

Comparative study of the force action of harvester work tools on potato tubers

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Citation: Siberev A., Aksenov A., Dorokhov A., Ponomarev A. (2019): Comparative study of the force action of harvester work tools on potato tubers. Res. Agr. Eng., 65: 85–90.

Abstract: The quality of the separation of root crops, onions and potatoes is known to primarily depend on the cultivation conditions. As a rule, these cultures are cultivated in mechanically light soils in order to improve the quality of separation, as well as to reduce the traction resistance of the harvester when extracting the root crops from the soil. When harvesting the root crops, it is very important to maintain the soil in a loose (light) state to improve the quality of the separation. Due to the fact that in digging up the root crops, there is a joint flow of strong soil lumps to the separating working bodies, which are difficult to separate on the slit working bodies of the harvester, which increases damage to the root crops when interacting with the soil lumps, the commercial quality of the products is subsequently deteriorated. The existing potato harvesters damage the commercial products as a result of the interaction of the potato tubers with each other, with the working bodies and with the soil lumps. However, the greatest percentage of damage to potato tubers occurs as a result of their interaction with the working bodies of the harvester. Field studies were conducted to determine the places of the greatest impact of the individual working bodies of the potato harvesters and to carry out subsequent actions for the elimination of these negative impacts in the design of the harvesters. This article presents a methodology for conducting field studies on the assessment of the impact of the working bodies on the scale of damage to potato tubers when harvesting. The results of the comparative studies of the impact of the working bodies of modern potato harvesters, which damage the potato tubers as a result of the interaction with them are presented. We have determined that the greatest scale of impact on the potato tubers during the mechanised harvesting is observed as the transition from the main elevator to the secondary separation devices takes place, irrespective of the design and technological scheme of the harvester, and reaches its minimum value from 6.5 N for the Bolko harvester to 21 N for the AVR-Spirit-6200 harvester.

Keywords: harvesting; force action; potato; work tools; harvester

Potato tuber damage during the mechanised harvest depends on many factors among which the most critical are the design of the potato harvesters (ANIKET et al. 2017), the material of the harvester's work tools and their modes of operation (AKSENOV et al. 2016). No less important are the physical and mechanical properties of the tubers (FARHADI et al. 2012) that, in turn, depend on the product brand (HAVERKORT, STRUIK 2005), the agricultural techniques used (MAYER

et al. 2017), the soil structure (NATENADZE 2016) and the climate.

In order to determine the location and record the value of the most severe force action of a potato harvester on the potato tubers in 2017, as well as to develop recommendations for future changes in the design and engineering parameters of the harvesters, experimental studies using the Electronic Potato Tuber Log software were carried out in the Moscow Region, at Ozery JSC.

MATERIAL AND METHODS

The Electronic Potato Tuber Log software (F.1.02) (Fig. 1) includes: a data logger (1), which has the form, dimensions and density similar to those of a standard potato tuber, a personal computer (2) or a tablet computer (3) with an installed software providing for the processing of the recorded tuber damage data and its subsequent analysis, as well as auxiliary tools (4).



Fig. 1. The general view of the electronic potato tuber log tool

1 – the data logger, 2 – a personal computer, 3 – a tablet computer, 4 – the auxiliary tools

The “electronic potato” makes it possible to record the amount of acceleration, as well as the impact impulse from its interaction with a work tool.

A study to determine the location of the damage to seed onions by the web of an open-web elevator of a potato harvester was carried out at various values of the open-web elevator travel speed V_{el} .

To record the location and time of the damage of the data logger, an Inspector Tornado video recorder (Inspector, China) having a resolution of 960×240 pixels and a diagonal aspect ratio of 150° was installed at the open-web elevator using a laboratory support.

A video recording of the travel path of the data logger along the surface of the open-web elevator is required since it is necessary to match the time periods recorded by the video recorder with the charts generated by the Electronic Potato Tuber Log and, subsequently, to superimpose them in order to determine the location of the largest power action of the open-web elevator on the data logger.

The experimental studies of the force action of the harvester work tools on the potato tubers were carried out on the following potato harvesters: an AVR-Spirit-6200 harvester (AVR, Belgium), a Dewulf RA-3060 harvester (Dewulf, Netherlands) and a Bolko harvester (UNIA, Poland). The procedure of the experimental study is shown in Figs 2–4.

Before the experimental studies, the following physical and mechanical properties of the soil at the record plot were determined: the humidity and hardness (STO AIST 8.7:2013 – Methods for assessing performance indicators).

