Analysis of agrotechnical indicators of the new the working body of the steam cultivator

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Abstract. The paper presents a comparative analysis of the work of a serial lancet paw with the proposed new working body of a steam cultivator through field research on the fields of the Donskoy Agricultural Scientific Center. Optimal modes and parameters of operation of proposed new working member are determined in comparison with serial working member of steam cultivator. The advantage of the new working element of the steam cultivator has been established in comparison with the standard lancet paw in terms of agrotechnical indicators.

1 Introduction

The high level of technology of the new generation is characterized by high productivity of the unit when meeting the agrotechnical requirements for a specific method of tillage [1-10].

It is known that when cultivating crops, up to 40-45% of all energy costs are spent on preparing the soil for sowing. The thin technological processes are surface - steam tillage of the soil, it is on it that the normal distribution of the inoculum in depth depends and, as a result, further uniformity of seedlings. To ensure the pre-sowing soil preparation process, a new working body for a steam cultivator was developed at the Donskoy Agricultural Scientific Center.

The design of a new working organ of a steam cultivator has been developed in the Department of mechanization of crop production at the Federal State Budgetary Scientific Institution of the "Donskoy" Agricultural Research Center. The new working body consists of a rack with a chisel and sequentially mounted left- and right-sided plane cutters (Figure 1).

The main requirements for the quality of crumbling of the soil treated by the working bodies of a steam cultivator are to ensure a finely lumpy structure and uniformity of the loosening depth [11-13].

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

When these requirements are met, the treated area of the field is leveled, with the height of the ridges and the depth of the furrows not exceeding the values allowed by agrotechnical requirements.

2 Materials and methods

Measurements of the depth of processing are carried out following the passage of the racks of the new working body of the steam cultivator and the standard pointed foot, immersing the ruler into the soil to the untreated layer. The number of measurements n_{depth} for each accounting pass should be 25 for tillage with a new working organ of a steam cultivator and a standard pointed foot.

To determine the stability of the stroke, the measurement data (current depth indicators a_i) are processed using a statistical method to obtain the arithmetic mean of the depth $a_{cp.}$, standard deviation σ_{depth} and coefficient of variation v_{depth}.

$$\sigma_{depth} = \pm\sqrt{\frac{\sum_{i=1}^{n_{zdepth}} \left(a_i - a_{cp}\right)^2}{n_{depth} - 1}},\ v_{depth} = \pm\frac{\sigma_{depth}}{a} \cdot 100\%. \quad (1)$$

The ridge characterizes the average height of irregularities on the surface of the field after tillage with a new working organ of a steam cultivator in comparison with a standard pointed foot.

The height of the irregularities is measured using a rack and ruler in 4 places in the forward and reverse direction of movement of the working bodies.

After passing the new working body of the steam cultivator and the standard pointed paw, a rail is applied to the top of the irregularities in randomly selected places along the width of the grip.

A ruler is applied perpendicular to the rail to measure the height of irregularities on the surface of the field. The number of measurements at each point is at least 10.

The quality of soil crumbling (the presence of lumps in the treated layer with a size of less than 25 mm) was determined after the passage of a new working organ of a steam cultivator and a standard pointed foot.

Since the gripping width of a standard pointed paw is less than the size of a pallet (0.5x0.5 m) divided into squares of 25x25 mm, superimposed on the treated layer to quantify lumps exceeding the size of 25 mm, the quality of crumbling of both working bodies was determined by weighing, by taking a sample of the treated soil and weighing individual fractions (Figure 2).

Fig. 2. Selection and weighing of lumps larger than 25 cm.

The quality of soil crumbling was determined from samples taken at 4 points in 3 repetitions in the forward and reverse directions of movement with manual analysis of fractions in laboratory conditions to isolate lumps larger than 25 mm and then weigh them (Figure 3).

Fig. 3. Weighing of the total soil sample.

