Research of the Possibilities to Improve the Quality of Potatoes Harvesting by Including an Experimental Heap Leveler-Distributor in the Design of Harvesting Machines

Semjons Ivanovs, Volodymyr Bulgakov, Simone Pascuzzi, Valerii Adamchuk, Viktor Kornuchin, Zinovii Ruzhylo, Oleksandra Trokhaniak, Janusz Nowak, Zbigniew Kiernicki, Francesco Santoro, and Oksana Bulgakova

Abstract Improving the quality indicators of the operation of potato harvesters under difficult soil and climatic conditions is an urgent scientific and practical task. The paper reflects a research of the impact upon the quality of operation of two kinds of potato diggers of an experimental design for additional levelling of a heap (mass of soil, potato tubers, plant residues, etc.) on the conveyor. This device evenly distributes the potato heap along the plane of the main rod elevator, improves the separation conditions, reduces the total loss of tubers from 2.5 to 0.8%, that is, 3.1 times. A rational mode of operation of the digger has been determined, which, under these conditions, provides acceptable values for the losses and damage to the tubers.

Keywords Potatoes · Harvesting · Tuber purity · Damage · Additional devices

S. Ivanovs
Latvia University of Life Sciences and Technologies, Jelgava, Latvia

V. Bulgakov · Z. Ruzhylo · O. Trokhaniak · O. Bulgakova
National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine

S. Pascuzzi · F. Santoro (✉)
Department of Agricultural and Environmental Science, University of Bari Aldo Moro, Bari, Italy
e-mail: francesco.santoro@uniba.it

V. Adamchuk · V. Kornuchin
Institute of Mechanics and Automation of Agricultural Production of the National Academy of Agrarian Sciences of Ukraine, Kyiv, Ukraine

J. Nowak
Department of Operation of Machines and Management of Production Processes, University of Life Sciences in Lublin, Lublin, Poland

Z. Kiernicki
Lublin University of Technology, Lublin, Poland

S. Pascuzzi and F. Santoro (eds.), *Farm Machinery and Processes Management in Sustainable Agriculture*, Lecture Notes in Civil Engineering 289,
https://doi.org/10.1007/978-3-031-13090-8_4

1 Introduction

Potato growing is an important branch of agricultural production in many countries of the world [1–3]. Potato harvesting is the most labor-intensive technological process in potato production [4–6]. Experience of the operation of potato harvesters shows that they do not always ensure high-quality potato harvesting; and they do not provide sufficient reliability of the technological process [7, 8]. The shortcomings are especially pronounced when working on heavy loamy and wet soils. In many countries, for harvesting potatoes in relatively small areas or on waterlogged soils potato diggers are used, which, compared to the expensive potato harvesters, have a smaller number of conveyors and separating devices [9, 10]. Even though such machines are mainly used for harvesting potatoes, intended for consumption in the local market (i.e., not on the large commercial potato farms), they have a large numerical distribution; and improvement of their designs is of current importance. To reduce losses and obtain tubers of the required purity under difficult working conditions on such machines, it is necessary to work at low speeds and carry out post-cleaning of the crop at the potato sorting stations, which leads to increased cost of potato production since it requires significant additional labour, including manual labor [11–13].

There are works of many scientists, devoted to the problem how to improve the quality and productivity of the potato harvesters [14–17]. However, the problem of improving the quality of potato harvesting in many countries is still relevant. One of the promising types of potato diggers that provide a higher quality of harvesting under difficult conditions are machines equipped with additional active rod rotors [18]. Yet in the process of their operation the supply of a mass of soil with tubers (heap) is observed in the central part of the rod separator-conveyor; and a layer of heap, uneven in thickness, is created (a mixture of soil, tubers, leaves of tops and weeds, etc.), (i.e. in the central parts of the thickness of this layer is greater. Obviously, due to this uneven layer the soil separation will not be optimal. Therefore, a device is needed that ensures the creation of a more uniform layer of soil with the tubers on the conveyor. At the same time, introduction of additional elements of impact upon the potato tubers into the structure may increase injuries to the tubers. Therefore, in such cases, a wider study of the impact of an additional device upon the quality indicators of potato harvesting is required.

The purpose of this work is to study the impact upon the quality of potato harvesting using an experimental design of a heap leveler-distributor, located above the supplying conveyor.

Fig. 1 An experimental potato digger KTH type from impurities during its operation

2 Materials and Methods

Investigations of digging and cleaning potatoes from impurities were conducted with two kinds of experimental potato harvesters: a two-row mounted potato digger (variant A) (Fig. 1), and a trailed two-row potato digger-loader (variant B) (Fig. 2).

