EXPERIMENTAL STUDIES OF IMPROVED POTATO DIGGER KRK-2 WITH V-SHAPED HEAP DISTRIBUTOR

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Abstract. Potato harvesting is a labor-intensive technological process that affects the losses of production and the degree of cleaning the tubers. We have improved the design of the KRK-2 potato digger with a V-shaped heap distributor. The purpose of this work was to find the influence of a V-shaped heap distributor upon the quality indicators of harvesting, and to determine rational design and technological parameters. On the basis of the developed methodology experimental dependences of the influence of the parameters of the distributor upon the contamination of the potato heap and damage to the tubers were obtained. By the results of these calculations it was found that the gap between the conveyor and the distributor has the greatest influence upon the weediness of the heap. To a less degree this process is influenced by the distance of the bar drums to the distributor and the opening angle of the distributor wing. The parameters of the distributor significantly affect the intensity of the process of separating the soil impurities from the potato heap since, when varying the variable parameters, the weediness value changes 7.6 times. It was determined that the minimum value of the soil content index will be at a distance L = 0.55-0.6 m. When the distances L are reduced, the soil content increases because, due to the small distance, a heap accumulates in front of the distributor, which leads to deterioration of the distribution process of the heap across the width of the conveyor.

Key words: potatoes, harvesting, separation, cleaning quality, damage.

Introduction

Potatoes are a widespread agricultural crop, used for food and industrial purposes. The most complicated and time-consuming operation in the production of potatoes is their harvesting [1-2]. In many cases the harvesting process is complicated by high humidity and the heavy soil texture (for example, loamy soils). The investigations, carried out in various countries to improve the potato harvesting machines, are aimed primarily at improving the quality indicators of cleaning the potato tubers and reducing their damage [3-4].

The problem of improvement is somewhat complicated by the fact that there is a wide variety of potato harvesters (they are produced in almost every country) and each of the machines has advantages in certain soil and climatic conditions, as well as disadvantages. The problem how to improve the quality indicators of the performance of the potato harvesters is a topic of research of many scientists [5-7]. In particular, there was studied the influence upon the degree of cleaning of the tubers of the distance between the slats of the conveyor, the magnitude of the vibration of the support rollers of the conveyor, the angle of inclination, and other parameters. However, the impact of distribution of potatoes along the width of the conveyor upon many design solutions of machines has not been studied fully enough.

Experimental studies [8] have shown that the intensification of the separation process utilizing uniform distribution of the heap across the width of the elevator web can improve the quality of the results seen in the use of the potato harvester.

We have improved the design of the KRK-2 potato digger by supplementing it with a V-shaped heap distributor) [9], which provides a more uniform distribution of the mass of soil with potatoes along the width of the conveyor. However, such a design needs optimization of the existing set parameters.

The aim of this work was to study the influence of the V-shaped heap distributor upon the quality indicators of harvesting, and to determine its rational design and technological parameters when installed on the KRK-2 potato digger.

Materials and methods

The quality of the performance of the potato harvester depends on the conditions of the process, namely: the type, density and moisture of the soil, its mechanical composition, the weediness of the field, the agricultural technology of growing potatoes in this field, the condition of the tops, the yields of the potatoes (Tabl.1). Therefore, these indicators were fixed before the start of the study according to a standard methodology [10-11].

The object of the experimental research is an improved separating working body of the potato harvester, its components and the components of the potato heap. The digging-separating working body can be represented as a "black box" [12], where the input parameters are the design, kinematic and technological parameters of the working body, and the initial parameters are the quality indicators of its work.

Table 1

Conditions of research

Name of the indicator	Value of the indicator
Type of soil and name by its mechanical composition	loamy chernozem
Relief:	
- transverse slope, º	2.0
- longitudinal slope, º	1.5
Microrelief	levelled off
Soil moisture, % in layers, cm:	
-from 0 to 10	13.6
-from 10 to 20	14.2
-from 20 to 30	15.3
Soil hardness, MPa	1.142
Air temperature, º C	18
Contamination of the plot with weeds, g m^{-2}	170.2

Based on theoretical investigations, it was established [9; 12-14] that the main parameters that most significantly affect the quality of the technological process of distribution of the heap along the width of the conveyor, and therefore affect the completeness of separation, are the following parameters of the distributor: the opening angle of the wings is 2α, the distance between the bar drums and the distributor – L, the gap between the conveyor and the distributor – Δ. To determine the rational parameters of the distributor, it is necessary to investigate the influence of the parameters of the distributor upon the contamination of the potato heap with the soil impurities.