Studies to determine the impact of the working bodies on the potato tubers in the mechanised harvesting have been carried out on sandy soils with a soil moisture and hardness along the horizons as indicated in Tables 1 and 2.

Table 1. The soil hardness

Amount of experiences	Soil horizons (m)		
	0–0.01	0.01–0.02	0.02–0.03
	hardness (MPa)		
1	0.16	0.47	0.92
2	0.18	0.45	0.95
3	0.21	0.54	1.21
Average value	0.56		

Table 2. The soil moisture over the horizons

Amount of experiences	Soil horizons (m)		
	0–0.01	0.01–0.02	0.02–0.03
	soil moisture (%)		
1	13.4	21.6	24.4
2	17.6	22.4	26.9
3	16.2	24.3	27.3
Average value	21.5		

Before the start of the studies, the process parameters of the potato harvester were set to the optimal modes of operation where the depth of the lifting ploughshare in the soil was set below the depth of the potato tuber heaps, within the range of 0.12 to 0.18 m, which conformed to the tuber panting depth.

During the experimental studies, the travel speed (V_M) of the potato harvester was set to 3 to $5.2 \text{ km} \cdot \text{h}^{-1}$.

The optimal values of the travel speed of the open-web elevator of the studied potato harvesters (V_{el}) were set within the range of 3.6 to $6.4 \text{ km} \cdot \text{h}^{-1}$ to prevent a tuberiferous heap piling up on the surface of the open-web elevator (TAUSEEF ASGHAR et al. 2014).

