BIO Web of Conferences **126**, 01025 (2024) https://doi.org/10.1051/bioconf/202412601025
AEEA2024

The layout of the cultivator's working bodies

Galina Parkhomenko[1], *Sergey* Kambulov[1,2], *Viktor* Rykov[1,2], *Dmitry* Podlesny[1,2*], *Olga* Pleskacheva[2], and *Alina* Gvozdikova[2]

[1]Federal State-Founded Scientific Establishment "Agricultural research center "Donskoy", 14, Lenina Street, Zernograd, 347740, Russia
[2]Federal State-Founded Educational Institution of Higher Education "Don State Technical University", 1, Gagarina Square, Rostov-on-Don, 344000, Russia

Abstract. The purpose of the study is to choose the rational placement of the developed working bodies on the frame of the steam cultivator. The types of media affecting the traction resistance of the working body of a steam cultivator are revealed: in the absence of destroyed soil on the sides, solid; in the presence of destroyed soil on one side – semi–flat; in the presence of destroyed soil on both sides - free. Calculations were made, as a result of which the following parameters of placement on the frame of the steam cultivator were determined: a two-row scheme with an even number of working bodies; the number of working bodies is 6; the width of the machine is 3 m; the distance along 52-54 cm; the distance across between the working bodies is 48-50 cm.

1 Introduction

Currently, existing steam cultivators do not always meet the quality requirements of the technological process of surface tillage.

Thus, when using pointed paws, there is a large unevenness in the depth of the stroke of the working organs of the steam cultivator, the removal of wet layers to the surface of the field, sticking, the formation of ridges and furrows.

The improvement of the working organs of a steam cultivator can be carried out by radically modernizing the structure, completely abandoning pointed paws.

2 Materials and methods

The design of a new working organ of a steam cultivator, which does not contain pointed paws, consists of a rack with a chisel and left- and right-sided plane cutters installed sequentially on it (Figure 1), has been developed in the Department of Plant Mechanization of the Donskoy ANC.

* Corresponding author: podlesniy.dmitri@yandex.ru

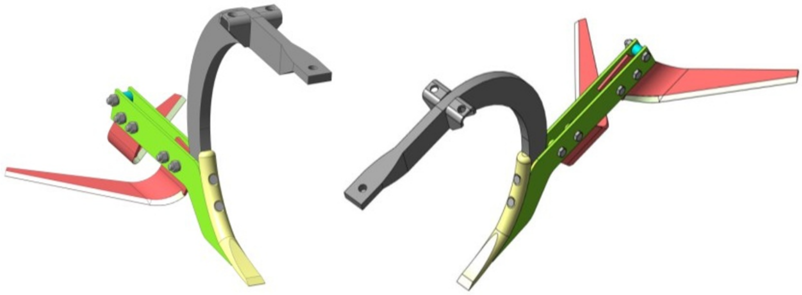

Fig. 1. The new working body of the steam cultivator.

The purpose of the study is to choose the rational placement of the developed working bodies on the frame of the steam cultivator.

3 Results and Discussion

When developing the design of a steam cultivator, it is necessary to choose such a scheme for the placement of working bodies, in which there is no jamming of soil lumps and clogging of gaps between adjacent racks with plant residues, but complete pruning of weeds and a smooth surface of the treated field with minimal ridges with a predominant fraction size of no more than 25 mm is ensured.

When placing the working bodies of a steam cultivator, it is necessary to strive to reduce its mass by reducing the length, while ensuring the required width of the machine, depending on the traction class of the aggregating tractor.

Also, a necessary condition for rational placement is the choice of the smallest possible number of working bodies on the frame of a steam cultivator operating in a continuous environment of untreated soil. The fulfillment of this condition significantly affects the reduction of the traction resistance of the steam cultivator.

The following types of media can be distinguished that affect the traction resistance of the working body of a steam cultivator:

- In the absence of destroyed soil on the sides – solid.
- In the presence of destroyed soil on the one hand , a semi – flat.
- If there is destroyed soil on both sides, it is free.

