Justification of the bottom softening parameters of working organ with a sloping column

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Abstract. At present, cultivator plows used in horticulture in Uzbekistan have a number of serious shortcomings. Their quality of work does not meet agrotechnical requirements. The purpose of study is to substantiate the parameters of lower ripper the working body with an inclined rack. The authors proposed a working body with an inclined rack, equipped with upper and lower rippers. The lower ripper loosens the lower soil layer. The scheme of a plow-ripper with improved working bodies is given. Theoretical studies were carried out using the laws of theoretical mechanics. In experiments, the height of irregularities at the bottom of arable land and traction resistance were taken as a criterion for evaluating the performance of a plow-ripper. Based on the results of theoretical studies, dependencies were obtained that allow determining the parameters lower ripper. According to the results of this proven research, the coverage width the bottom softener is in the range 9.5-9.9 cm, and its grinding angle is in the range of 16,3-27º, in order to ensure the required level of coulters in the bottom the plow. The angle of installation the blade in relation to the direction of movement should be 30º.

1. Introduction

In the world, the use of energy-resource-efficient and high-performance technical tools for the main processing the garden occupies one the leading positions. The area of fruit crops in the world is 53.4 million hectare, of which 20 mln. taking into account that 1 hectare is fruit orchards, the quality and productivity of work protecting the soil in the main tillage requires the implementation of energy-efficient machines and tools. Researchers F Maiviatov [1, 2], V Dubrovin [3], Yu Syromyatnikov [4], H Fang [5], F Mamatov [6, 7], K Gangwar [8], Z Kogut [9], G Sineokov [10], V Strelbitskiy [11], M Tsimmerman [12], Z Zeng [13], I Bozhko [14], A Vagin [15] and others were involved in the development and research of working bodies with chisels. In the following years, as a result of research carried out in the United States of America, Great Britain, Norway, the Netherlands, Germany, Russia and other countries, the side profile for tillage without a tiller was in the form of a parabola *S*-shaped columns and spindles with a curved-helicoid working surface and parabolic working bodies in the transverse-vertical plane, *Y*-shaped, *X*-shaped working bodies of "paraplau" type were created. I Bojko [14], the layered softening working body with an elliptical softener softens the soil qualitatively with low energy consumption due to the warping and bending deformations created on the surface and inside the elliptical ring. However, in these studies, the issues of justifying the parameters of lower softener the improved inclined column working body, which works between garden rows without a tipper, have not been studied.

2. Materials and Methods

Based on the analysis of technical tools and weapons used abroad and in our country for working between garden rows and the agrotechnical requirements for them, an improved plug-softener for working between garden rows without a tiller was developed (Fig.1).

During the operation the machine, the softening claw 1 works the soil at a depth $a_1>a$ along the axis of symmetry the weapon. In this case, the softener pawl 1 deforms the soil and softens it during its work. The cross-section the deformation zone has the shape a trapezoid. The softener operates under closed cutting conditions. The blade the improved inclined column softener located in the left and right sections penetrates the driving layer and breaks the soil into small pieces. The resulting cracks spread to the soil surface at an angle of w_k. After that, the blade the

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column enters the soil zone deformed by the chisel. The soil separated by the chisel rises along its surface and falls on the blade. In this case, a piece of soil bends and stretches in longitudinal and transverse sections, which causes it to rapidly disintegrate. In the process of work (Fig.2), the bottom softener 5, which is covered with a cone, softens the scythe at the bottom the soil layer and the bottom of ridge. As a result, the height scythe at the bottom the ridge is significantly reduced.

The main task softening pawl 1 is to soften the field along the axis of symmetry of the inclined column working bodies 2 and 3, the front working surfaces of which are opposite to each other. As a result, working bodies 2 and 3 work in semi-open cutting conditions. This dramatically reduces their traction resistance and improves the technological process, eliminating clogging the working bodies with plant debris and soil.