<https://doi.org/10.17221/96/2018-RAE>

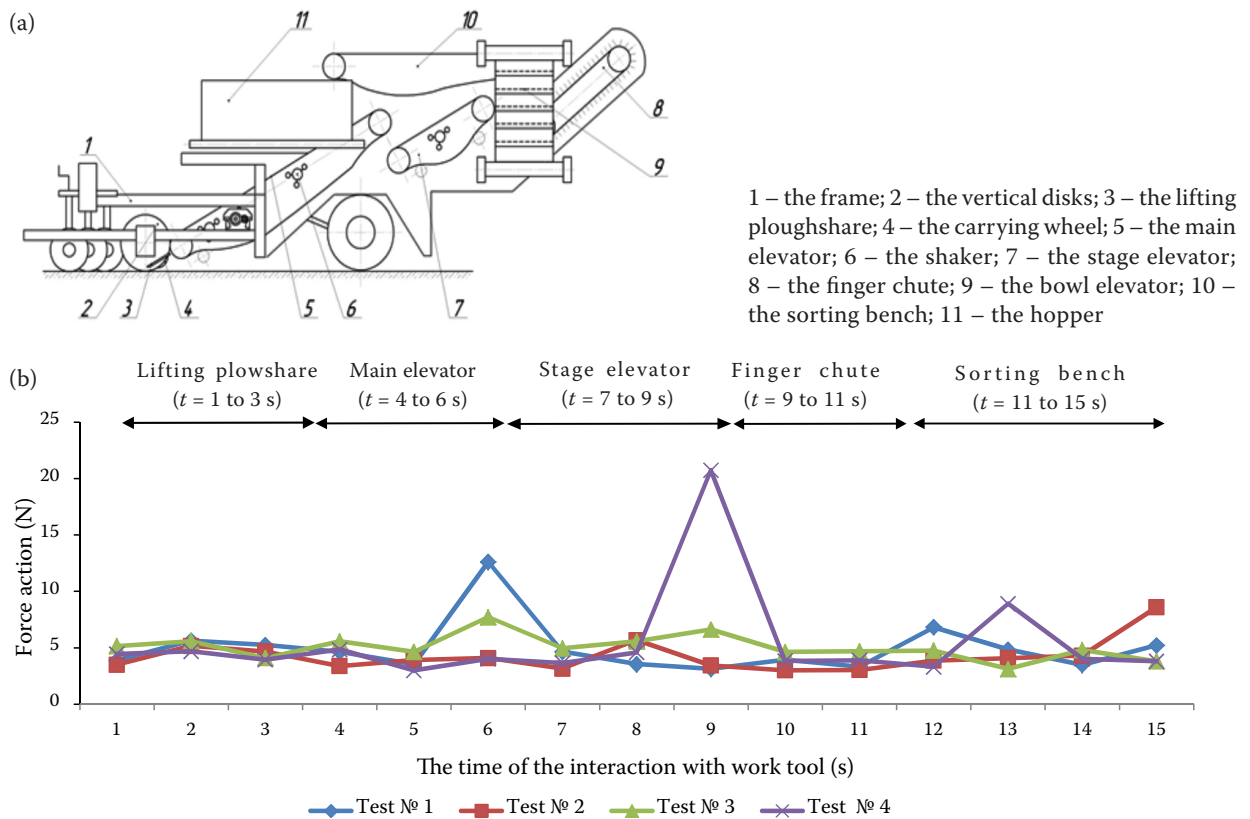


Fig. 2. Design (a) and the flow diagram (b) of AVR-Spirit-6200 harvester

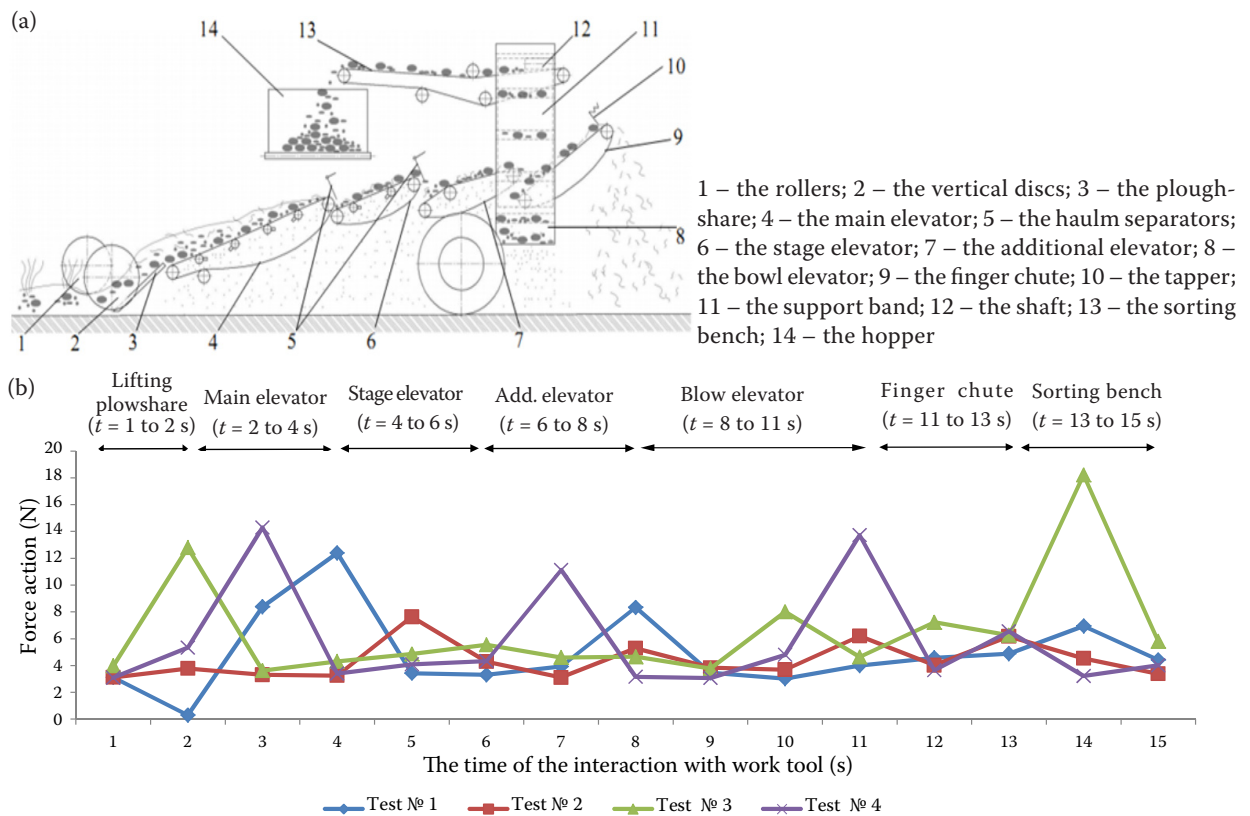


Fig. 3. Design (a) and the flow diagram (b) of Dewulf RA-3060 harvester

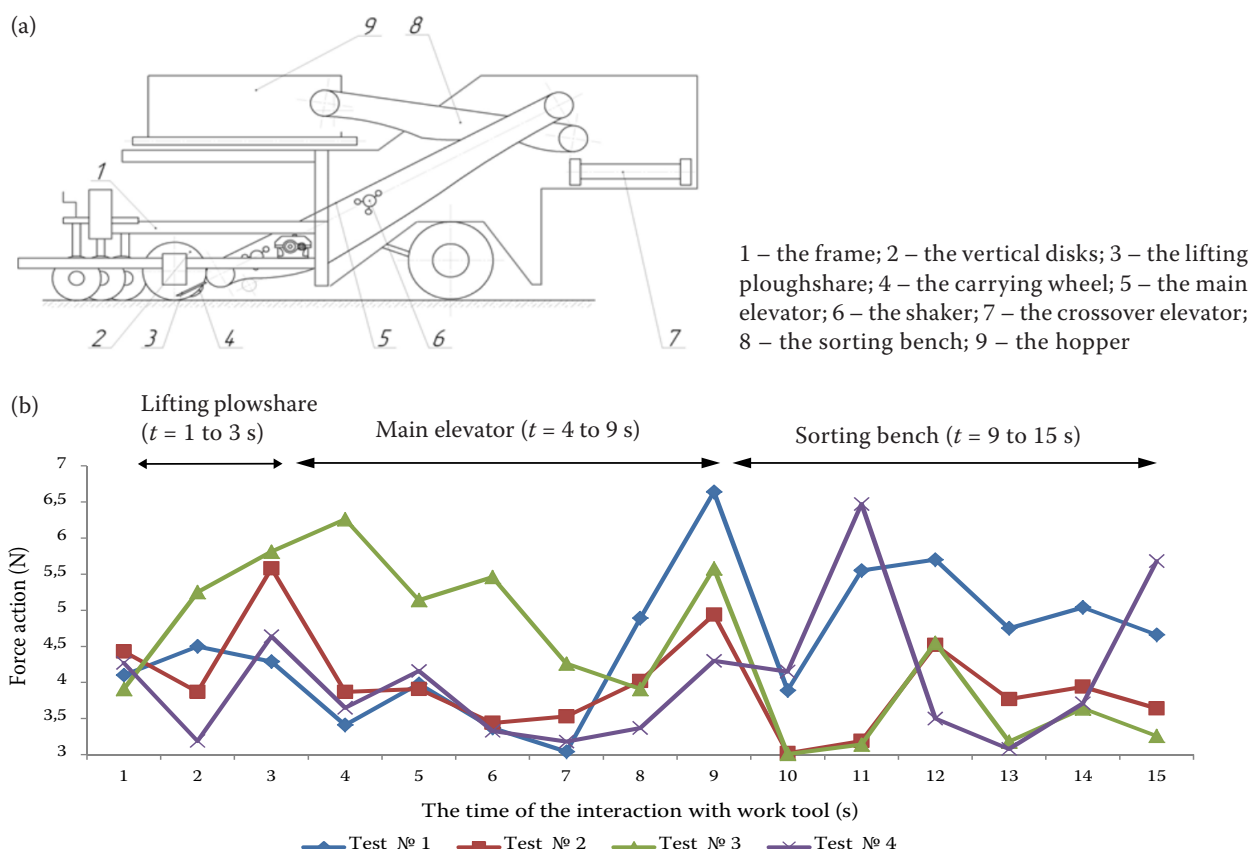


Fig. 4. Design (a) and the flow diagram (b) of the Bolko harvester

After the pre-set mode of movement of the open-web elevator had been achieved, the Electronic Potato Tuber Log was fed from haulm carrying wheel 4.

After the data logger (Fig. 1) had passed over the surface of the open-web elevator, the data logger was switched off, the studied factors were changed and the experiment was repeated in accordance with the adopted plan of studies.

Measurement of the studied parameter – the force impact on the potato tuber – was carried out three times, after which the average values of the mass measurements were used to estimate the variation series. At the same time, the concepts and elements characterising the variation series were used in the generally accepted variation statistics: average variation ($\bar{X}$), standard deviation (σ), variation coefficient (ν). Each of the main elements was determined using variation statistics formulas.

This made it possible to determine the accuracy of the experimental data and to establish acceptable limits, within which they are sufficiently reliable.

To determine the number of intervals (K) of variation in the values of the impact on the potato tuber, we used the empirical dependence (Eq. 1):

$$K = \sqrt{n} \quad (1)$$

where: n – the number of examined bulbs, pcs.