The maximum value of the traction resistance of a steam cultivator is observed when placing the working bodies in one row, since their interaction with untreated soil is characterized by the presence of a continuous medium. In addition, it is possible to clog the gaps between adjacent racks of the working bodies of the steam cultivator with plant residues and soil (Figure 2).

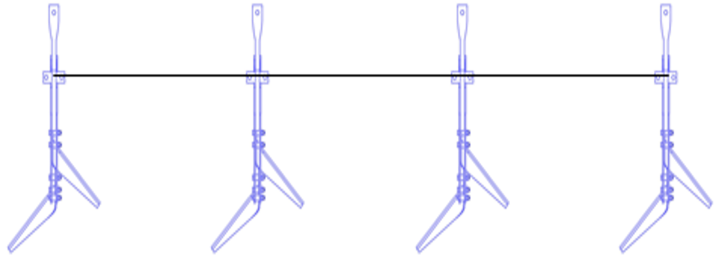

Fig. 2. The layout of the working bodies of the steam cultivator in one row.

 https://doi.org/10.1051/bioconf/202412601025

When placing the working bodies of a steam cultivator in two or more rows, clogging of the gaps between adjacent racks with plant residues and soil is excluded (Figure 3).

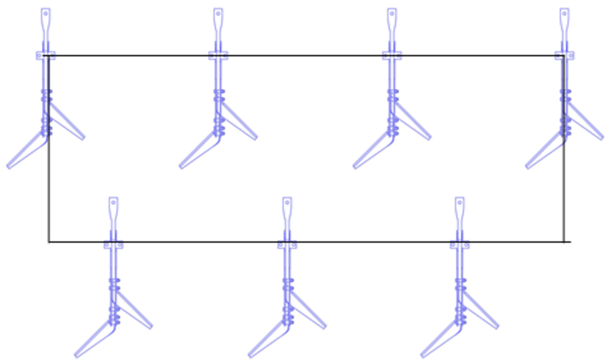

Fig. 3. Layout of an odd number of working bodies of a steam cultivator in two rows (option 1).

At the same time, the traction resistance of the steam cultivator is reduced due to a reduction in the number of working bodies operating in a continuous medium of loosened soil. In a continuous environment, the working organs of the steam cultivator function only in the first row, and the following ones interact with the loosened soil, carrying out the process of semi-flat (on the one hand) and free cutting (on both sides). When operating the working bodies of a steam cultivator in a semi-flat environment, the traction resistance decreases compared to the conditions of a continuous medium due to stress dissipation at the boundary of loosened soil.

When installing the working bodies in two rows, various options are possible (Figure 3-5).

One of the options is the layout of an odd number of working bodies of a steam cultivator, shown in Figure 3.

With this arrangement, the four front working bodies of the steam cultivator function in a continuous environment, the three rear ones in a free environment.

Figure 4 shows an arrangement scheme in which three front working bodies function in a continuous environment, two side rear ones – a semi–flat and two central ones - a free environment.

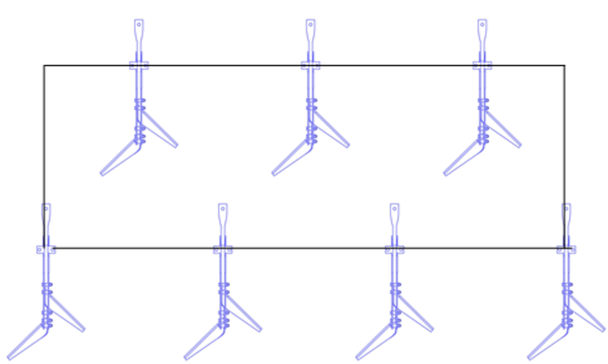

Fig. 4. Layout of an odd number of working bodies of a steam cultivator in two rows (option 2).

Another option (3) for placing a steam cultivator on the frame is the scheme with an even number of working bodies shown in Figure 5.

In option 3 of placing a steam cultivator (Figure 5), half of the working bodies operate in a continuous environment, one is semi–flat, and the rest are free environments with the lowest traction resistance.