The $m_{\sum}$ mass of isolated lumps is determined as a percentage of the total mass of the sample $m_{>25mm}$ according to the formula (1):

$$m_{<25mm} = 100 - \frac{m_{>25mm} \cdot \cdot 100\%}{m_{\sum}} .. \quad (2)$$

3 Results and Discussion

The results of the study of the depth of tillage are presented in Tables 1 and 2.

Table 1. Results of a study of the stability of the stroke of a new working organ of a steam cultivator at a depth of tillage of 8 cm.

The name of the indicator	The value of the indicator, % at driving speeds, km/h		
	8.0	**10.5**	**13.0**
Average depth, cm	9.0	8.6	8.4
Standard deviation of the depth, ± cm	0.71	0.89	0.89
Depth variation coefficient, %	7.86	10.40	10.65

Table 2. Results of a study of the stability of the course of a standard pointed foot at a depth of 8 cm of tillage.

The name of the indicator	The value of the indicator, % at driving speeds, km/h		
	8.0	**10.5**	**13.0**
Average depth, cm	8.8	9.2	9.0
Standard deviation of the depth, ± cm	0.84	2.0	2.10
Depth variation coefficient, %	9.55	15.21	23.30

The permissible deviation from the set depth of tillage by the new working body of the steam cultivator and the standard pointed foot is ± 2 cm.

The data obtained (Tables 1 and 2) are combined into Table 3 for a comparative assessment of the stability of the stroke depth of the new working organ of the steam cultivator and the standard pointed foot.

Table 3. Results of comparing the stability of the course of the new the working body of a steam cultivator and a standard pointed foot at a depth of tillage of 8 cm.

Name of the working body	Standard deviation of the depth, ± cm	Depth variation coefficient, %
Figure 1 – The new working body of the steam cultivator	0.71-0.89	7.96-10.65
Standard pointed foot	0.84-2.10	9.55-23.30

The analysis of the data obtained (Table 3) shows that the new working body of the steam cultivator meets the agrotechnical requirements for the stability of the stroke depth in the entire speed range, since the standard deviation of this indicator is ± 0.71-0.89 cm, which does not exceed the permissible (± 2 cm).

The standard pointed foot meets the agrotechnical requirements for the stability of the stroke depth only at speeds up to 10.5 km/ h inclusive (standard deviation ± 0.84-2.0 cm), and at 13.0 km/ h it does not correspond, since the required indicator (± 2.1 cm) exceeds the permissible value (± 2 cm).

The coefficient of variation of 15.21 and 23.30% when cultivating the soil with a standard pointed foot at a speed of 10.5 and 13.0 km/h, respectively, indicates an excessive spread relative to the average depth value at a given 8 cm.

This is a confirmation of the instability of the stroke depth of the standard pointed foot when operating in these modes and the unsuitability of this working body for high-speed tillage equipment.

The uneven depth of the stroke of the working bodies affects the levelling of the field surface after tillage.

The obtained data on the ridges are shown in Table 4.

Table 4. Results of the study of the ridge of the field surface after tillage by working bodies to a depth of 8 cm.

Name of the working body	The value of the indicator, cm at driving speed, km/h		
	8.0	**10.5**	**13.0**
Figure 1 – The new working body of the steam cultivator	2.3	2.2	2.4
	2.3	2.4	2.2
	2.6	2.5	2.3
	2.1	2.7	2.6
On average	2.3	2.5	2.4
Standard pointed foot	3.6	3.4	3.9
	3.5	3.4	4.1
	3.5	3.3	4.3
	3.2	3.6	4.2
On average	3.5	3.4	4.1

After the passage of the new working body of the steam cultivator and the standard pointed foot, the ridge of the field surface should be no more than 4 cm.

The new working body of the steam cultivator meets the agrotechnical requirements for the ridge of the field surface after tillage (2.1-2.7 cm) and changes slightly (by 4%) with increasing speed.

At the same time, the greatest rippling of the field surface (on average 2.5 cm), which does not exceed the permissible (up to 4 cm), is observed at an average speed of movement (10.5 km/ h), and then decreases to 2.4 cm when it increases to 13.0 km/h.