Fig. 2 Advanced design of a double-row experimental potato digger-loader (equipped with a heap leveler-distributor)

In both cases, the machines had bar cleaning drums with a diameter of 570 mm (frequency of rotation – 57 rpm), which improved the separation of soil from tubers; yet they created an uneven layer of the potato heap on the inclined conveyor (UA 63436A). In both versions the technological scheme included an experimental heap leveler-distributor, installed above the supply conveyor of the potato harvester (at a height of 15 cm) (Fig. 3).

This device was easy-to-remove, and it allowed conducting comparative experiments on harvesting potatoes both with and without a leveler-distributor.

The mounted experimental potato digger of the KTH type has a working width of 1.4 m (2 rows). Its operating speed is – 2.0…2.5 km h^{-1}, the maximum travel depth of digging shares is 0.27 m, productivity is 0.28…0.0.35 ha h^{-1}, its mass is 1500 kg.

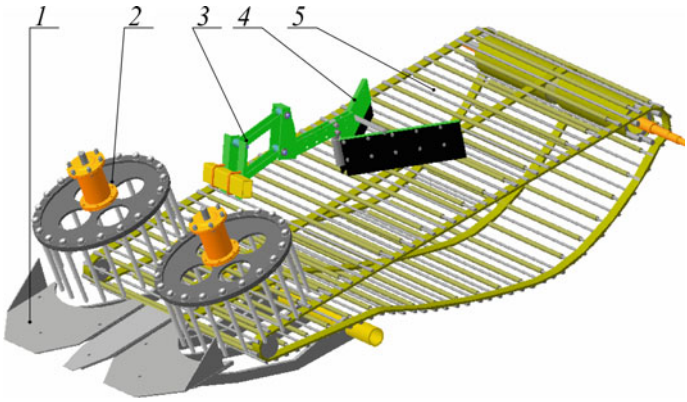

Fig. 3 General view of the experimental digging-separating body of the potato digger: 1 – the digging shares; 2 – the bar separating drums; 3 – a mechanism for installing the heap distributor; 4 – the distributor of a V-shape type; 5 – the supplying bar separating conveyor

The potato digger consists of a frame, track rollers, plough shares, bar drums, the main supply conveyor, a leveler-distributor, a haulm-separating device, a cascade elevator, a mechanism for driving the working bodies and the cutting discs. After the passage of such a digger the potato tubers remain on the surface of the field, and then they need to be manually picked, or a special picking machine must be used for this purpose.

The trailed double-row experimental potato digger-loader has a similar design at the stage of digging and primary separation, but then, at the exit, it has a system of conveyors for the supply of tubers directly into the body of a transport trailer (moving along it). Considering that this option has more conveyors, the process of separation from the soil in it is more intense, and therefore it was important to evaluate the efficiency of the leveler-distributor and to determine whether it is needed in this option. A brief description of the trailed double-row potato digger-loader: it harvests potatoes from two rows (the working width 1.4 m) and ensures loading the tubers into the body of the nearby vehicle; the operating speed – 1…6 km h^{-1}, the maximum travel depth of the digging shares – 0.25 m, efficiency – 0.45…0.0.65 ha h^{-1}, weight 3500 kg. When conducting experimental studies of the new cleaner, potatoes of the Nevsky variety were harvested, cultivated on ridges (beds) with a row spacing of 70 cm. When harvesting the tubers, the tops were previously mowed, the average height of the ridges was 19.2 cm, the average depth of the lower tuber was 18.2 cm, and the width of the ridges was on average 22 cm. The mass ratio of tubers by fractions was: 52.9% up to 50 mm including, 17.6% from 50 to 80 mm including, and 29.5% more than 80 mm. The conditions under which the tests were carried out were typical for heavy soils, the soil hardness in the layer of the tubers was from 1.4…3.0 · 10^6 N m^{-2}. The type of soil is loamy chernozem with a flat relief. Soil moisture content in the layers was 16.1…17.0%, The quality characteristics of work were determined at the operating speeds of 3.2…4.8 km h^{-1}, the air temperature during the potato harvesting was 10° C. The plot was covered with weeds and haulm residues (1.56 t ha^{-1}). Overall, during the experimental studies the potatoes were harvested on an area of 10.1 ha. When the leveler-distributor is on, the impurities amount in the second elevator is much less than when the leveler-distributor is off. This leads to an improvement in the purity of tubers in the containers. Standard methods were used during the investigations for testing the potato harvesters [19–21], as well as additionally developed methods for assessing the influence of various factors. The quality of harvesting the potatoes by machines in Ukraine and other countries of Eastern Europe is regulated by the so-called agricultural requirements [14] which define the criteria and their minimum values that the machines must satisfy from an agronomic point of view.