In our case, we get (Eq. 2):

$$K = \sqrt{100} = 10 \quad (2)$$

Sample range (Eq. 3):

$$R = x_{\max} - x_{\min} \quad (3)$$

where: $x_{\max}$, $x_{\min}$ – the maximum and minimum values of the studied feature

The interval width of the studied feature (Eq. 4):

$$D = \frac{R}{K} \quad (4)$$

where: R – sample range, K – the number of intervals

RESULTS AND DISCUSSION

The analysis of the characteristic curves (Fig. 2) generated during the experimental studies of an AVR-Spirit-6200 harvester allows us to conclude that the most severe force action ($F = 20.3$ N) on the potato tubers occurred during the transition

<https://doi.org/10.17221/96/2018-RAE>

from the working surface of the additional elevator onto the finger chute within the time interval of 9 to 11 seconds.

This could be explained by the fact that in the course of the motion of the tuberiferous heap along the separating surfaces of the potato harvester, each subsequent separator receives less soil material as a result of the separation of the haulm by the previous separator.

All this leads to a decrease in the soil „cushion“ between the working elements of the separating working body and the potato tubers, which leads to an increase in the impact on the tubers and an increase in the damage.

Analysing the results of the experimental studies of the force impact on the potato tuber by the working bodies of the AVR-Spirit-6200 harvester, it should be noted that the measured value varies widely depending on the location of the tuber on the functioning element. ($v = 26.9\%$, $\sigma = 5.52$).

The greatest impact (up to 22 N) on the potato tuber is observed in a time interval of 8.5 to 9.5 s (Fig. 2) corresponding to the location of the tuber on the cascade elevator, while $\sigma = 5.7$ and $v = 24.8\%$, respectively.

This circumstance is explained by a decrease in the soil «cushion» between the working surface of the cascade elevator and the potato tubers with the simultaneous impact of the plate vibrators intensifying the commercial products' separation process.

The interpretation of the characteristic curves presented on Fig. 3 obtained during the experimental studies of the Dewulf RA-3060 harvester confirms the following conclusion: just as in the case of the AVR-Spirit-6200 harvester, the highest impact ($F = 18$ N) on the potato tubers was observed during the transition of the sorted products from the bowl elevator onto the finger chute within the time inter-

val of 10 to 11 s, as well on the sorting bench, at the 14th s during the separation of the tuberiferous heap.

Besides that, an increase of the force action during the separation of the tuberiferous heap was observed during the transition from the lifting ploughshare to the main elevator – up to 14 N ($t = 2$ s), as well as at the main elevator itself ($F = 14$ N, $t = 3$ s).

The studied indicator (Fig. 3) varies within a wide range of values and reaches the highest value equal to 18 N at a time interval of 13.5 to 14.5 s ($v = 32.4\%$, $\sigma = 7.6$).

The Bolko S harvester's (Fig. 4) working bodies have the most «gentle» impact on the tuberiferous heap in which the minimum impact on the separated products is observed within the range from 3 to 6.5 N ($v = 28.4\%$, $\sigma = 4.6$) during the entire harvesting process, which is 28–31 % of the maximum impact of working bodies of the AVR-Spirit-6200 and the Dewulf RA-3060 harvesters (Fig. 5).

A comparative analysis of the force action of the lifting and separating work tools providing the initial separation (the main and the stage elevator) on the potato tubers applied by the AVR-Spirit-6200 and the Dewulf RA-3060 harvesters makes it possible to acknowledge that the operating devices of the Dewulf RA-3060 act more intensively on the sorted products (within the range of 12 to 14 N at the lifting and the separating devices of the initial separation, accordingly), which is higher than the force action of the AVR-Spirit-6200 harvester by 8 N (at the lifting work tool) and 9 N (at the main stage elevators).

The Bolko S harvester is the most forgiving in terms of the force action of the work tools on the tuberiferous heap. Throughout the harvesting process, the minimal force action is observed, within the range of 3 to 6.5 N, which is 28 to 31% of the maximum force action of the work tools of the AVR-Spirit-6200 and the Dewulf RA-3060 harvesters (Fig. 4).

