Justification of the width of the tooth spacing and the distance between the rows of teeth of the ripper for the harrower

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Abstract. The article substantiates the degree of immersion of working bodies in the soil and soil deformation on the basis of scientific and experimental studies of the harrowing unit used. The parameters of the harrow teeth, the qualitative performance of the technological process of the accepted parameters are also theoretically justified.

1 Introduction

In our republic, soil harrowing is carried out in two tracks per one pass of the unit with BZSS-1.0, BZTS-1.0 or BZTH-1.0 harrows arranged in two rows. At the same time, heavy harrows BZTS-1.0 and BZTH-1.0 are used in fields that have received multiple washings, and in other cases – medium harrows BZSS-1,0 [1-8].

The use of existing heavy, wide-reach harrowing units has a number of disadvantages, i.e., when cultivating the soil, the ripper teeth are clogged with soil and plant residues, which leads to a deterioration in the quality of processing and violation of agro-technical requirements.

2 Materials and methods

The width of the ripper teeth spacing is set in such a way as to ensure continuous loosening of the treated soil layer. To solve this problem, consider the process of destruction (loosening) of the soil by a vertically mounted wedge with a sharpened angle 2β and a straight lower edge (i.e., the lower end of the tooth does not have a bevel) when moving it at a given h depth at a V_n speed (figure 1).

According to the data of Academician G.M. Rudakov, it is known [1] that the destruction of the soil under the influence of a vertically installed wedge occurs by chipping. As the wedge progresses, the soil is first crushed in the horizontal direction, its particles are pressed into the adjacent medium. Then, when the deformation of the crumple reaches the limit value, the soil is destroyed with the formation of chipping surfaces. For

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example, when the wedge moves from position I to position II, the wedge cheek removes the OO_1B_1 section, as a result of which horizontal crumpling stresses arise in the soil, leading to the appearance of two shear planes: $O_1AO_1^{'}$ located at an angle ψ_1 to the direction of movement, and located at an angle $O_1AO_1^{'}$ to the working face ψ_2 of the wedge. As a result, a block in the form of a triangular prism is separated from the soil. With further movement of the wedge, the shifted volume of soil begins to slide up along the wedge surface and shear planes. At the same time, the crumpling of the soil occurs, ending with the chipping of the next part of it.

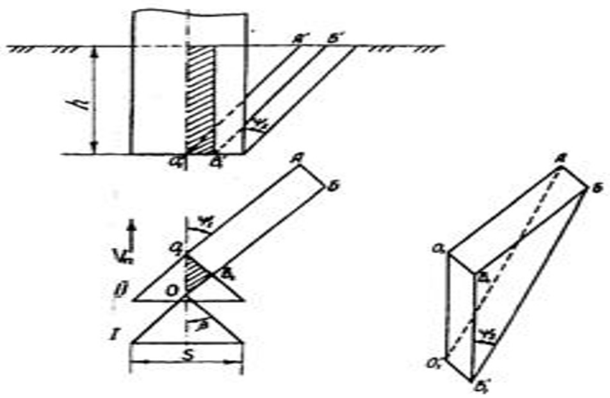

Figure 1. Deformation of soil in vertical wedge.

Using Mohr's strength theory, V.P. Goryachkin [2] determined

$$\psi_1 = \frac{\pi}{2} - \frac{\beta + \varphi + \varphi^{'}}{2}, \tag{1}$$

Where $\varphi, \varphi^{'}$ – angles of internal and external friction of the soil.
According to G.M.Rudakov [1]:

$$\psi_2 = 42 - 45^0 \tag{2}$$

As noted, the teeth of the ripper of the harrowing unit are arranged in two rows. During the operation of the unit, the teeth of the first row act on the soil that has not yet been deformed, the second row - on the soil partially deformed by the teeth of the first row.

3 Results and Discussion

As our experimental studies have shown, depending on the width of the interline, the nature of soil deformation by the teeth of the second row changes: up to a certain value of the interline of the teeth, the soil shift in the transverse-vertical plane from the impact of the teeth of the second row occurs not along the inclined plane N-N, but along the horizontal plane M-M (figure 2).

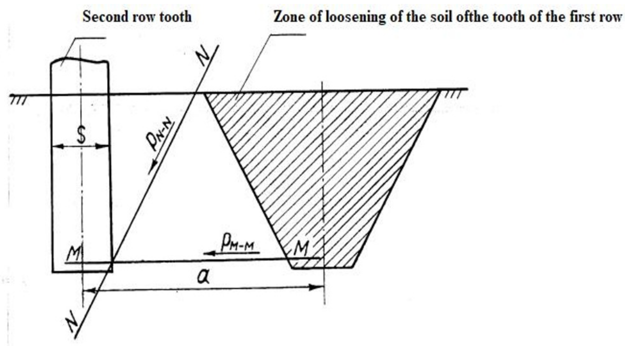

Figure 2. Scheme to substantiation of the width of the tooth spacing.

When the width of the tooth spacing reaches a certain value, the soil begins to shift along the inclined plane N-N, as described above.