3 Results and Discussion

The quality indicators of work of the potato digger with a heap leveler-distributor were determined at an operating speed of 2.1 km h^{-1}. Table 1 shows the results of studies of an experimental sample.

Figure 4 shows the results of investigations of the loss of the potato tubers and the degree of their damage when digging out with a potato digger, equipped with the new cleaner from impurities.

When changing the depth of the plough shares h at a working speed $V = 2.1$ m s^{-1} from 20 to 22.8 cm, the loss L of the potato tubers increases by 16…18%, and their damage D decreases by 8…10%. When the plough share travel depth is 21.4 cm and the tuber depth is 18.3 cm, the loss of tubers was 2.5%, and the damage was 4.8%, which is within the acceptable limits. The quality of work was significantly affected by the heap leveler-distributor, which, when put into operation, evenly distributed the potato heap along the plane of the main rod elevator, improved the conditions for separating the heap, reduced soiling of the tubers, which made it possible to reduce the total loss of tubers from 2.5 to 0.8%, that is, in 3.1 times. Sprinkling of tubers with

Table 1 Quality indicators of tuber digging, using a potato digger (variant A) with an experimental heap leveler-distributor

Name of the indicator	Value or characteristic according to agricultural requirements		
	With a leveler-distributor	Without a leveler-distributor	According to requirements
Working speed, km h^{-1}	2.1	2.1	2…4
Depth of the share travel, cm	21.4	21.4	up to 25
Losses of tubers, %	0.8	2.5	up to 3%
Damage to tubers by mass (weight), %	4.8	4.8	up to 7%
Number of the damaged per 100 tubers, pcs.:			
– the peel torn off from 1/4 to 1/2 of the surface	2	2	–
– the peel torn off more than 1/2 of the surface	0	0	–
– the mass torn out more than 5 mm	2	2	–
– cracks longer than 20 mm	1	1	–
– compressed tubers	2	2	–
– cut tubers	1	1	up to 1.5%
Strip width of the dug out tubers, cm	110.0	58.0	–

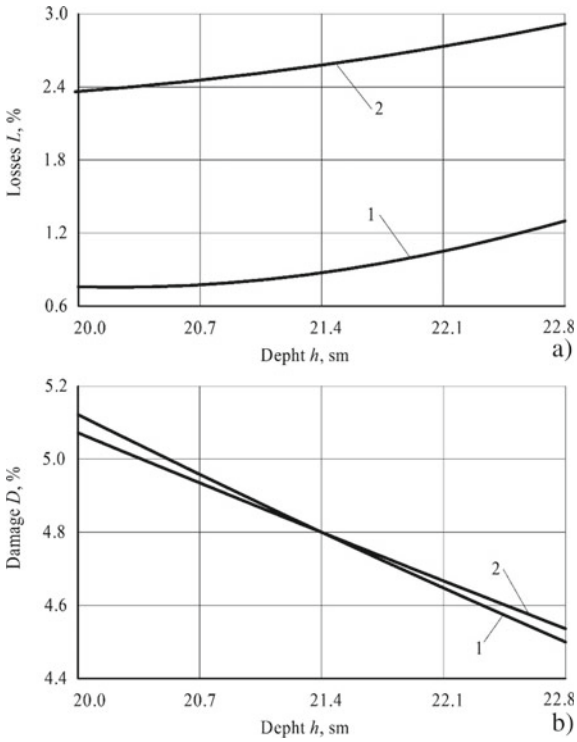

Fig. 4 Graphical dependences of the degree of losses of the potato tubers L **a** and their damage D **b** during digging by a potato digger (variant A) at the depth of the plough shares h at a working speed V = 2.1 m s^{-1}: 1 – with a heap leveler-distributor; 2 – without a heap leveler-distributor

the soil is reduced, which leads to an increase in the efficiency of workers-potato diggers. A rational mode of operation of the digger has been determined, which, under these conditions, provides acceptable values for the losses and damage to the tubers. At a speed of the aggregate 2.1 km h^{-1} the labour efficiency was 0.29 ha h^{-1}. To the quality of work, the experimental potato digger basically meets the agricultural requirements (Table 2).

Figure 5 presents the results of studies of the degree of the loss of the potato tubers, their damage and the purity of potatoes when dug up by a two-row potato digger-loader.