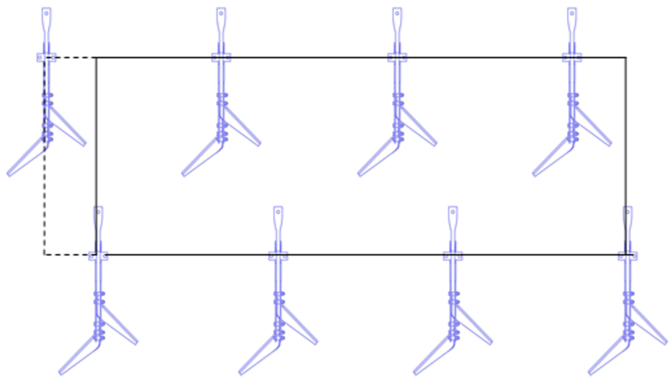

Fig. 5. The layout of an even number of working bodies of a steam cultivator in two rows (option 3).

In addition, with this arrangement, it is possible to adjust the width of the steam cultivator by dismantling the extreme working body of the front row (Figure 5).

When the working body of the steam cultivator is functioning, weeds are destroyed during the sliding cutting process.

Therefore, when placing the working bodies on the frame of the steam cultivator, it is necessary to take into account the overlap of the flat-cut rippers (projections of neighboring flat-cut rippers when placed in two rows) in the transverse direction (Figure 6).

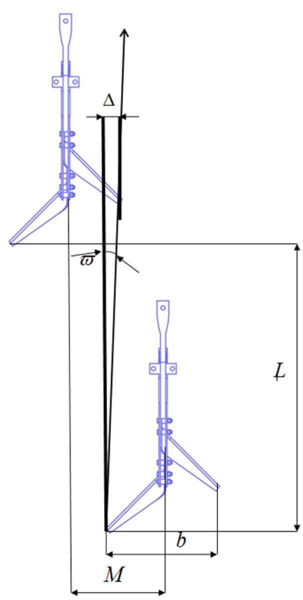

Fig. 6. Determination of the distance between the workers of the steam cultivator body taking into account overlap.

This condition is necessary so that there are no flaws when pruning weeds and continuous loosening of the soil during operation of the steam cultivator, since it does not always move in a straight line across the field.

The deviation of the trajectory of the steam cultivator from the rectilinear one is taken into account by the angle ϖ .

The angle of deviation from the rectilinear trajectory is determined depending on the placement along the L working bodies during overlap Δ according to the formula:

$$tg\varpi = \frac{\Delta}{L} \tag{1}$$

Size across there M is a gap between the racks (projections of the racks when placing the working bodies of the steam cultivator in two rows) in the transverse direction (Figure 6).

When determining the lengthwise size, L it is necessary to take into account the presence of an advancing crack when the bit of the working body of the steam cultivator interacts with the soil.

The bit of the working body of the steam cultivator forms a leading crack in the longitudinal direction, and the flat-cut rippers cut the separated soil mass in the transverse direction.

An advanced crack leads to the appearance of a region of stress l'' and destruction of the soil in front of the frontal surface of the bit of the working body of the steam cultivator at the angle of soil chipping.

At the same time, the higher the movement speed, the further the crack front propagates, which is accompanied by a greater intensity of soil crumbling by the new working body of the steam cultivator.

When the working parts of a steam cultivator are placed along L the surface of the area of stress l'' in the inter-column space, it is characterized by the removal of the bit l' in the longitudinal direction, which is determined taking into account the front of the advancing crack (Figure 7).

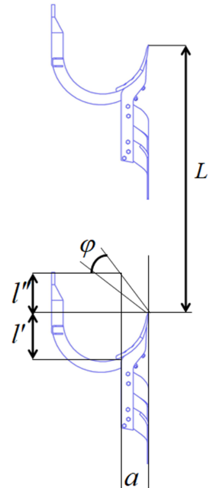

Fig. 7. The distance between the workers of the body along the direction of movement of the steam cultivator.

$$L \geq l' + l''. \tag{2}$$

Dependence (2) is a condition under which the steam cultivator cannot become clogged with soil and plant debris in the space between the front and rear rows of working bodies when they are placed in two rows.

