosening on the depth of soil cultivation:
1 – $B_k = 60 \text{ cm}$; 2 – $B_k = 70 \text{ cm}$; 3 – $B_k = 80 \text{ cm}$

where $K_y$ – is a coefficient that takes into account the destruction of the ridge.

Taking into account (20), formula (19) has the following form

$$h_y = K_y \frac{B_k \cdot \text{ctg} \beta_k \cdot 2 \cdot b_1 \cdot \text{tg} \psi_2}{2}.$$  \hspace{1cm} (21)

The value of $K_y$ is within the following range of 0.49-0.61 [35].

It can be seen from (21) that the height of the crest at the bottom of the furrow depends on the lateral distance between the subs oilers, the height of their working part, the width of the bit, and the physic mechanical properties of the soil.

3. Results and Discussions

Experimental studies were carried out to study the effect of the mutual arrangement of subsoilers, as well as the operating speed on the degree of soil crumbling. The results of the experiments are shown in Fig. 4. According to the data of the experiments, it was found that at speeds of 6-9 km/h, to ensure the required quality of work with minimal energy consumption, the longitudinal distance between the subs oilers should be 75 cm, and the transverse distance should be 60 cm.
Figure 4. Graphs of the dependence of the degree of soil loosening on the longitudinal and transverse distance between subs oilers: 1, 2, 3 – respectively, at a soil cultivation depth of 25, 27.5 and 30 cm

4. Conclusions

The scheme of pairwise arrangement of subsoilers inclined to the right and left of the combined machine with working surfaces facing each other, as well as offset from each other in the longitudinal plane, provides the required quality of work with minimal energy consumption.

With a longitudinal distance between the subsoilers of 75 cm and a transverse distance of 60 cm, high-quality operation of the combined machine is ensured according to the required requirements with minimal energy consumption.

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