Table 2 Performance indicators of a two-row experimental potato digger-loader (variant B)

Name of the indicator	Value of indicators	
	Without a leveler-distributor	With a leveler- distributor
Working speed of travel: km h^{-1}	2.8…3.6	3.2…4.8
Digging depth, cm	19.3	19.3
Purity of potato cleaning, %:		
– Tubers	85.8	97.4
– Free soil	2.2	0.9
– Soil clods (up to 50 mm in size)	11.8	1.7
– Vegetable admixtures	0.2	0
Completeness of collection of the tubers, %:		
– Collected in a container	98.6	99.4
– Left on the surface	1.4	0.6
– Total loss, % kg	1.4 340	0.6 146
Damage to the potato tubers, %:		
– Total	4.6	4.6
– Tubers cut by the plough shares	1.6	1.6
– Cracks on the tuber surface more than 20 mm long	0.8	0.8
– Turn out crumbs, more than 5 mm deep	2.2	2.2
– Piece by piece (from 100 tubers)	6.0	6.0

When changing the depth of the plough shares h at a working speed $V = 3.2$ m•s^{-1} from 17.9 to 20.7 cm, the loss L of potato tubers increases by 12–15%, and their damage D decreases by 6–8%. A positive effect of the heap leveler-distributor on the quality of the machine: the purity of tubers in the container reached 97.4% (without the leveler-distributor it was 85.8%) at a digging depth h = 19.3 cm. That is, the use of a leveler-distributor increases such an important indicator of the operation of the potato harvester as the purity of tubers in the container by at least 10%.

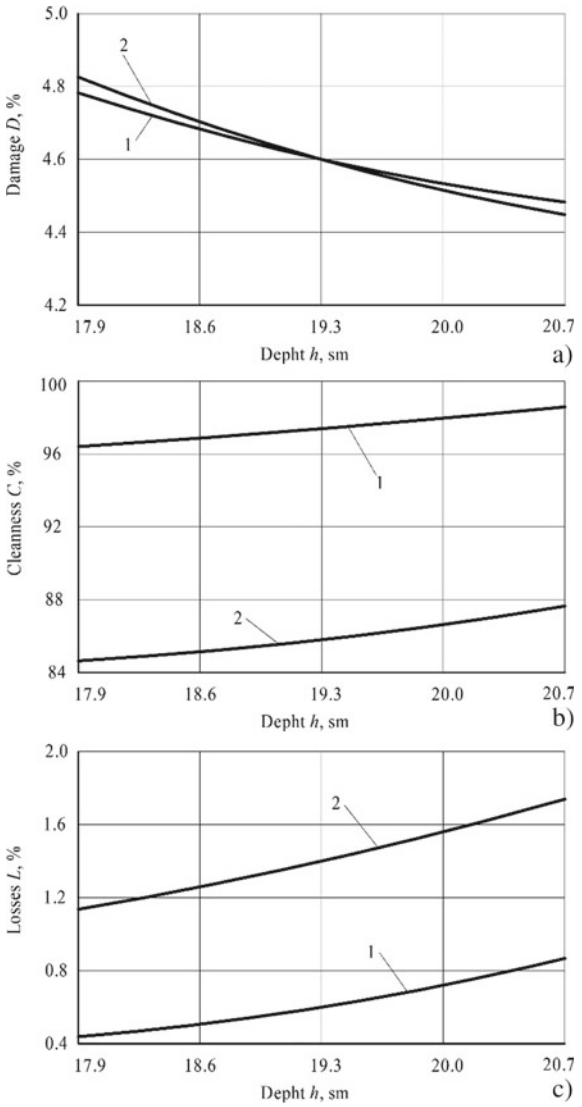

Fig. 5 Dependences of the degree of losses L of the potato tubers **a**, their damage D **b** and the purity of potatoes C **c** when digging by potato digger-loader (variant B), equipped with a new cleaner, from the depth of digging h at a working speed $V = 3.2$ m s^{-1}: 1 – with a heap leveler-distributor; 2 – without a heap leveler-distributor

4 Conclusions

Inclusion of a heap leveler-distributor into the potato harvesters of the considered design significantly improves the quality of potato harvesting.

The potato digger with a heap leveler-distributor, located above the supply conveyor, when harvesting potatoes with a yield of 30.6 t h^{-1}, reduces the losses of tubers by 31%, when using a leveler-distributor, and 2.5% without a leveler-distributor, while damage to the tubers was 4.8%.