The removal l' of the bit affects the nature of the interaction of the working body with the soil layer.

With a small value of this parameter, the formation, under the influence of the front of an advancing crack formed by the bit of the working part of the steam cultivator, diverges to the sides and the stand functions in the destroyed soil, which reduces traction resistance and has a positive effect on the quality of soil cultivation.

Excessively increased bit removal can lead to the formation of a mound-shaped soil [1] in front of the working body of the steam cultivator and an increase in traction resistance, and also increases the ridge quality of the field surface.

With a rationally chosen size of bit removal, the leading crack formed in front of the working body of the steam cultivator opens, the layer breaks off and moves to the sides, a longitudinal crack is formed and the stand moves along the treated soil.

Taking into account the relationship for determining the soil chipping angle [2]:

$$L \geq a tg \frac{\beta + \varphi + \rho}{2} + l', \tag{3}$$

Where β is the angle of crumbling or installation of the bit of the working body of the steam cultivator to the bottom of the furrow (not shown in the diagram), degrees; φ – angle of external soil friction on the surface of the working body, degrees; ρ – angle of internal soil friction (not shown in the diagram), degrees.

The area of stress in front of the working body of the steam cultivator in the transverse direction forms a soil deformation field, the width Π of which can be determined for the pointed paw according to dependence (4) presented in the literature [3]:

$$\Pi = 2 \cdot a + в + 0.5 \cdot a tg \frac{\beta + \varphi + \rho}{2} \cdot \cos \frac{\gamma}{2}, \tag{4}$$

a $в$ where – cultivation depth, m; Insert a tag – working body width, m; – angle of the pointed paw, degrees. γ

$\gamma = \pi, \cos\pi = 0$ Since for flat-cut rippers of the working body of a steam cultivator, the opening angle of the known relationship (4) will take the form:

$$\Pi = 2 \cdot a + в. \tag{5}$$

In the transverse-vertical plane, three areas of soil stress can be distinguished [4] in front of the working body of the steam cultivator:

- The area of formation crumbling, determined by the contour of the working body.
- The area of formation crumbling outside the working body, determined by the propagation front of the advancing crack.
- The area of stress state of the deformed formation, which does not reach the fracture limit.

 https://doi.org/10.1051/bioconf/202412601025

At the same time, the more energy is spent in areas 1 (E_1) and 2 (E_2), the lower the energy intensity (E) of tillage with a steam cultivator.

The area of formation crumbling outside the working body of the steam cultivator determines the conditions of operation in a continuous, semi-flat or free environment.

The author introduced the term efficiency coefficient of the working body η , which is calculated according to the formula [2]:

$$\eta = \frac{E_1 + E_2}{E} = \frac{E_1 + E_2}{E_1 + E_2 + E_3}, \tag{6}$$

The component of total energy consumption (E) spent on deformation of the soil without crumbling (E_3) is spent irrationally on excessive compaction of the soil.

The ratio of the components of formula (6) depends on the placement of the M working bodies across the frame of the steam cultivator.

To ensure continuous cultivation of the soil without gaps and flaws in the form of untreated strips, it is necessary to place the working bodies across in M such a way that the condition is fulfilled:

$$M > \Pi. \tag{7}$$

Substituting dependence (5) into inequality (7), we obtain a formula for determining the size across M :

$$M > 2 \cdot a + в. \tag{8}$$

The size across M between adjacent working bodies of a steam cultivator has a significant impact on the quality of tillage.

When placing the working bodies in a row on the frame of a steam cultivator, as a rule, either the space between the working bodies of the steam cultivator is clogged at low M , or flaws remain in the form of not fully trimmed weeds and untreated soil M .

Therefore, it is advisable to place the working bodies in two rows on the frame of the steam cultivator.