As the criterion for evaluation of the impact of these parameters upon the quality of the machine the indicator of contamination of the tubers with the soil impurities was taken, which is defined as the ratio of the mass of the soil elements of the heap to the total mass of the heap at the output of the potato harvester.

Taking into account the results of the theoretical and experimental investigations [12-13], a specimen of a two-row potato digger KRK-2, equipped with a combined digging-separating working body, was made (Fig. 1). The basis of the improved design was the KRK-2 serial potato digger. The potato digger KRK-2 is designed for digging potatoes, separating soil from the tubers and laying them on the field surface. The machine is designed to work on all types of soil, including the difficult loamy soils with a moisture content within the range of 10-27%.

The experimental potato digger consists (Fig. 2) of the frame 4, track rollers 3, ploughshares 11, bar drums 10, the main conveyor 5, the distributor 6, the topping device 7, a cascade conveyor 8, the support wheels 9, the hitch 1, a mechanism for driving the working bodies 2 and the cutting discs 12.

The previous theoretical analysis showed that the main factors that affect the quality of the heap distribution process and the completeness of separation are the following parameters of the distributor:

- the opening angle of the distributor wings - 2α;
- the distance between bar drums and the distributor – L;
- the gap between the conveyor and the distributor – Δ.

Fig. 1. **General view of the experimental potato digger KRK-2 in operation**

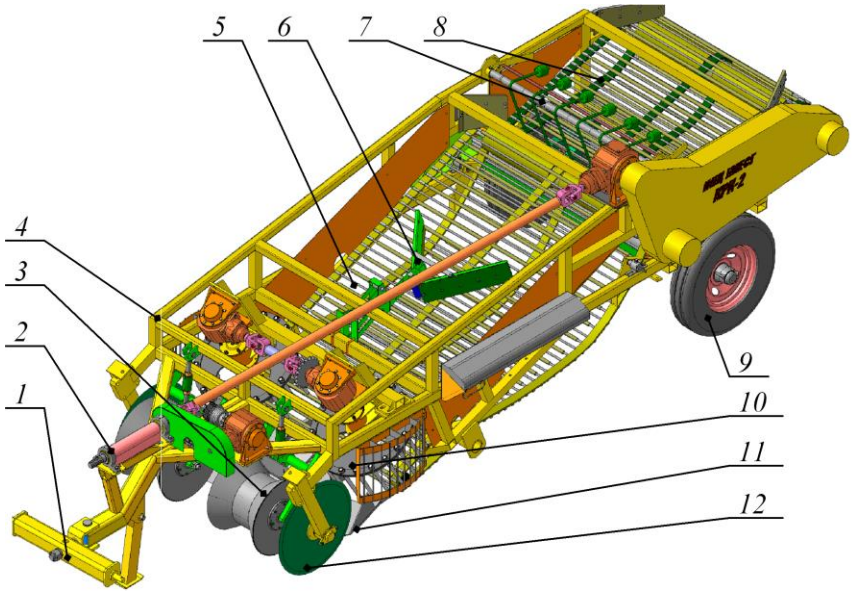

Fig. 2. **General view of the experimental potato digger KRK-2:** 1 – towing device (hitch); 2 – drive mechanism; 3 - track roller; 4 – frame; 5 – main conveyor; 6 – distributor; 7 – topping device; 8 – cascade conveyor; 9 – support wheel; 10 – bar drum; 11 –plowshare; 12 – cutting disc

The results of processing the obtained experimental data are presented in the form of a regression equation of the technological process of the distributor, which links the parameters of the working body with the quality of performance. The equation (1) has the form of a polynomial of the second degree (the probability level $P = 0.80$, *tα-critical* = 1.302):

$$Z = 39.4 + 3.74L\text{-}0.24\alpha\text{-}13.78\Delta\text{-}0.05L^2 + 0.84\Delta^2, \quad (1)$$

where Z – infestation of the tubers with the soil impurities, %;
L – distance from the drums to the distributor, cm;
α – distributor wing opening angle, deg;
Δ – gap between the conveyor and the distributor, cm.

