

# Upgraded rotary harrow for vineyards

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**Abstract.** To improve the quality of surface loosening, it is necessary to search for new approaches to soil maintenance and solving problems related to the reproduction of soil fertility, maintaining production volumes. In this connection, in order to increase operational reliability, simplify the design and clean the teeth from weed stalks in the basic technical tool, which includes a frame in the form of a beam equipped with a suspension system with mounted teeth. The teeth are made of a rectangular strip section, with a bend, with an oval surface on the side opposite to the direction of the bend and a formed arrow-shaped tip. They are placed on batteries of rigidly fixed disks. The teeth have reinforcing annular plates, which are located on the free length of the teeth, and their width is made at least equal to the width of the teeth. The cam element is made in the form of a cylindrical ring equipped with a rounded recess. The use of a modernized rotary harrow in the inter-row spacing of vine-yards will increase the operational reliability and quality of surface loosening, as well as simplify the design and clean the teeth from weed stalks.

## 1 Introduction

The modern vineyard is intensive cultivation. Without regular intervention from the outside, the biological and ecological systems cannot maintain balance.

The most important "bridgehead" of intervention is the soil [1]. One of the main elements in the farming system is tillage, which is an important condition for improving its structure and physicochemical properties and significantly affects the growth and fruiting of grapes. This creates favorable conditions for the development of the root system, the conservation and accumulation of moisture, as well as increasing soil fertility. The main task of soil cultivation in vineyards is its constant maintenance in a loose state, maintenance and

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replenishment of plant nutrition, accumulation and conservation of moisture, improvement of aeration, destruction of weeds, creation of favorable conditions for the vital activity of soil microorganisms, soil protection from erosion. In vineyards under black fallow, under conditions of intensive production, there is an increasing exploitation of the natural fertility of the soil. With a high intensity of arable land use, humus reserves decrease, nutrients are transformed into hard-to-reach and inaccessible forms, the natural process of fertility reproduction is disrupted, which leads to soil degradation, weakening of stability and a decrease in the productivity of the agroecosystem. Further intensification of grape production using black fallow in monoculture mode becomes problematic.

In this regard, there is a need to search for new approaches to soil maintenance and solving problems related to the reproduction of soil fertility, the preservation of ever-increasing production volumes. From this it follows that there is a scientific problem - how to improve the means of mechanization for maintaining the soil under black fallow, import substitution and reducing energy costs for tillage in vineyards.

Thus, at the moment, it is relevant to solve the problem of improving the means of mechanization for keeping the soil under black fallow, import substitution, as well as reducing energy costs for tillage in vineyards.

## **2 Purpose of research**

Development of technical means to improve the quality indicators of the technological process of inter-row cultivation of the soil of vineyards, through modernization (improvement).

To solve this goal, the following research tasks are proposed:

- To carry out a review and brief analysis of technologies and technical means of inter-row tillage of grapes.
- To develop an improved constructive and technological tool for surface tillage in the aisles of vineyards.
- To carry out experimental studies by planning a three-factor experiment.

## **3 Materials and methods**

When implementing the research tasks, a review of the sources was carried out, from which it was revealed that the "Rotary harrow-hoe and notched disk of the working body (options)" [2] are known, including a battery of working sections mounted on the frame, each working section consists of a pair of working organs in the form of toothed discs mounted on curved rods, and the frame is equipped with elements for connecting to the power tool. At the same time, each working section is fixed on the frame by means of a collar and a base, with working bodies installed on it by means of copying units, consisting of hinges, on the bushings of which copying elements are fixed with rotation limiters under the lower plane of the frame, curved elements are fixed on the copying elements. traction with toothed discs. At the same time, the teeth of the disk are made of a strip of rectangular cross-section, with a bend, with an oval surface on the side opposite to the direction of the bend and a swept edge formed, the teeth are connected to the reinforcing annular plates by bolted joints, the reinforcing annular plates are located on the free length of the teeth, and their width is made at least equal to the width of the teeth.