The most rational scheme for placing an even number of working bodies on the frame of a steam cultivator is a two-row with a variable grip width, shown in Figure 5.

The number of working bodies of the steam cultivator is selected depending on their placement on the frame [5].

The number of n working bodies of a steam cultivator with a working width, B taking into account the overlap, is Δ determined by the formula:

$$n = \frac{B}{b - \Delta}. \tag{9}$$

The width of the steam cultivator is selected for a certain tractor traction class based on the total traction resistance of the working bodies [6-7].

At the same time, the traction resistance of the working bodies operating in a continuous, semi-flat or free environment varies depending on the location and layout along the frame of the steam cultivator.

Based on the above dependencies, calculations were performed, as a result of which the following parameters of placement on the frame of the steam cultivator were determined:

- The scheme is two-row with an even number of working bodies.
- The number of working bodies is 6.
- The width of the machine is 3 m.
- Distance along 52-54 cm.
- The distance across between the working bodies is 48-50 cm.

4 Conclusion

The improvement of the working organs of a steam cultivator can be carried out by radically modernizing the structure, completely abandoning pointed paws. The design of a new working body of a steam cultivator has been developed, which does not contain pointed paws, consists of a rack with a chisel and left- and right-sided plane cutters installed sequentially on it.

Also, a necessary condition for rational placement is the choice of the smallest possible number of working bodies on the frame of a steam cultivator operating in a continuous environment of untreated soil.

When placing the working bodies of a steam cultivator in two or more rows, clogging of the gaps between adjacent racks with plant residues and soil is excluded (Figure 3). At the same time, the traction resistance of the steam cultivator is reduced due to a reduction in the number of working bodies operating in a continuous medium of loosened soil.

The most rational scheme for placing an even number of working bodies on the frame of a steam cultivator is a two-row with a variable working width. In option 3 of placing a steam cultivator (Figure 5), half of the working bodies operate in a continuous environment, one is semi–flat, and the rest are free environments with the lowest traction resistance.

The parameters of placement on the frame of the steam cultivator are determined: a two-row scheme with an even number of working bodies; the number of working bodies is 6; the width of the machine is 3 m; the distance along 52-54 cm; the distance across between the working bodies is 48-50 cm.

References

1. V.V. Myalo, O.V. Myalo, E.V. Demchuk, Justification of the main parameters of the cultivator's working body for continuous tillage, Bulletin of the Omsk State Agrarian University, **2**, **34**, 153-164 (2019)
2. Mechanization of soil protection from water erosion the Non-Chernozem zone, Edited by A.T. Vagina (Kolos, Leningrad, 1977)
3. G.N. Sineokov, Design of tillage machines (Mechanical engineering, Moscow, 1977)
4. G.G. Parkhomenko, S.G. Parkhomenko, Theoretical study of the mechanisms of movement of working bodies for tillage, Intelligent machine technologies and equipment for the implementation of the State program for the development of agriculture: Collection of scientific reports of the International Scientific and Technical Conference, FGBNU VIM, Moscow, 210-214 (2015)

https://doi.org/10.1051/bioconf/202412601025

5. M.V. Nikonov, S.S. Buneev, S.Yu. Shubkin, A.V. Klapp, Mathematical justification of the layout of the working bodies on the cultivator frame, Agro-industrial technologies of Central Russia, **2**, **16**, 98-103 (2020) DOI 10.24888/2541-7835-2020-16-98-103
6. V.L. Andreev, S.L. Demshin, V.V. Ilyichev, D.A. Cheremisinov, G.S. Yunusov, Multifunctional tillage unit with replaceable working bodies, Vestnik NGIEI, **11**, **90**, 87-102 (2018)
7. S.G. Parkhomenko, V.G. Yarovoy, V.A. Kravchenko, I.M. Melikov, Patent No. 2085891 C1 Russian Federation, IPC G01M 17/02. Tire tester: No. 95111419/11: application 03.07.1995: publ. 27.07.1997, Applicant Azov-Black Sea Institute of Agricultural Mechanizatio (1997)