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Quality of Soil Loosening by Subsoilers of a Combined Machine

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Annotation. The purpose of the study is to study the influence of subsoiler parameters on the quality of soil loosening when preparing the soil for sowing melons under a film using a combined machine. The authors have developed a combined machine for preparing the soil for sowing melons and melons under film. A design diagram of the developed combined machine is presented. The completeness of soil loosening by machine subsoilers is theoretically determined based on their parameters and relative position.

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

Theoretical and experimental studies have established that the pairwise arrangement of subsoilers of a combined machine inclined to the right and left with working surfaces facing each other, as well as offset relative to each other in the longitudinal plane, provides the required quality of work. With a longitudinal distance between subsoilers of 75 cm and a transverse distance of 60 cm, high-quality loosening of the soil is ensured according to the requirements.

Key words: machine, soil, melons, technology, subsoiler, film, tunel

Introduction.

High-quality soil preparation for the cultivation of melons and melons is an urgent task in agriculture. Existing technologies for preparing the soil for sowing melons are carried out with single-operation machines in several passes, which leads to excessive soil compaction, decreased labor productivity, increased labor and money consumption, delayed soil preparation, intensive drying of the soil, which entails a decrease in yield [1-14].

The problems of preparing soils for sowing melons and melons are considered in many scientific works [1-14]. Research on improving technologies for preparing soil for sowing melons, creating machines for melon growing, substantiating the designs and parameters of their working bodies was carried out by F.Mamatov [2-7], D.Chuyanov [8, 11], I.Ergashev [5, 6 , 7], V.I.Malyukov, V.G.Abezin, A.D.Em, V.N.Zhukov [6] and others. V.G.Abezin substantiated and developed working bodies for pre-sowing tillage and sowing of 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 when preparing the soil for sowing melons under a tunnel-type film.

The purpose of the study is to study the influence of subsoiler parameters on the quality of soil loosening when preparing the soil for sowing melons under a film using a combined machine.

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

The authors have developed a combined machine (Fig. 2) for preparing the soil for sowing melons under a film, which consists of a frame 1, a lancet paw 2, paired left 3 and 5 and right deep loosening 4 and 6, a furrow cutter 7 and rotary working parts 6 (Fig. .2). The machine, based on the technology of sowing melons under a closed tunnel type film, must process and prepare a strip with a width of 1.4 m in one pass. During operation of the machine, the pointed paw 4 superficially processes a strip equal to the working width of the furrow cutter 7, loosens the soil and cuts off the roots of weeds. First, the chisels of subsoilers 5 and 6 with an inclined stand enter the soil and loosen it. In this case, the formed cracks spread to the soil surface at an angle ψ =40-45º. And after that, subsequent subsoilers 5 and 6 act on the soil in a similar way. As a result, the best crumbling of the soil in the sowing area is ensured. Then the furrow cutter 7 cuts furrows in the middle of the sowing area. The process of preparing the soil for sowing under a closed tunnel-type film ends with processing the strip for sowing melons and melons using rotary working bodies 9.

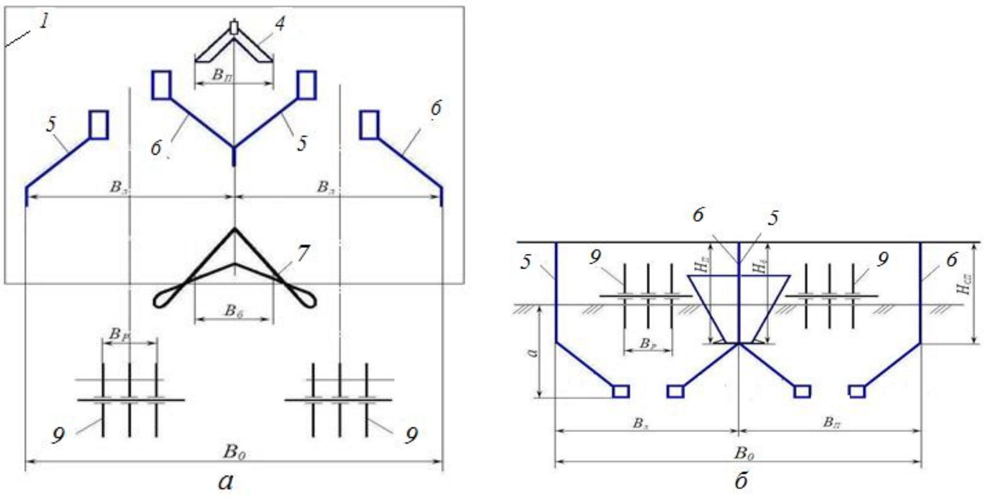

Fig.1. Schematic diagram of a combined machine for preparing the soil for sowing melons under film: a – top view; – rear б-view