Results and discussion

The results of the experimental investigations are presented in the form of graphs in Fig. 3-4, which show the influence of the main parameters of the distributor upon the indicator of contamination of the tubers with the soil impurities.

As evident from the graphs in Figs. 3-4, the dependence of contamination of the tubers upon these factors has a parabolic character, respectively, with steeply increasing curves for the dependence of the

contamination upon the gap between the conveyor and the distributor Δ, and steeply falling curves for the dependence of the contamination upon the distance between the drums and the distributor *L* (Fig. 3-4).

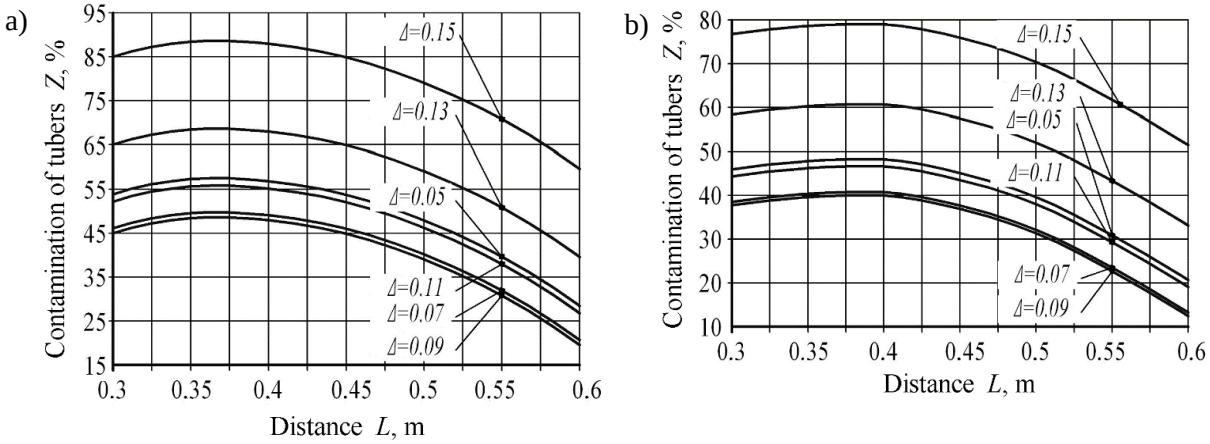

Fig. 3. **Dependence of contamination of the tubers with impurities upon the distance between the drums and the distributor L, and the gap between the conveyor and the distributor Δ:**
a, b – the opening angle of the wing of the distributor *α*, respectively, 15° and 45°

The graphs in Figs. 3-4, which characterize the dependence of contamination of the tubers with the soil impurities upon the distance between the drums and the distributor *L*, show that the minimum value of the soil content indicator will be at a distance L = 0.55-0.6 m. At reduced distances *L* the soil content increases because, due to the small distance, the heap accumulates in front of the distributor, which leads to a deterioration of the distribution process of the heap along the width of the conveyor. At a distance $L < 0.3$ m, violation of the technological process occurs since the movement of the heap flow in the space between the drums and the distributor will stop, which leads to the stop of the aggregate.

Influence of the working body upon the damage of the tubers was also studied. It was found that the value of damage to the tubers in all experiments was, on average, within 2.8-3.1%. When the machine was operating without a spreader, damage to the tubers was about 3.0%.

Table 4 shows the results of investigations of the experimental specimen of the potato digger.

Analysis of the results of the laboratory and field investigations, presented in Table 2, shows that, according to the performance quality, the KRK-2 potato digger meets the agrotechnical requirements. With a ploughshare travel depth of 21.4 cm and the tuber depth of 18.3 cm, the losses of the tubers were 2.5%, and the damage was 4.8%, which corresponds to the indicators, allowed for agricultural requirements. The use of a distributor reduces the losses of the tubers to 0.8%.

