Reduction of soil layer losses when harvesting sugar beet in the conditions of the central black earth region

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Abstract. When cultivating sugar beets, harvesting is one of the most labor-intensive operations. But in terms of quality and operational and technological performance, the machines used do not meet modern agrotechnical requirements, especially in conditions of high soil moisture (25 - 29%). With an increase in soil moisture, its adhesion to the working surfaces of the digging organs and the heap cleaner increases, reducing their separating ability. We propose to improve the cleaning technology by modernizing the design of the separating stars. This is achieved by using cylindrical brushes (in the amount of three pieces), which are mounted vertically to the horizontal plane of the star's rods. One end of the cylindrical brush is attached to one of the ends of the star bar, and the other end of the brushes is in the hollow bracket. All brushes are located at the same distance from each other along the periphery of the star. The second ends of the brushes, located in the hollow bracket, are fixed to each other and move freely in it. This improved design will allow the brushes to interact with the contaminated surface of the sprocket guard, improving their cleaning ability and eliminating cleaning breaks when working in harsh conditions.

1 Introduction

Harvesting is one of the most time consuming operations in sugar beet cultivation.

When determining the timing of harvesting, it must be borne in mind that the intensive growth of root crops and the accumulation of sugar in them occurs from the second decade of September. In the conditions of the Central Black Earth Region, this period begins in late autumn, which is characterized by a deterioration in the agrophysical properties of the soil (moisture and stickiness increase). As a result, soil sticking occurs in the digging and separating working bodies of beet harvesters, the cleaning capabilities of root crops deteriorate, which sharply reduces the quality of harvesting [1, 2].

The studies carried out comply with the Decree of the Government of the Russian Federation №717 of July 14, 2012 "On the State Program for the Development of Agriculture and Regulation of Agricultural Products, Raw Materials and Food Markets for 2013–2020" [3], and the development of a highly efficient working body for cleaning sugar

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beets adapted to the conditions of harvesting in unfavorable weather conditions, allowing to reduce the pollution of excavated root crops, ineffective costs of their transportation and prevent the loss of fertile soil and humus, is a very urgent task [4].

Scientific research has confirmed the effectiveness of the use of brushing devices.

Research goal - improving the cleaning quality of sugar beet root crops by improving the device and preventing the loss of the fertile soil layer.

2 Materials and methods

The research methodology is based on the analysis of patent literature, scientific articles of domestic and foreign authors, information publications and books on scientific and industrial topics. Theoretical research was carried out using the laws of mathematics, physics, theoretical mechanics and analytical geometry. Experimental studies were carried out in the field using generally accepted methods in accordance with the current GOSTs, as well as using the planning of multifactor experiments.

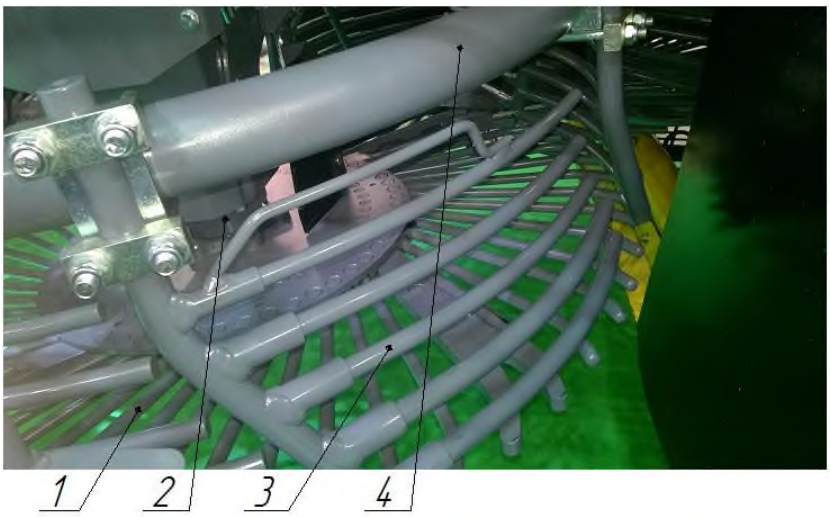
3 Objects, conditions and research methods

Harvesting complexes, previously developed and based on the use of self-propelled machines KS-6B, RKS-6, tractors MTZ-80, MTZ-82, T-70S, made it possible to mechanize the process of harvesting sugar beets. But in terms of quality and operational and technological performance, the machines used do not meet modern agrotechnical requirements, especially in conditions of high soil moisture (25 - 29%).

The use of foreign harvesters and machines from such manufacturers as GRIMME, ROPA, and others in harvesting allows to achieve good results when working on any soil, but this does not solve the problems associated with contamination of working bodies and loss of humus [4].

With an increase in humidity, the adhesion of soil to the working surfaces of the digging organs and the heap cleaner increases, reducing their separating ability, which leads to losses of root crops on the surface of the field.

The considered foreign machines [5-7], in order to improve the cleaning of root crops, install rotary cleaners (Figure 1), which cope quite well with the process of transportation and cleaning, however, production use has shown that after certain intervals, they need to be stopped for technological breaks ... This is done to protect the 3 stars of 1 rotary cleaner from adhering impurities, which reduce the degree of cleaning of root crops during the operation of the combine.



1 – sprocket; 2 – pivot center; 3 – guardrails of sprockets (grates or sieve springs); 4 – guardrail mounting bracket

Fig. 1. Rotary cleaners of the ROPA beet harvester

The first sprocket, 170 cm in diameter, is located under the frame hinge and is mounted in the center of the pivot axis (Figure 2) [8].