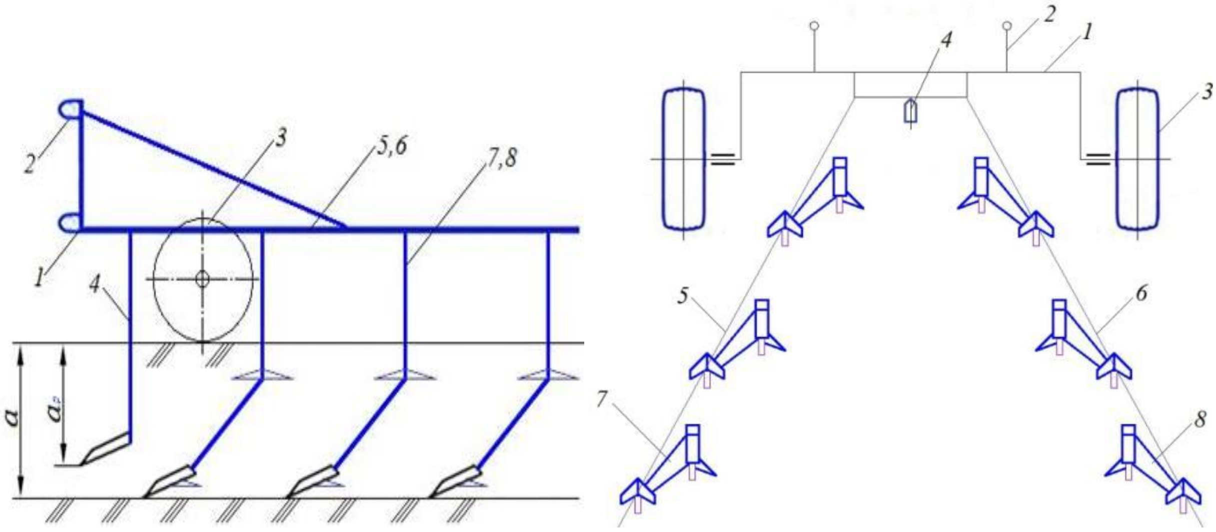


Fig. 1. Scheme of improved plug softener: 1-frame; 2-hanging device; 3-base wheels; 4-softening paw; 5 and 6 - frame of left and right sections; 7-softeners with slanted columns bent to the right; 8-bent to the left inclined pillar softeners

We determine the coverage width of lower softener based on the condition that the height the hump formed under its influence is at the level of agrotechnical requirements. According to Fig.2, the height the hump at the bottom of ridge

$$H_{dp}=\frac{1}{2}(M-b_i-b_{py})-a(1-K_{kr}). \tag{1}$$

Then the coverage width of lower softener

$$b_{py}\geq M-b_i-2H_{dp}-2a(1-K_{kr}). \tag{2}$$

If we express the height the ridge H_{dp} allowed by the agrotechnical demand in the bottom of ridge by the depth of processing

$$b_{py}\geq M-b_i-2na-2a(1-K_{kp}), \tag{3}$$

where n – is the coefficient of dependence the height the roundness at the bottom the processing depth, n=0.1-0.2.

a=28 cm, M=30 cm, n=0.1-0.2, b_i=5 cm and K_{kr}=0.85, and calculations made according to the expression (3) cover width of the lower softener is 5. We determine that it should be in the range of 4-11 cm.We accept 8 cm.

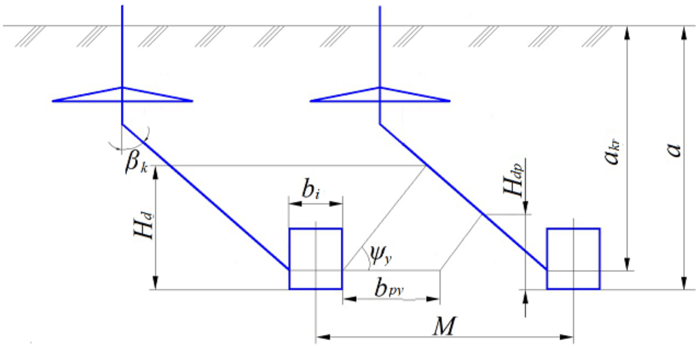


Fig. 2. Scheme for determining the coverage width of the bottom softener

The bottom softener works like a three-sided pan. Its total drag resistance is the sum of following resistances

$$R_{ax} = R_{1ax} + R_{2ax} + R_{3ax} + R_{4ax}, \tag{4}$$

in this R_{1ax} – the resistance the soil softener blade, kN; R_{2ax} – resistance to soil shear deformation, kN; R_{3ax} – resistance created by the rise of soil softener along the surface, kN; R_{4ax} – inertia the soil rising along the softener surface resistance created by force, kN.