Experimental digger-loader with a heap leveler-distributor ensures the completeness of collection of the tubers – up to 99.4%, while the purity of the tubers in the container is 97.4% (without the leveler-distributor – 85.8%) with an acceptable damage to the tubers of 4.6%.

References

1. Adamchuk V, Prysyazhnyi V, Ivanovs S, Bulgakov V (2016) Investigations in technological method of growing potatoes under mulch of straw and its effect on the yield. Eng Rural Dev 15:1098–1103
2. Bulgakov V, Pascuzzi S (2021) Mathematical model of the movement of a potato body along the surface of a spiral separator. Acta Hortic 1311:447–454. https://doi.org/10.17660/ActaHortic.2021.1311.57
3. Pascuzzi S, Bulgakov V (2021) The theory of sifting the soil mass when cleaning potatoes on a spiral separator. Acta Hortic 1311:417–424. https://doi.org/10.17660/ActaHortic.2021.1311.53
4. Bulgakov V, Pascuzzi S, Ivanovs S, Nadykto V, Nowak J (2020) Kinematic discrepancy between driving wheels evaluated for a modular traction device. Biosys Eng 196:88–96. https://doi.org/10.1016/j.biosystemseng.2020.05.017
5. Bulgakov V, Pascuzzi S, Adamchuk V, Ivanovs S, Pylypaka S (2019) A theoretical study of the limit path of the movement of a layer of soil along the plough mouldboard. Soil Tillage Res 195:104406. https://doi.org/10.1016/j.still.2019.104406
6. Pascuzzi S, Anifantis AS, Santoro F (2020) The concept of a compact profile agricultural tractor suitable for use on specialised tree crops. Agriculture 10:123. https://doi.org/10.3390/agriculture10040123
7. Bulgakov V, Pascuzzi S, Ivanovs S, Ruzhylo Z, Fedosiy I, Santoro F (2020) A new spiral potato cleaner to enhance the removal of impurities and soil clods in potato harvesting. Sustainability (Switzerland) 12(23):9788. https://doi.org/10.3390/su12239788
8. Bulgakov V et al (2021) Study of the steering of a wide span vehicle controlled by a local positioning system. J Agric Eng LII:1144. https://doi.org/10.4081/jae.2021.1144
9. Bulgakov V, Ivanovs S, Adamchuk V, Ihnatiev Y (2017) Investigation of the influence of the parameters of the experimental spiral potato heap separator on the quality of work. Agron Res 15(1):44–54
10. Vereshchagin N, Pshechenkov K, Gerasimov V (1983) Harvesting potatoes in difficult conditions, p 208. Kolos, Moscow
11. Hevko RB, Tkachenko IG, Synii SV, Flonts IV (2016) Development of design and investigation of operation processes of small-sclale root crop and potato harvesters. INMATEH Agric Eng 49(2):53–60
12. Zavgorodniy AF, Shumilo MM (1986) Combined digging-separating body of potato harvesters. Tech Agric 10:60–61

13. Bulgakov V, Pascuzzi S, Nadykto V, Ivanovs S, Adamchuk V (2021) Experimental study of the implement-and-tractor aggregate used for laying tracks of permanent traffic lanes inside controlled traffic farming systems. Soil Tillage Res 208:104895. https://doi.org/10.1016/j.still.2020.104895
14. Petrov G (2004) Potato Harvesting Machines, p 320. Mashinostroenije, Moskow
15. Ichiki H, Van Nguyen N, Yoshinaga K (2013) Stone-clod separation and its application to potato cultivation in Hokkaido. Eng Agric Environ Food 6(2):77–85
16. Bulgakov V, Pascuzzi S, Beloev H, Ivanovs S (2019) Theoretical investigations of the headland turning agility of a trailed asymmetric implement-and-tractor aggregate. Agriculture 9:224. https://doi.org/10.3390/agriculture910ZS0224
17. Bulgakov V, Pascuzzi S, Adamchuk V, Kuvachov V, Nozdrovicky L (2019) Theoretical study of transverse offsets of wide span tractor working implements and their influence on damage to row crops. Agriculture 9:144
18. UA 63436A: (2004) Digging and separating device of potato harvester. Ukrainian patent
19. Standard DSTU 7794: (2015) Potato harvesters. Test methods. Kyiv, Ukraine, p 14
20. Standard DSTU 7572: (2014) Potato harvesters. General technical requirements. Kyiv, Ukraine, p 8
21. Pascuzzi S, Santoro F, Manetto G, Cerruto E (2018) Study of the correlation between foliar and patternator deposits in a “Tendone” vineyard. Agric Eng Int CIGR J 20(3):97–107