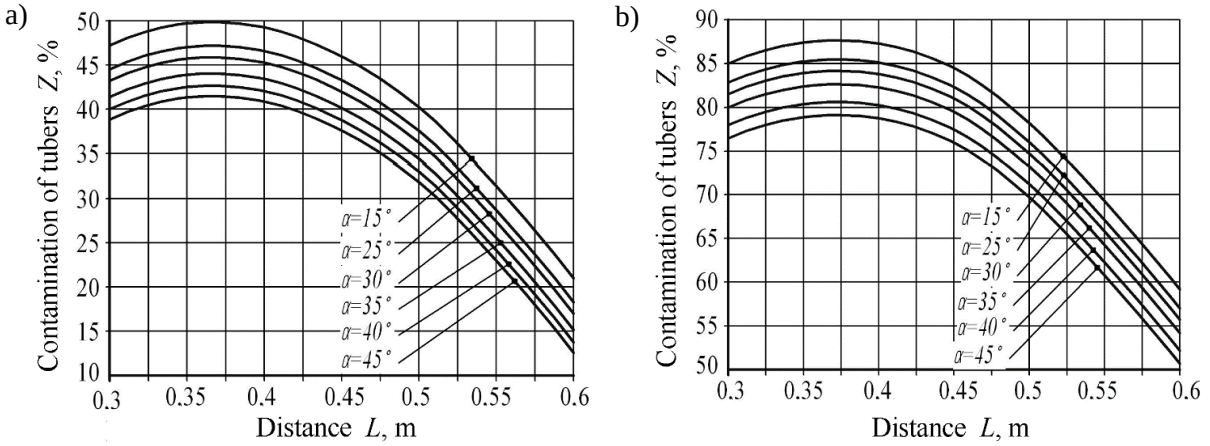

Fig. 4. **Dependence of contamination of the tubers with impurities upon the distance between the drums and the distributor L, and the opening angle of the distributor wing *α*:**
a, b – gap between the conveyor and the distributor Δ, respectively, 0.08 m and 0.15 m

Table 2

Quality indicators of digging the tubers by means of the potato digger

Name of the indicator	Value of the indicator		
	Experimental potato digger with a distributor	Serial machine	According to agro-requirements
Operating speed, km·h^{-1}	2.1	2.1	2-4
Depth of the plowshares, cm	21.4	21.4	< 25
Losses of the tubers, %	0.8	2.5	< 3%
Damage to the tubers by mass (weight), %	4.8	4.8	< 7%
- peeled skin from 1/4 to 1/2 of the surface of the tuber	1.2	1.2	-
- peeled skin more than 1/2 of the surface of the tuber	0.1	0.1	-
- pulling out the pulp to a depth of more than 5 mm	0.9	0.9	-
- cracks longer than 20 mm	1.0	1.0	-
- flattened (crushed) tubers	0.6	0.6	-
- cut tubers	1.0	1.0	< 1.5%
Width of the strip of the dug out tubers, cm	110.0	58.0	-

Conclusions

1. The potato digger KRK-2, equipped with the developed combined digging-separating working body, provides better performance of the technological process. At the same time, in the experiments the losses of the potato tubers were 0.8%, and in the variant without a distributor, they were 2.5%. The tuber damage did not exceed 4.8%.
2. It was determined that the minimum value of the soil content index will be at a distance L = 0.55-0.6 m. When the distances L are reduced, the soil content increases because, due to the small distance, a heap accumulates in front of the distributor, which leads to deterioration of the distribution process of the heap across the width of the conveyor. At a distance L < 0.3 m violation of the technological process occurs, since the movement of the heap flow in the space between the drums and the distributor will stop, which leads to the stop of the aggregate.

Author contributions

Conceptualization, V.B.; methodology, S.I. and V.A.; software, F.S.; validation, Y.I. and V.K.; formal analysis, V.B, S.I. and. Y.I.; investigation, V.B., S.I., V.A. and Z.R.; data curation, Z.R., V.B. and V.K.; writing—original draft preparation, V.B.; writing—review and editing, Z.R. and V.B.; visualization, Y.I..; project administration, V.B.; funding acquisition, S.I. All authors have read and agreed to the published version of the manuscript.

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