To determine the tensile strength the bottom softener, we will consider the process of deformation of soil under its influence.

We determine the force of resistance to the blade of lower softener as follows [15]

$$R_{1ax} = \frac{b_{py}}{\sin\gamma} t_l \sigma_o \sqrt{1+f^2}\cos(\gamma+\varphi), \tag{5}$$

in this σ_o – temporary resistance to crushing the soil with a blade, Pa; t_l – thickness of softener blade, cm.

Under the influence the working surface of lower softener, the soil is first compressed, and then breaks and moves at an angle of ψ_1 relative to the bottom the embankment. We define the sliding surface according to the following expression

$$F_1 = \frac{H_{dp} b_{py}}{\sin\gamma \sin\psi_1}. \tag{6}$$

We put the value of H_{dp} in (6) according to the expression (1)

$$F_1 = \frac{[(M - b_i - b_{py}) - 2a(1-K_{kr})]b_{py}}{2\sin\gamma\sin\psi_1}. \tag{7}$$

This is the shear force acting on this surface

$$S_1 = \tau F_1 = \tau\frac{[(M - b_i - b_{py}) - 2a(1-K_{kr})]b_{py}}{2\sin\gamma\sin\psi_1}. \tag{8}$$

Projection of S_1 onto the X axis

$$S_{1x} = S\cos\psi_1. \tag{9}$$

It is known that the sliding force S creates the friction force fN_1 on the surface the tool. The softener's resistance to soil deformation is equal to the projection the forces S_1 and fN_1 on the X axis

$$N_1 = S_1\sin(\varepsilon+\psi_1), \tag{10}$$

$$R_{2ax} = S_1[\cos\psi_1\sin\gamma + f\sin(\varepsilon+\psi_1)\cos\alpha_1\cos\gamma_1]. \tag{11}$$

Putting the value of S_1 according to (8) into the expression (11), we get the following

$$R_{2ax} = \tau\frac{[(M - b_i - b_{py}) - 2a(1-K_{kr})]b_{py}}{2\sin\psi_1\sin\gamma}[ctg\psi_1 + \frac{f\cos\alpha_1\cos\gamma_1\sin(\varepsilon+\psi_1)}{\sin\psi_1\sin\gamma}], \tag{12}$$

in this $\alpha_1 = \arcsin tg\alpha\cos\varepsilon,$ (13)

$$\gamma_1 = arctg\frac{(1-cos\,\varepsilon)tg\gamma}{1+tg^2\gamma\, cos\,\varepsilon}. \tag{14}$$

Putting the values of α_1 and γ_1 in expression (12) according to (13) and (14), we get the following

$$R_{2ax} = \tau\frac{b_p[(M - b_{py} - b_i) - 2a(1-K_{kr})]}{2\sin\psi_1\sin\gamma}\{ctg\psi_1 + \\ + \frac{\cos\arcsin(tg\alpha\cos\varepsilon)f\sin(\varepsilon+\psi_1)\cos[arctg\frac{(1-\cos\varepsilon)tg\gamma}{1+tg^2\gamma\cos\varepsilon}]}{\sin\psi_1\sin\gamma}\}. \tag{15}$$