The main qualitative indicator of the operation of a combined machine, which determines its effectiveness, is the quality of soil loosening. The area of the soil loosened by subsoilers affects, on the one hand, the energy intensity of soil cultivation, and on the other hand, the ability to retain and accumulate soil water. Therefore, when choosing the layout of subsoilers and their parameters, it is necessary to study the quality of soil loosening.

The quality of loosening is assessed by the completeness of loosening - loosening coefficient η. For subsoilers, coefficient η is the ratio of the cross-sectional area of the loosened soil zone between the right and left subsoilers 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.

$$\eta = \frac{S_1 + S_2}{S}, \tag{1}$$

here S_1 - is the area of the loosened layer with the working body of the first row, m^2:

S_2 – area of the loosened layer with the working body of the second row, m^2:

S – total cross-sectional area of the non-traversable loosening layer with the working bodies of the first and second row, m^2.

In a certain complete loosening, the width of the bits and the height of the inclined part of the working body of each pair will be considered the same and we will assume that the movement of the inclined part of the working body moves along the line of soil refraction.

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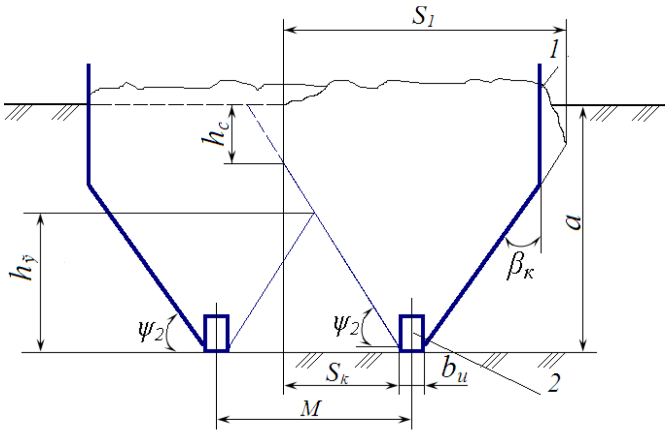

Fig.2. Scheme of loosening the soil with subsoilers

From figure 2 it can be seen that during the process of loosening the soil with a subsoiler in the loosened zone with chisels of the left and right working parts, the zone of distribution of soil deformation intersect with each other. As a result, a ridge is formed under a layer of arable land with a height hў.

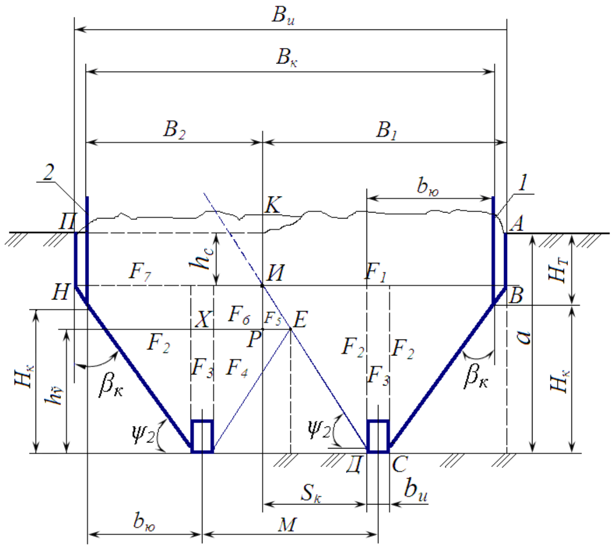

Fig.3. Scheme for determining the completeness of soil loosening with subsoilers

Area of the loosened layer with the working body of the first row (Fig. 3)