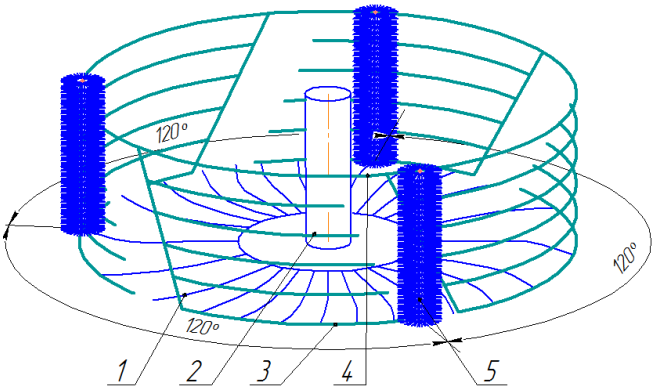
a) b)

Fig. 2. The working process of cleaning root crops: a - with favorable; b - unfavorable conditions (using sieve springs)

The sprocket guard (Figure 2) consists of gratings or sifting springs (combination is possible), the lifting height of which is hydraulically adjusted from the cab.

We propose to improve the cleaning technology by improving the design of the separating stars. This consists in the use of cylindrical brushes (in the amount of three pieces), which are fixed vertically to the horizontal plane of the arrangement of the rods of the star (Figure 3). One end of the cylindrical brush is attached to one of the ends of the star bar, and the other end of the brushes is in the hollow bracket. All brushes are located at the same distance from each other along the periphery of the star. The second ends of the brushes located in the hollow bracket are fixed to each other and move freely in it (Figure 3).

The design of an improved rotary cleaner using cleaning cylindrical brushes is protected by patent № 177192 [5].



1 – sprocket; 2 – pivot center; 3 – guardrails of sprockets (grates or sieve springs); 4 – guardrail mounting bracket; 5 – cylindrical brush

Fig. 3. Diagram of an improved rotary cleaner using cylindrical cleaning brushes

4 Research results

This improved design will allow the brushes to interact with the contaminated surface of the sprocket guard, improving their cleaning ability and eliminating cleaning breaks when working in harsh conditions.

The contamination of root crops after harvesting significantly affects the amount of proceeds from the sale of sugar beets delivered to the sugar factory [9].

Table 1 shows the amount of lost profit from the sale of root crops, due to their pollution.

Table 1. The results of calculating the lost profit due to soil contamination of root crops

Indicator	Indicator value
1. Average yield of root crops, t/ha	50
2. Losses from contamination of root crops, %	10
3. Losses from contamination of root crops, t	5
4. Selling price of 1 ton of root crops, thousand rubles	1.6
5. Lost revenue, thousand rubles/ha	0.8

Analyzing the data in Table 1, we can conclude that with the contamination of root crops within 10%, the lost proceeds from their sale will be 0.8 thousand rubles/ha.

Let's calculate the cost of transportation of sugar beet root crops after harvesting with and without the use of the proposed cleaning device [9-15].

The initial data for the calculation are presented in Table 2.

The use of the developed device reduces contamination up to 70% compared to serial models of harvesting machines. Consequently, the contamination of beet root crops will be 3%.

The number of trips for the export of the grown crop from 1 hectare can be calculated using the formula:

$$n = \frac{U_{av}}{q} \quad (1)$$

After substitution, we find $n \approx 1{,}67$ runs.

Table 2. Initial data for the calculation (as of 2019)

Indicator	Symbol	Value
Average yield of sugar beet, t/ha	U_{av}	50
Carrying capacity of a car with a trailer, t	q	30
Average transportation distance, km	L	15
Cost of transportation of 1 ton of root crops over a distance of 1 km, rub.	C	5
Average cost of transportation of 1 ton of root crops, rubles.	C_{1t}	75
Contamination of root crops without the use of the developed device, %	3	10
Average humus content in chernozem soil , %	z	6

The ineffective costs of transporting crops from 1 ha without using the proposed device will amount

$$3 = C_{1t} \cdot m \cdot n \quad (2)$$

where m – removal of soil with a harvest of root crops when contaminated 10%, t/ha: without using the proposed device – m_{re} = 5 t/ha; using the developed device – m_{cl} = 1,5 t/ha.

Removal of humus from 1 hectare during harvesting and transportation of crops is determined by the formula:

$$M_{hum} = m \cdot z \quad (3)$$

The calculation results are presented in the table 3.

Table 3. Calculation results

Indicator	Indicator value	
	without using the proposed cleaning device	using the developed cleaning device
Carrying out the soil with the yield of root crops when contaminated 10%, t/ha	5	1.5
Ineffective crop transportation costs, rubles/ha	626.3	187.9
Carrying out humus during crop transportation, t/ha	0.3	0.09

According to the calculations presented above, taking into account the results of the calculations presented in the tables above, we will finally get the economic efficiency presented in table 4.

Table 4. Evaluation of the effectiveness of using the device for removing sticky soil when harvesting in high humidity conditions (28-32%)

Indicator	Cleaning working body	
	Basic	Experimental
Area, ha	100	100
Carrying out of soil with a yield of root crops	5	1.5

with contamination of 10%, t/ha		
Ineffective crop transportation costs, rubles/ha	626.3	187.9
Removal of humus during crop transportation, t/ha	0.3	0.09
Cost of modernization, thousand rubles	-	283.3
Reduced cleaning time, days	-	5
Specific economic efficiency, thousand rubles/ha	-	7.1…12.6
Economic effect, thousand rubles	-	709.9…1255.7
Energy efficiency ratio	-	2.53…4.48
Payback period, years	-	0.4…0.22

5 Conclusion

The use of the proposed device will reduce the irretrievable loss of the fertile soil layer from 5 to 1.5 t/ha, humus from 0.3 to 0.09 t/ha and reduce the ineffective costs of transporting the crop from 626.3 to 187.9 rubles/ha.

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