The projection the traction resistance on the X axis, which is formed by the rise of soil softener along the surface, is shown by A.Vagin. We determine using the formula obtained [15]

$$R_{3ax} = G_1(\sin\alpha_1 + f\cos\gamma)\cos\alpha_1\cos\gamma_1, \tag{16}$$

$$G_1 = \frac{\gamma a_p b_{py}^2}{2tg\gamma}, \tag{17}$$

in this G_1 – weight soil on the sloping surface the softener, N; a_n – depth of softening claw installation, cm.
Putting in the expression (16) the values of α_1, γ_1 and G_1 (13), (14) and (17), we get

$$R_{3ax} = \frac{\gamma a_p b_{py}^2}{2tg\gamma}(tg\alpha\cos\varepsilon + f\cos\gamma)x$$

$$x\sqrt{1-(tg\alpha\cos\varepsilon)^2}\cos[arctg\frac{(1-\cos\varepsilon)tg\gamma}{1+tg^2\gamma\cos\varepsilon}]. \tag{18}$$

We determine the resistance created by the inertial force the soil rising along the surface the softener according to the following formula [15]

$$R_{4ax} = \rho F_2 V^2 \cos\psi_1 (1 - i_{\max})\sin\gamma \times$$

$$\times [f\sin(\varepsilon+\psi_1)\cos\alpha_1\cos\gamma_1 + \sin\gamma\cos\psi_1], \tag{19}$$

where F_2 – is the real cross-sectional area the plastic that breaks down under the influence of softener, cm^2; i_{Max} – the maximum coefficient of subsidence the soil in front the loaded plane.
From Fig.3

$$F_2 = \frac{b_{py}h_p tg\psi_y + h_p^2}{2tg\psi_y}, \tag{20}$$

We put the values of α_1, γ_1 and F_2 according to (13), (14) and (20) to (19)

$$R_{4ax} = \frac{\rho(b_{py}h_p tg\psi_y + h_p^2)}{2tg\psi_y}V^2\cos\psi_1(1-i_{\max})\sin\gamma[\sin\gamma\cos\psi_1 +$$

$$+\cos(\arcsin tg\alpha\cos\varepsilon) f\sin(\varepsilon+\psi_1)\cos arctg\frac{(1-\cos\varepsilon)tg\gamma}{1+tg^2\gamma\cos\varepsilon}]. \tag{21}$$

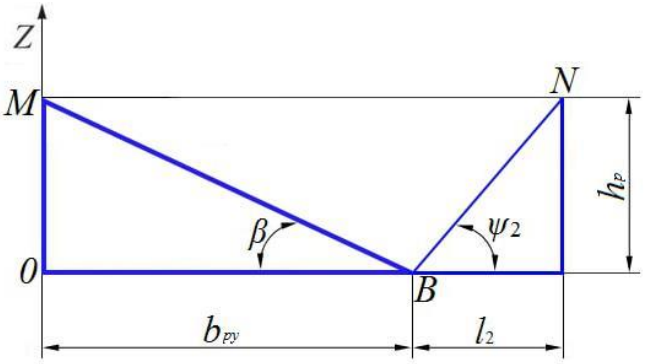


Fig. 3. The scheme of moving the blade in the transverse-vertical plane with an inclined blade

Putting the values of R_{1ax}, R_{2ax}, R_{3ax}, and R_{4ax} into expression (4) according to (5), (15), (18) and (21), we get the following formula for determining the tensile strength of the softener;

$$R_{ax} = \frac{b_{py}}{\sin\gamma}t_p\sigma_o\cos(\gamma+\varphi)\sqrt{1+f^2} + \tau\frac{[(M-b_i-b_{py})-2a(1-K_{kr})]b_{py}}{2\sin\gamma\sin\psi_1}\{ctg\psi_1 +$$

$$+\frac{\cos\arcsin(tg\alpha\cos\varepsilon)f\sin(\varepsilon+\psi_1)\cos[arctg\frac{(1-\cos\varepsilon)tg\gamma}{1+tg^2\gamma\cos\varepsilon}]}{\sin\gamma\sin\psi_1}\} +$$

$$+\frac{\gamma a_p b_{py}^2}{2tg\gamma}(f\cos\gamma + tg\alpha\cos\varepsilon)\times\cos[arctg\frac{(1-\cos\varepsilon)tg\gamma}{1+tg^2\gamma\cos\varepsilon}\sqrt{1-(tg\alpha\cos\varepsilon)^2}] + \tag{22}$$

$$+\frac{\rho(b_{py}h_p tg\psi_y + h_p^2)}{2tg\psi_y}V^2\sin\gamma\cos\psi_1(1-i_{\max})[\sin\gamma\cos\psi_1 +$$