$$S_1 = F_1 + 2F_2 + F_3 \quad (2)$$

Area of the loosened layer with the working body of the second row

$$S_2 = F_2 + F_3 + F_4 + F_5 + F_6 + F_7 \quad (3)$$

Therefore, from figure 3

$$F_1 = [2(a - h_c)ctg\psi_2 + b_u]h_c; \quad (4)$$

$$F_2 = \frac{1}{2}(a - h_c)^2 ctg\psi_2; \qquad (5)$$

$$F_3 = b_u(a - h_c); \qquad (6)$$

$$F_4 = h_{\breve{y}}^2 ctg\psi_2; \qquad (7)$$

$$F_5 = \frac{1}{2}[(a - h_c) - h_{\breve{y}}]^2 ctg\psi_2; \qquad (8)$$

$$F_6 = [2h_{\breve{y}} ctg\Psi_2 - (a - h_c)ctg\psi_2](a - h_c - h_{\breve{y}});$$

$$F_7 = Mh_c - \frac{1}{2}h_c cg\Psi_2 \qquad (9)$$

here M is the distance between the tracks of the working parts

From figure 3

$$M = B_\kappa - 2H_\kappa ctg\beta_\kappa - b_u, \qquad (10)$$

Here B_κ - angle of inclination of the vertical transverse plane of the subsoiler holder.

Substituting value F_1, F_2, F_3, F_4, F_5 F_6 и F from equations (3) – (9) , (2) - (3), we get,

$$S_1 = (a^2 - h_c^2)ctg\psi_2 + ab_u, \qquad (11)$$

$$S_2 = (a - h_c)^2 ctg\psi_2 + b_n(a - h_c) + \frac{3}{2}h_{\breve{y}}^2 ctg\psi_2 - (a - h_c)h_{\breve{y}} ctg\psi_2 + \\ + (2h_{\breve{y}} - a + h_c)(a - h_c - h_{\breve{y}})ctg\psi_2 + (B_\kappa + 2H_\kappa ctg\beta_\kappa - b_u)h_c. \qquad (12)$$

The total cross-sectional area of the non-traversable loosening layer with the working bodies of the first and second row is determined by the following formula

$$S = B_u a, \qquad (13)$$

Here B_u – width of working grip of working parts, m.

From the drawing 2

$$B_u = 2(a - h_c)ctg\psi_2 + b_u + M \qquad (14)$$

From equation (10), substituting the values of M into equations (13) and (14), we obtain

$$B_u = 2(a - h_c)ctg\psi_2 + B_\kappa - 2H_\kappa ctg\psi_2. \qquad (15)$$

$$S = [2(a - h_c)ctg\psi_2 + B_\kappa - 2H_\kappa ctg\psi_2]a. \qquad (16)$$

Substituting values S_1, S_2 ,S (1), we obtain the following dependence for determining the loosening coefficient η.

$$\eta = \frac{(a^2 - h_c^2)ctg\psi_2 + ab_u}{a[2(a-h_c)ctg\psi_2 + B_\kappa - 2H_\kappa ctg\psi_2} +$$

$$+\frac{(a-h_c)^2 ctg\psi_2 + b_n(a-h_c) + \frac{3}{2}h_{\breve{y}}^2 ctg\psi_2 - (a-h_c)h_{\breve{y}} ctg\psi_2}{a[2(a-h_c)ctg\psi_2 + B_\kappa - 2H_\kappa ctg\psi_2} +$$

$$+\frac{(2h_{\breve{y}} - a + h_c)(a - h_c - h_{\breve{y}})ctg\psi_2 + (B_\kappa + 2H_\kappa ctg\beta_\kappa - b_u)h_c}{a[2(a-h_c)ctg\psi_2 + B_\kappa - 2H_\kappa ctg\psi_2},$$

(17)

From the resulting equation (17) it is clear that the working bodies are installed oppositely and the coefficient of soil loosening, the parameters of the subsoiler are related to the physical and mechanical properties of the soil and the transverse distance between the working bodies, as well as the cultivation height.

Having accepted β_κ=45° and ψ_2=45° and b_u=5 см, In Figure 2.13, using the equation, a graph of changes in the loosening coefficient is plotted depending on the transverse distance between the working bodies and the processing depth. From this graph it is clear that the greater the distance between the working bodies and the greater the depth of processing, the greater the loosening coefficient. The main reason is the sharp increase in the area processed by the working bodies of the second row during deep processing and with an increase in the distance between the working bodies. However, in all variants the values of the loosening coefficient do not differ sharply from each other. Therefore, it is advisable to take the distance between the working bodies and the depth of processing according to the recommended technology based on the requirements of agricultural technology.