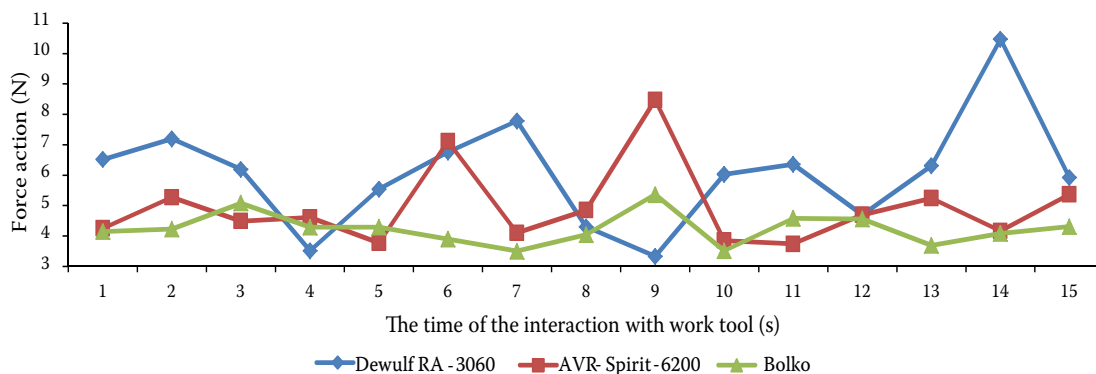


Fig. 5. The comparison of the impact action of the harvester devices on the potato tubers

CONCLUSION

The analysis of the experimental data shown in Figure 5 calls for the conclusion, that during the separation, the tubers interact with the active and passive work tools of the potato harvesters. The tubers fall when passing the shaking section onto the elevator bars, as well as when passing from one elevator to another. This is represented by the above characteristic curves.

At the drops between the different elevators, the tubers fall from a height of no more than 0.2 m, which corresponds to an impact velocity of $1.9 \text{ m}\cdot\text{s}^{-1}$ and conforms with the acceptable impact velocity of the tubers with the work tools ($2.2 \text{ m}\cdot\text{s}^{-1}$).

The impact velocity of the tubers tossed by the elevator bars due to the shaker action is over $2.6 \text{ m}\cdot\text{s}^{-1}$ when the vertical component of the elevator rod speed is $0.7 \text{ m}\cdot\text{s}^{-1}$ and more, which is above the acceptable impact speed of the tubers with the harvester work tools. As a result, the tubers are damaged in this section.

As it can be seen from the above, the analysis of the field studies of the force action of the AVR-Spirit-6200, the Dewulf RA-3060 and the Bolko S potato harvesters work tools calls for the conclusion that the smallest force action on the potato tubers is caused by the lifting ploughshare, which is due to the fact that there is a soil cushion between the work surface of the operating component and the tuber.

The largest force action on the potato tubers is observed at the separating surface of the elevators. This is caused by the action of the various separation enhancers on the tuberiferous heaps, which results in the separation of the mechanical impurities from the mass, as well as in serious damage to the potato tubers.

The good qualities of the potato harvesting process require the theoretical and experimental studies to be aimed at improving the design and process of the operating and separating work tools of the potato harvesters.

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Good quality of potato harvesting process requires theoretical and experimental studies aimed at improvement of the design and process of operation of separating work tools of potato harvesters.

References

- Aksenov A.G., Sibirev A.V., Emelianov P.A. (2016): Technical equipment for vegetable growing. *Tractors and Agricultural Machines*, 8: 25–30.
- Aniket U., Dongre, Battase R., Dudhale S., Patil V. R., Chavan D. (2017): Development of potato harvesting model. *International Research Journal of Engineering and Technology*, 4: 1567–1570.
- Farhadi R., Sakenian N., Azizi P. (2012): Design and construction of rotary potato grader. *Bulgarian Journal of Agricultural Science*, 18: 304–314.
- Haverkort A.J., Struik P.C. (2005): *Potato in progress: science meets practice*. Netherlands. Wageningen Academic Publishers, 365.
- Mayer V., Vejchar D., Pastorková L. (2017): Measurement of potato tubers resistance against mechanical loading. *Research in Agricultural Engineering*, 54: 22–31.
- Natenadze N. (2016): The design and theoretical justification of a vibratory digger shovel. *Scientific Technical Union of Mechanical Engineering Bulgarian Association of Mechanization in Agriculture*, 5: 9–12.
- Tauseef Asghar M., Ghafoor A., Iqbal A.M.M., Choudhary M.A. (2014): Design modification and field testing of groundnut digger. *Asian Journal of Science and Technology*, 5: 389–394.

Received for publication September 15, 2018

Accepted after corrections July 23, 2019

Acknowledgements

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