Slotting mechanization for intensive garden planting

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Abstract. The paper presents a structure diagram of a slot trencher when planting a garden, consisting of a frame on which working sections, a bevel gear reducer and support wheel stands are fixed. On the working section there is a shaft with a working body - a disk slot cutter. It is made in the form of a disc with teeth, one cutting edge of each tooth is straight and the other edge is parabolic. On the parabolic edge the working elements are fixed in the form of knives with a cutting edge consisting of two parts. A straight one is along the periphery; the other is in the form of a guide along the entire length of the curved edge of the tooth and equal to the width of the cutting edge of the knife. The theoretical substantiation of the main structure parameters is carried out as a result of which the length of the inclined knife is determined, which allows satisfying the operating conditions of the device.

1. Introduction

The problem of human health is one of the priority tasks of the development of Russian society, which is largely depends on high-quality, rational nutrition based on fruits and vegetables.

Maintaining food security of the state is impossible without highly developed agriculture. Gardening is one of the most important branches of agriculture, which provides the population with fruits and berries which are irreplaceable sources of biologically active compounds.

Providing the population with fresh fruits and berries, high-quality processed products all the year round is important in the improvement of the quality of human life, physical health and the health of the nation in general.

However, the population is suffering from acute shortage of fresh fruits and berries, primarily due to the low efficiency of Russian gardening.

Thus, at the present stage, gardening is undergoing a difficult period due to several reasons such as:

• Unfavorable natural and climatic conditions on a large territory of Russia and the ability of perennial plants to accumulate negative consequences of exposure to stressors;

• Outdated and worn out material and technical base of the majority of former horticultural enterprises;

• Outmoded technologies of cultivation of existing perennial plantations [1-4]

The increase in domestic production of fruits and berries is possible with an increase in the intensification of production. In order to intensify the production of horticulture, the scheduled replacement of old fruit plantations with more intensive ones is necessary. When laying an intensive
garden, the seedlings are placed in a row more densely, therefore a different scheme and planting technology should be applied. Thus, it is required to create other types of garden machines for planting a garden [5].

2. Materials and methods
For this purpose we propose a device for cutting slots according to the scheme of planting an intensive garden.

The device for cutting slots when planting a garden (Figure 1) consists of a frame 1, on which the working sections 2, the bevel gear reducer 3 and the support wheel stands 11 are fixed. A block with replaceable gears 5 is attached to the working section to change the rotational speed of the working body. It also has a shaft with a working body - a disk slot cutter 7 [6].

![Figure 1. Scheme of a device for cutting slots for planting a garden: 1-frame; 2-working sections; 3-bevel gear reducer; 4-cardan; 5-block of gears; 6-chain; 7-disk slot cutter; 8-tooth; 9-knife; 10-casing; 11-support wheel stands.](image)

It is made in the form of a disc with teeth 7 (Figure 2). One cutting edge 12 of each tooth is straight, and the other edge 13 is parabolic, given by the formula 

\[
y^2 = 2px.
\]

On the parabolic edge the working elements are fixed in the form of knives 9 with a cutting edge consisting of two parts. One 14 is straight along the periphery, the other is 15 in the form of a guide along the entire length of the curved edge of the tooth and equal to the width of the cutting edge of the knife.

The straight cutting edge of the knife is set at an angle \( \alpha = 65\ldots70^\circ \) and is 60 mm long. To overlap the space between the lower part of the curved edge of each tooth and the disk sleeve, a slope 16 is attached to it at an angle of 70 ... 75\(^\circ\) with the lower edge at the level of the edge of the next tooth. The width of a slope is made with the possibility to overlap the slot width.

The proposed machine works as follows: the unit moves at a speed \( v_m \). Rotation of disc slots is reverse from bottom to top with angular velocity \( \omega \) from the take-off shaft of tractor power.
Figure 2. Working body scheme: 7-disk; 8- tooth; 9 - knife; 12 - straight cutting edge; 13- parabolic cutting edge; 14 - straight part of the knife; 15- parabolic part of the knife; 16 – slope.

3. The results of a study of cutting slits

The equation of motion of the working body of the disk with the translational and rotational motion of the extreme point of the knife is as follows: [6]

\[
\begin{align*}
x &= v_m t + R \sin \omega t; \\
y &= R(1 - \cos \omega t).
\end{align*}
\]

where \( R \) – disk circle radius, m; \( v_m \) – machine speed, m/s; \( t \) – movement time, s.

Time \( t \) of one rotation:

\[
T = \frac{2\pi}{\omega},
\]

Disc circumferential speed

\[
v_{\text{circ}} = v_m \frac{2\pi}{\omega},
\]

Then the kinematic indicator of the operation of the machine is determined from the following expression:

\[
\lambda = \frac{R \omega}{v_m}
\]

During the process of filling a limited space with soil, a certain volume of soil must be supplied, which is determined from the following expression

\[
V_{\text{soil}} = b \cdot \delta \cdot \frac{C_1 + C_2}{2},
\]

where \( b \) – chip width, m; \( \delta \) – chip thickness, m; \( C_1 \) – overall dimension of the chip arc, m; \( C_2 \) – internal size of the chip arc, m.

The feed per knife is determined by the following formula:

\[
x_z = \frac{2\pi \cdot R}{\lambda \cdot z},
\]

where \( z \) – number of knives, pieces; \( \lambda \) – kinematic index,

\[
\lambda = \frac{R}{R - a} = \frac{1}{1 - m'}
\]
where \( a \) – the depth of the slot to be cut, m.

Let us define the volume under the slope. To do this, we consider Figure 3.

![Figure 3 – Scheme to determine the volume of soil](image)

1- disc; 2- slope; 3- the wall of the slot to be cut;

From \( \Delta ABC \) define what is equal to \( AC \)

\[
AC = b \cdot \text{ctg} \beta
\]

Area of a triangle

\[
S_{\Delta ABC} = \frac{1}{2} b^2 \cdot \text{ctg} \beta
\]  \hspace{1cm} (7)

The length of the slope will be equal to the difference

\[
l_{\text{slope}} = (R - h) - r_f,
\]  \hspace{1cm} (8)

where \( r_f \) – flange radius, m

Then the volume under the slope is determined from the following expression

\[
V_{\text{slope}} = S_{\Delta ABC} \cdot l_{\text{slope}} = \frac{1}{2} b^2 \cdot \text{ctg} \beta \cdot l_{\text{slope}}
\]

Let us determine the volume \( V_{f.s.} \), which can be filled with soil in a closed space after the knife according to the following equation:

\[
V_{f.s.} = V_a - V_{\text{slope}}
\]  \hspace{1cm} (9)

4. Conclusion

Thus, it follows that the volume of soil supplied to closed space should be less than the volume of soil after the knife.

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