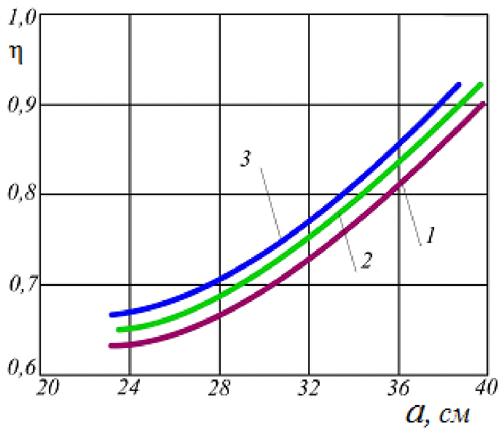

Fig.4. Graphs of the dependence of the soil loosening coefficient on the depth of tillage:

1 - B_κ =60 см; 2 - B_κ =70 см; 3 - B_κ =80 см

One of the main agrotechnical indicators is the height of the ridge formed in the bottom of the loosened layer of the ridge, based on the above figure

$$h_{\breve{y}} = \frac{M - b_u}{2} tg\psi_2. \qquad (18)$$

Substituting the values of M from equation (17) into (18), we obtain

$$h_{\breve{y}} = \frac{B_\kappa - 2H_\kappa ctg\beta_\kappa - 2b_u}{2} tg\psi_2. \qquad (19)$$

It is known that during tillage the upper edge of the ridge will collapse, resulting in a decrease in its height. In this case, the actual height of the ridge is determined by the following formula

$$h_{\breve{y}x} = K_{\breve{y}} h_{\breve{y}}, \qquad (20)$$

Here $K_{\breve{y}}$ – taking into account the coefficient of ridge destruction.

If we take into account the formula (20), then the formula (19) looks like

$$h_{\breve{y}} = K_{\breve{y}} \frac{B_{\kappa} - 2H_{\kappa} ctg\beta_{\kappa} - 2b_{u}}{2} tg\psi_{2}. \qquad (21)$$

Meaning $K_{\breve{y}}$ within 0,49-0,61

From the resulting formula it can be seen that the height of the ridge formed at the bottom of the bed depends on the transverse distance between the working bodies installed oppositely and on the height of the inclined part of the working bodies and on the width of the chisels and on the physical and mechanical properties of the soil.

Results and discussions. To study the influence of the mutual arrangement of subsoilers, as well as operating speed on the degree of soil crumbling, experimental studies were carried out. The results of the experiments are shown in Fig. 5. According to the experiments conducted, it was established that at speeds of 6-9 km/h, in order to ensure the required quality of work with minimal energy consumption, the longitudinal distance between subsoilers should be 75 cm, and the transverse distance - 60 cm.

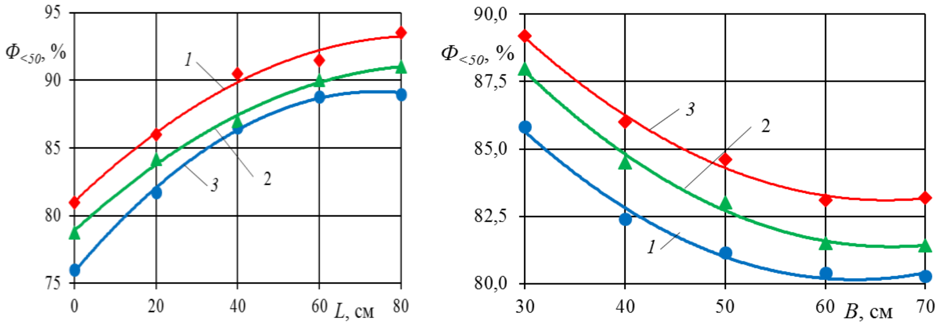

Fig.5. Graphs of the degree of soil loosening depending on the longitudinal and transverse distance between subsoilers: 1, 2, 3 - respectively, at tillage depths of 25, 27.5 and 30 cm

Conclusions.

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

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

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