The uneven depth of tillage due to the instability of the stroke depth of the standard pointed foot at a speed of 13.0 km/ h was the cause of increased ridges (3.9-4.2 cm), which does not meet the agrotechnical requirements for this indicator (up to 4 cm).

At speeds of 8.0 and 10.5 km/h, the ridge after the passage of the standard pointed foot was 3.2-3.6 and 3.3-3.6 cm, respectively, which is on average 1.4-1.5 times higher than that of the new working organ of the steam cultivator, but does not contradict agrotechnical requirements regarding the levelling of the field surface.

The results of the study of the quality of crumbling and the background after tillage by working bodies are presented in Table 5 and Figure 4.

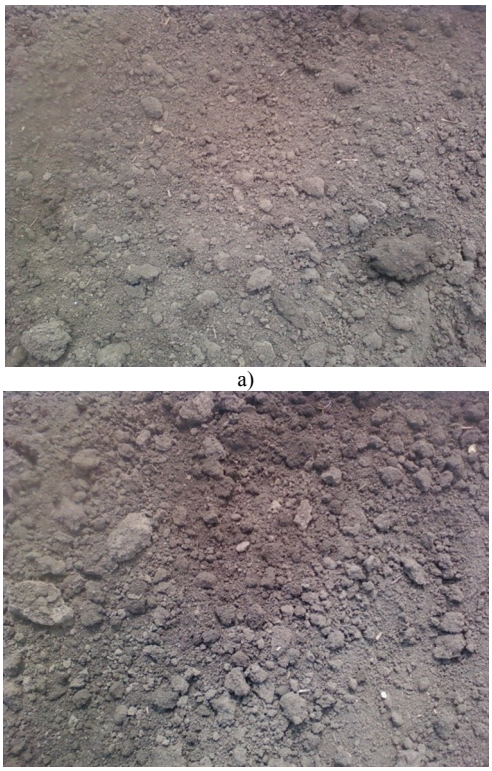
Table 5. Results of a study of the quality of soil crumbling by a new working organ of a steam cultivator (depth 8 cm).

Name of the working body	The value of the indicator, % at			
	Lumps of less than 25 mm in size, %			
	driving speeds, km/h			Allowed according to agrotechnical requirements
	8.0	**10.5**	**13.0**	
Figure 1 – The new working body of the steam cultivator	88.9	91.3	93.2	At least 80 %
	89.3	92.1	92.5	
	89.5	91.8	92.9	
	88.7	92.0	93.4	
On average	89.1	91.8	93.0	
Standard pointed foot	86.0	87.4	85.9	
	86.8	86.5	85.7	
	86.7	87.7	86.6	
	86.9	86.7	87.0	
On average	86.6	87.1	86.3	

The analysis of the data obtained (Table 5) shows that both working bodies comply with agrotechnical requirements for the quality of crumbling at a cultivation depth of 8 cm, since after passing through the treated soil layer, lumps of less than 25 mm in size contain 85.7-93.4%.

The new working body of the steam cultivator with an increase in movement speed from 8.0 to 13.0 km/h provides an increase in the quality of soil crumbling from 88.7 to 93.4%, respectively.

With the operation of a standard pointed foot, the quality of soil crumbling is at the same level: 85.7-87.7% of lumps less than 25 mm in size in the treated layer.



a)

b)

Fig. 4. Background after tillage by working bodies: a) the new working body of the steam cultivator; b) standard pointed foot of the steam cultivator.

It should be noted that in the most efficient mode of operation, from the point of view of increasing productivity (at a speed of 13.0 km / h), the standard pointed foot provides the worst crumbling quality (on average 86.3%), and the new working body of the steam cultivator, on the contrary, the best (on average 93.0%).

In general, the new working body of the steam cultivator provides an improvement in the quality of crumbling by the presence of lumps less than 25 mm in size in the treated soil layer compared to the standard pointed foot by 2.2-7.3% on average.