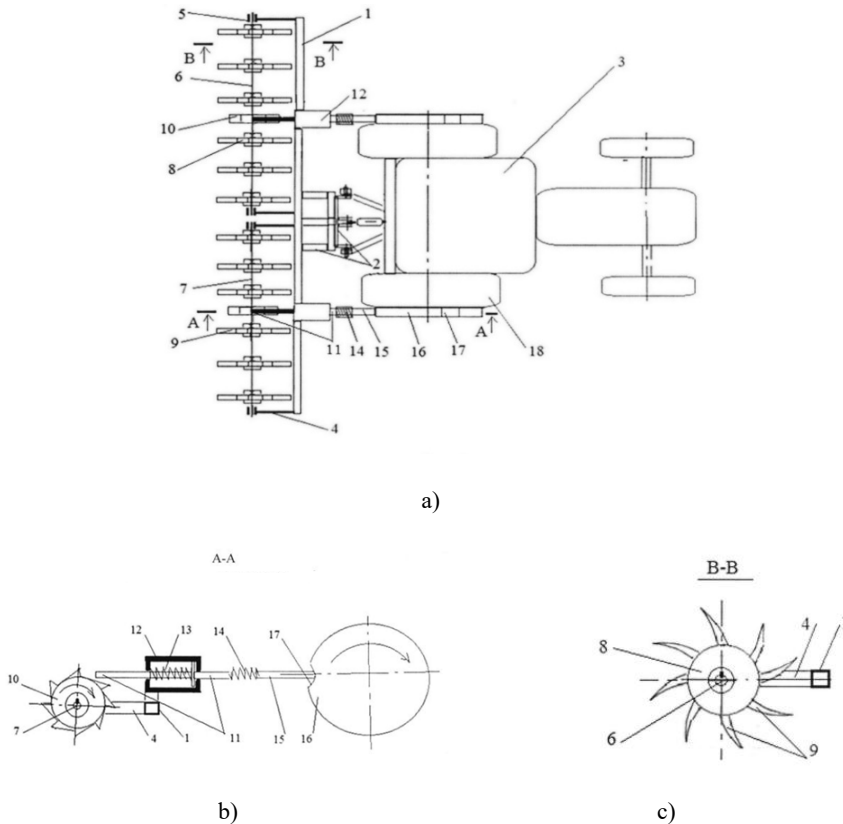
However, the disadvantages of this tool is the low quality of loosening and cutting weeds due to the fact that the teeth make a piercing effect on the soil when rolling, and this is not enough when weeds are destroyed.

The closest in terms of technical essence and achieved economic effect is the "vibrating tooth ripper" [3,4], which includes a frame equipped with a suspension system, on which a drive mechanism connected to a power tool is mounted, kinematically connected to a transverse bar equipped with teeth, while the transverse the beam is made in the form of a carriage frame mounted with the help of rings that can be easily moved on the guide elements with  $n$  rows of teeth fixed in a checkerboard pattern, and the drive mechanisms on the frame are mounted symmetrically on both sides and each contains a spring-loaded rod connected to the pusher - with its second end connected to a cam ring fixed on the wheel of the power tool, and at the rear the frame is equipped with a self-aligning press roller, and the carriage is kinematically connected with the spring-loaded rods of the drive mechanisms by means of gear racks and a block of double gears, and the teeth of the ripper are made conical.

The disadvantages of this device include the low operational reliability of the teeth and the quality of loosening due to clogging of the teeth with weed stems, as well as a complex loosening mechanism.

The technical solution of the problem is to increase the operational reliability and quality of surface loosening, as well as to simplify the design and clean the teeth from weed stalks.

Based on the method of exploratory research in solving inventive problems, using logical thinking, we proposed [5] a modernized rotary harrow, shown schematically in Fig.1.



**Fig. 1.** Scheme of the modernized rotary harrow: a – plan view; b and c – types A-A and B-B.

The harrow-hoe contains a frame made in the form of a transverse beam 1, equipped with a hitch system 2, on the power tool 3. The beam 1 is equipped with brackets 4 with bearing assemblies 5, in which two shafts 6 and 7 are symmetrically installed on both sides. On the shafts 6 and 7, batteries are mounted from rigidly fixed toothed disks 8, the teeth 9 of which

are made of a strip of rectangular section, with a bend, with an oval surface on the side opposite to the bend direction and a swept point formed. Ratchet wheels 10 are also rigidly mounted on the shafts 6 and 7. On the beam 1, drive mechanisms communicated with the power tool 3 are mounted symmetrically on both sides, containing a rod 11 placed in the housing 12 spring-loaded by an expanding spring 13. In turn, the rod 11 through another expanding the spring 14 is connected to the pusher 15, which, with its second end, is connected to the cam ring 16. In this case, the cam ring 16 is equipped with one rounded recess 17. The cam rings 16 are fixed on the rear wheels 18 of the power tool 3. The ratchet wheels 10 are placed on the shafts 6 and 7 in places providing kinematic connection with spring-loaded rods 11. Teeth 9 are connected to the reinforcing annular plates by bolted connections (not shown in the diagrams), the reinforcing annular plates are located on the free length of the teeth, and their width is made at least equal to the width of the teeth 9. The teeth 9 of the disks 8 are directed so that, when in contact with the soil, the swept point coincides with the direction of movement of the power tool 3.