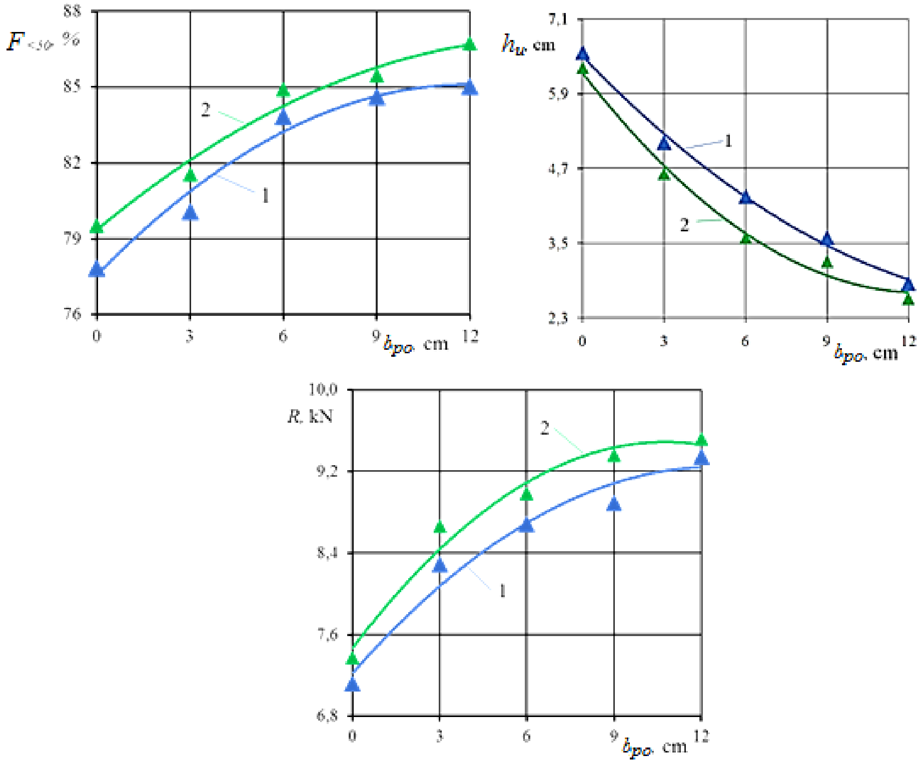
$$+\cos(\arcsin tg\alpha\cos\varepsilon)f\sin(\varepsilon+\psi_1)\cos arctg\frac{(1-\cos\varepsilon)tg\gamma}{1+tg^2\gamma\cos\varepsilon}]$$

3. Results and Discussion

In experimental studies, the coverage width of bottom softener was varied from 4 cm to 10 cm in 2 cm intervals. In this case, the movement speed of unit was 6.0 and 9.0 km/h, the working depth of working body with an inclined column was 28 cm, the coverage width of the lower softener was 8 cm, and the grinding angle the lower softener was 20º.

The height the scythes at the bottom the plow, the degree of compaction of soil and its resistance to traction were taken as the criteria for evaluating the performance the device.

According to the data presented in Figure 4, it can be seen that with the increase in the coverage width the bottom softener at both speeds of the device, the level of compaction and traction resistance the soil increased according to the law the bubble parabola, and the height of scythes decreased according to the law the concave parabola. The lower softener provides the required level of soil compaction and the height of scythes at the bottom the soil with low energy consumption when the coverage width is in the range of 8-10 cm.