The improvement in the quality of crumbling by the new working body of the steam cultivator is explained by the occurrence, with an increase in the speed of movement, of the impact interaction of the formation with the chisel, which forms a leading crack in the longitudinal direction (Figure 5), and plane-cutting rippers cut in the transverse direction of the separated soil mass (Figure 6).

Fig. 5. Formation of a leading crack with a chisel.

Fig. 6. Crumbling of the soil with flat-cut rippers.

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

This is due to the close relationship between the amount of energy required to crumble the soil and the energy of the formed crack, which is directly proportional to the surface tension of the lump.

The process of crumbling the soil is due to the presence of trapped air inside the formation, which is released when the equilibrium of external forces is disturbed from the support from the untreated massif and from the impact of the working body. At the same time, at the surface depth of tillage, external forces from the side of the working body acting on the formation cannot be balanced and turn into compression, stretching and shear deformations, which is accompanied by crumbling into individual lumps when the connection between them is lost.

The crumbling of the soil by the new working organ of the steam cultivator is accompanied by an increase in the volume of the soil, which occurs when deforming normally to the surfaces of destructive shear deformations. The increase in soil volume is due to the looser laying of the formed lumps.

The standard pointed foot does not contain a chisel, and impact interaction with the formation does not occur when it functions at an increased speed of movement.

At the same time, the soil mass under the influence of compression and shear deformations arising due to the configuration of the working surface of a standard pointed foot is subjected to crumbling for some time, which is determined by the duration of interaction with the soil, which decreases with increasing speed of movement.

Therefore, the higher the speed of movement of the standard pointed foot, the less time the soil is subjected to crumbling, which is accompanied by a decrease in its quality.

4 Conclusion

The analysis of the data obtained (Table 3) shows that the new working body of the steam cultivator meets the agrotechnical requirements for the stability of the stroke depth in the entire speed range, since the standard deviation of this indicator is ± 0.71-0.89 cm, which does not exceed the permissible (± 2 cm). The standard pointed foot meets the agrotechnical requirements for the stability of the stroke depth only at speeds up to 10.5 km/ h inclusive (standard deviation ± 0.84-2.0 cm), and at 13.0 km/ h it does not correspond, since the required indicator (± 2.1 cm) exceeds the permissible value (± 2 cm).

The coefficient of variation of 15.21 and 23.30% when cultivating the soil with a standard pointed foot at a speed of 10.5 and 13.0 km/h, respectively, indicates an excessive spread relative to the average depth value at a given 8 cm. This is a confirmation of the instability of the stroke depth of the standard pointed foot when operating in these modes and the unsuitability of this working body for high-speed tillage equipment.

The uneven depth of tillage due to the instability of the stroke depth of the standard pointed foot at a speed of 13.0 km/ h was the cause of increased ridges (3.9-4.2 cm), which does not meet the agrotechnical requirements for this indicator (up to 4 cm). At speeds of 8.0 and 10.5 km/h, the ridge after the passage of the standard pointed foot was 3.2-3.6 and 3.3-3.6 cm, respectively, which is on average 1.4-1.5 times higher than that of the new working organ of the steam cultivator, but does not contradict agrotechnical requirements regarding the levelling of the field surface.

The new working body of the steam cultivator with an increase in movement speed from 8.0 to 13.0 km/h provides an increase in the quality of soil crumbling from 88.7 to 93.4%, respectively. With the operation of a standard pointed foot, the quality of soil crumbling is at the same level: 85.7-87.7% of lumps less than 25 mm in size in the treated layer. It should be noted that in the most efficient mode of operation, from the point of view of increasing productivity (at a speed of 13.0 km / h), the standard pointed foot provides the worst crumbling quality (on average 86.3%), and the new working body of the steam cultivator, on the contrary, the best (on average 93.0%). In general, the new working body of the steam cultivator provides an improvement in the quality of crumbling by the presence of lumps less than 25 mm in size in the treated soil layer compared to the standard pointed foot by 2.2-7.3% on average.

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