The work of the "Harrow-hoe vineyard" is carried out as follows. In the working position, when the bar 1 is lowered, with the help of the hitch 2 of the power tool 3, respectively, the brackets 4 with bearing assemblies 5, shafts 6 and 7 are lowered, and the battery of toothed disks 8 with teeth 9 touches the soil. Further, when the power tool 3 moves, thanks to the ratchet wheels 10 controlled by the drive mechanisms, the shafts 6 and 7, and with them the toothed disks 8 with teeth 9, the first cycle does not rotate. This occurs due to the impact on the ratchet wheel 10 by the spring-loaded rod 11, which emerges from the body 12 fixed on the bar 1, on which, by overcoming the force of the expanding spring 13, it presses through the expanding spring 14, the pusher 15 and the cylindrical cam 16, fixed on the wheel 18 of the energy means 3. Thus, when the cylindrical part of the cam 16 acts on the ratchet wheel 10, the teeth 9 with an arrow-shaped tip penetrate like chisel paws into the soil, loosen the surface layer and cut the weeds. When the second end of the pusher 15 falls into the recess 17 on the cam 16, the spring 13 will take the rod 11 away from the ratchet wheel 10, and it will turn a step, and with it the disks 8 with teeth 9. Then the pusher 15 again touches the cylindrical part of the cam 16, and the ratchet wheel 10 is locked again. Thus, the teeth 9 work for a short time cyclically, one by one, being cleaned during the incremental rotations of the disks 8, increasing the operational reliability and quality of processing. Thanks to the unclamping spring 14, there is protection against excessive penetration and contact with stones or other obstacles. In this case, the ratchet wheel 10 will overcome the force of the spring 14 and rotate.

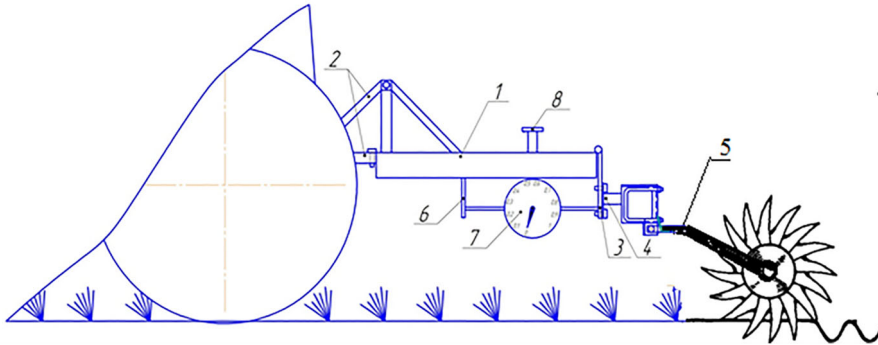
The novelty lies in the fact that thanks to a ratchet wheel, a spring-loaded rod, and spring-loaded pushers connected kinematically with a cam equipped with a notch, the teeth work briefly cyclically, alternately and like chisel paws, loosening the surface layer, cutting weeds and clearing when the discs are stepping, and also in the fact that, thanks to the spring-loaded pushers, there is protection against excessive penetration and contact with stones or other obstacles.

The program and methodology of experimental studies provided for the method of planning a 3-factor experiment [6-8] optimization of parameters: uniformity of the depth of tillage, quality of crumbling, determination of energy costs and specific resistance of the proposed working body.

To this end, the following scope of work is planned:

- determination of the physical and mechanical properties of the soil;
- determination of the resistance force of the experimental section of the rotary harrow and the working body with its different diameters (mm) and the number of needles (teeth) on it, the speed of the unit, productivity, fuel consumption;
- dynamometer testing of the working bodies of the harrow (Fig.2), which was carried out in accordance with GOST R 52777-2007 "Agricultural equipment. Methods of

energy assessment". Resistivity data were determined from the results of measurements in each of the operating modes; in this case, measurements were carried out at least four times and for a duration of at least 20 s.



**Fig. 2.** Technological scheme of the experimental setup to determine the energy performance of a rotary harrow: 1 – dynamometric frame, 2 – tractor hydraulic hitch, 3 – hinge link, 4 – bracket, 5 – hoe section, 6 – bracket, 7 – dynamometer, 8 – video camera with fast shooting.

## 4 Research results

During mathematical processing of data (imaginary factors, real factors, variation intervals) of the experiment according to the  $B_k$  plan

$$x_1 = \frac{x_1 - x_{10}}{\Delta_1}, x_2 = \frac{x_2 - x_{20}}{\Delta_2}, x_3 = \frac{x_3 - x_{30}}{\Delta_3} \quad (1)$$

The equation for crumbling the surface layer of soil by a rotary working body, depending on the selected factors:

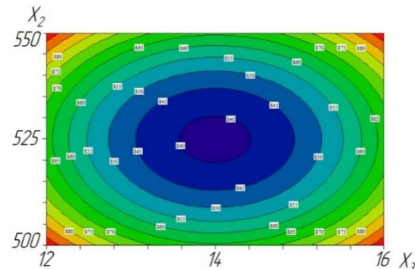
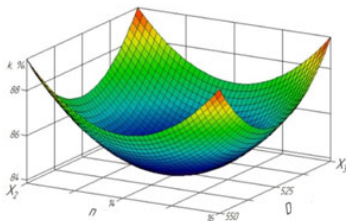
$$Y = 85,0153 + 1,851 \cdot x_1 + 2,503 \cdot x_2 - 1,066 \cdot x_3 + 1,2375 \cdot x_1 \cdot x_2 + 0 \cdot x_1 \cdot x_3 + 0,105 \cdot x_2 \cdot x_3 + 1,038 \cdot x_1^2 + 2,768 \cdot x_2^2 + 2,753 \cdot x_3^2, \quad (2)$$

where  $Y$  – crushing the soil with a rotary disc.

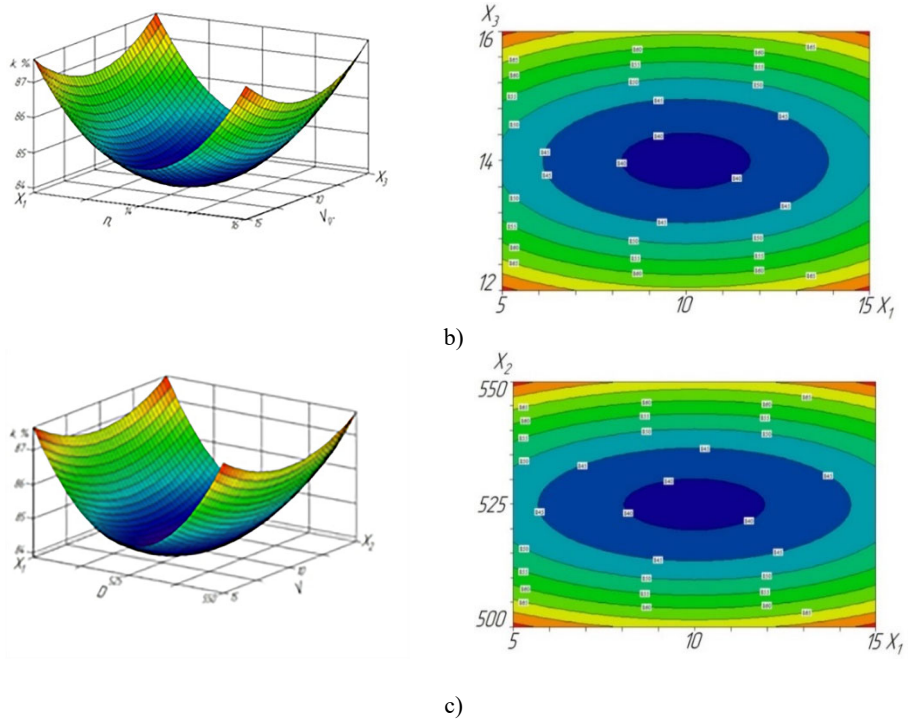
The coefficients of the regression equation were tested using the Student's criterion, the adequacy of the model was checked by the Fisher criterion.

Optimization values:  $Y_s = 83,877\%$ ; – optimum driving speed  $V_p = 6,43$  km/h; – optimum disc diameter  $D_0 = 518$  mm; – optimal number of needles (teeth)  $n = 14$  pcs.

After canonical transformations of the surface and two-dimensional sections of the dependencies (Fig.3) of soil crumbling on the diameter of the disk and the number of needles (teeth); crumbling of the soil from the speed of movement and the number of needles (teeth) of the unit; crumbling of the soil on the speed of movement and the diameter of the disc.



a)



**Fig. 3.** Dependence surfaces and their two-dimensional sections: a – soil crumbling on the disk diameter and the number of needles (teeth); b – crumbling of the soil from the speed of movement and the number of needles (teeth) of the unit; c – crumbling of the soil on the speed of movement and the diameter of the disk.

## 5 Discussion and conclusions

The objectives of the study have been completed.

On the basis of exploratory research, a modernized rotary harrow was developed for surface tillage in the inter-row spacing of vineyards.

Based on the planning of a multifactorial experiment, the parameters and mode of operation of the proposed disk working body of a rotary hoe were optimized: the diameter of the disk is 518 mm, the number of teeth on the disk is 14, the spacing of the teeth is 0.118 m, the number of teeth simultaneously in the soil is three. The optimal working speed of the hoe was 6.43 km/h.

The specific traction resistance of a rotary hoe with the proposed working bodies is 1.0 kN per meter of hoe grip at a working depth of 5 cm. With an increase in speed by 1 km/h, the resistance increases by 3.6%. The dependence of the specific traction resistance of the hoe on the working speed is obtained.

The new proposed technique and the combination of technological operations are more efficient than the base case.

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