1 – 6,0 km/h; 2 – 9,0 km/h

Fig. 4. Changes in the height of the scythes at the bottom of the lake (h_u), the level of soil compaction ($F_{<50}$) and the traction resistance (R) the working bodies depending on the width the lower softener coverage (a_{py})

The graphical relationships presented in Figure 5 can be expressed by the following empirical formulas determined by the method of least squares:

1 **2** **3** **4**
***b*=10 cm (1); *b*=8cm (2); 6 cm (3); 4 cm (4)**

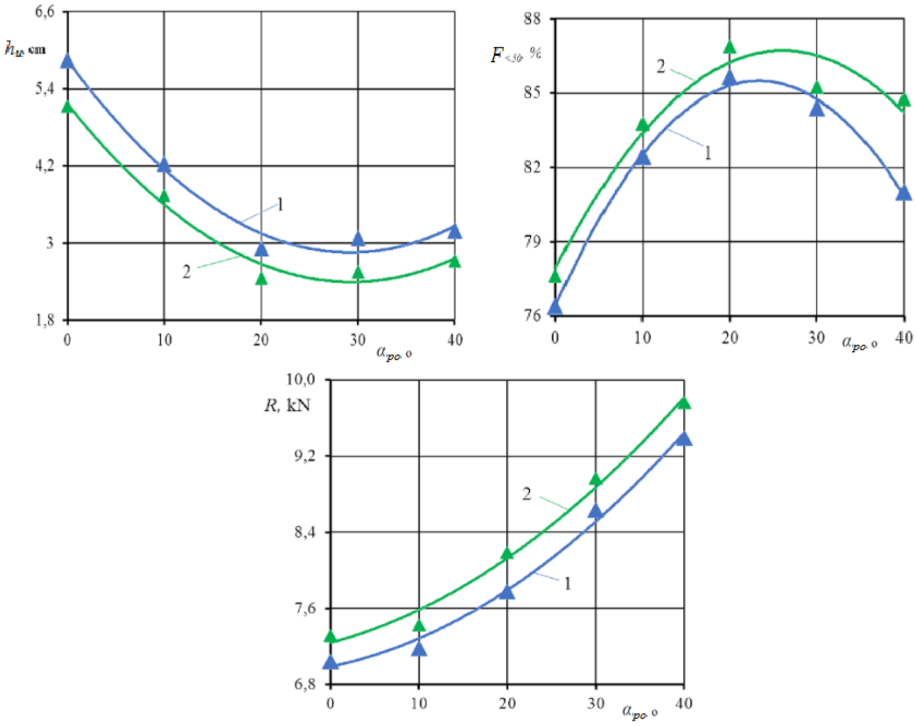
Fig. 5. Trial copies of lower cushions in different sizes

In experimental studies, the grinding angle the lower softener was changed from 0° to 40° in 10° intervals. In this case, the movement speed of unit was 6.0 and 9.0 km/h, the working depth the working body with an inclined column was 28 cm, the working depth of the upper softener was 8 cm, and the coverage width the lower softener was 8 cm.

The height the scythes at the bottom of plow, the degree of compaction the soil and its resistance to traction were accepted as criteria for evaluating the performance the device.

According to the given data, the degree of soil compaction increased according to the law the bubble parabola when the angle of lower softener was reduced from 0 to 20° at both speeds the device, and then decreased with its value after it increased from 20°. When the value of lower softener rubbing angle increased to 20°, the thickness the scythes at the bottom the ridge decreased sharply, and at values greater than 20° it almost did not change. With the increase of bottom softener grinding angle, the tensile strength increased according to the law of bubble parabola.

According to the results the research, the grinding angle lower softener is in the range of 20-26°, while consuming less energy, it ensures that the degree of grinding of soil and the height the scythes at the bottom the soil are at the required level.



1 – 6,0 km/h; 2 – 9,0 km/h

Fig. 6. Changes in the height scythes at the bottom of ridge (h_u), the level of soil compaction ($F_{<50}$) and the traction resistance (R) of working bodies depending on the angle of compaction lower softener (a_{py})

4. Conclusions

Obtained analytical dependence and mathematical model, enabling the specified parameters and mode of operation of oscillatory rods. According to the results the conducted studies, in order to ensure that there are required level of scythes in the bottom the plow, the coverage width of lower softener is in the range of 9.5-9.9 cm, its grinding angle is in the range of 16.3-27.0º, the blade the angle of installation of in relation to the direction of movement should be 30º.

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