Obviously, in order to achieve continuous loosening of the treated soil layer, the width of the tooth spacing should be such that the soil is shifted along the horizontal plane M-M. Obviously, a shift of the soil along the M-M plane is possible if:

$$P_{M-M} < P_{N-N} \tag{3}$$

Where: P_{M-M}, P_{N-N} – the forces of soil resistance to chipping along the M-M and N-N planes.

It is known that [3;9-12]:

$$P_{M-M} = \tau_{M-M} \cdot S_{M-M} \tag{4}$$

And:

$$P_{N-N} = \tau_{N-N} \cdot S_{N-N} \tag{5}$$

Where: τ_{M-M}, τ_{N-N} – specific resistance of the soil to shear in planes M-M and N-N; S_{M-M}, S_{N-N} – the area of soil cleavage along the M-M and N-N planes.

By analyzing pic. 3 and 4, we find that:

$$S_{N-N} = O_1B_1 \cdot h / \cos\psi_2 \tag{6}$$

And:

$$S_{M-M} = O_1B_1(a - \frac{S}{2})\cos\beta \tag{7}$$

Where: a - the width of the tooth spacing; S-is the thickness of the tooth.

Substituting values S_{M-M}, S_{N-N} – in (4) and (5),then values P_{M-M} and P_{N-N} in (3) then excepting $\tau_{M-M} = \tau_{N-N}$ we note:

$$(a - S/2)\cos\beta < h / \cos\psi_2 \tag{8}$$

Where:

$$a \le (h / \cos\psi_2 \cdot \cos\beta) + S/2 \tag{9}$$

It follows from (9) that the width of the tooth spacing, at which continuous loosening of the treated soil layer is ensured, depends on the depth of processing and the physic-mechanical properties of the soil, the thickness and the angle of sharpening of the teeth.[12-18]

By inserting in (9) $h = 5\,sm,\ \psi_2 = 42^0$, $\beta = 45^0\ u\ \ S = 2.2sm$ we find $a \le 10.7\ \ sm$

Thus, in order to ensure continuous loosening of the treated soil layer, the width of the gap between the teeth of the ripper should not exceed 10.7 sm.

The distance L between the rows of teeth is chosen from the condition of preventing clogging of the gaps between them by plant residues and soil. When clogging, the technological process of the ripper is disrupted, its traction resistance increases.

In order to avoid clogging the gap between the front and rear rows of teeth with soil, the distance L should be made larger than the zone of propagation of l - deformation of the soil along the course of the teeth (figure 3), i.e.

$$L > l \tag{10}$$

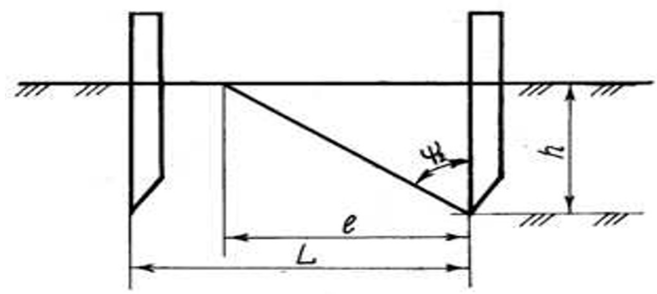

Figure 3. Diagram for determining the distance between rows of ripper teeth.

According to figure 3, the greatest value of the zone of propagation of soil deformation along the course of the teeth is equal to:

$$l = h_{max}\, tg\psi_2 \cos\psi_1 \tag{11}$$

Where h_{max} - the greatest depth of immersion of the teeth in the soil;

Taking into account (11) and the width of the tooth spacing, equation (10) will take the form:

$$L > h_{max} \cdot tg\psi_2 \cos\psi_1 + Sctg\beta \tag{12}$$

In expression (12), we introduce a coefficient K that takes into account the unloading of the soil in front of the ripper teeth [19-20], i.e.

$$L > \kappa h_{max} \cdot tg\psi_2 \cos\psi_1 + Sctg\beta \tag{13}$$

The value of the coefficient K depends on the condition of the soil and the parameters of the working body.

By accepting $h_{\max} = 10sm$ [13], $\psi_2 = 45^0$ [14], $\psi_1 = 20^0$ u $K = 1.8$ [14 – 18], we receive $L > 1.8 \cdot 10 \cdot 1.0 \cdot 0.866 + 2.2 \cdot 1.0 = 19.1 \quad sm$

Therefore, in order to avoid clogging the ripper with soil, the distance between the rows of teeth should be at least 19.1 sm.

4 Conclusion

Analytical studies have shown that the best quality of tillage is provided by the vertical installation of the ripper teeth.

It was revealed that the spacing of the ripper teeth depends on the depth of tillage, physical and mechanical properties, thickness and angle of sharpening of the teeth. To ensure continuous loosening of the treated soil layer, the spacing of the teeth should not exceed 10.7 sm.

To avoid clogging the gap between the transverse rows of ripper teeth with soil and plant residues, it is necessary to set the distance between the rows of teeth at least 19.1 sm.

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