

Experimental study of an improved root crop cleaner from admixtures

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Abstract. One of the ways to raise the quality of sugar beet harvesting is the use of improved digging tools that are able to dig out root crops from the soil without any loss and considerable damage, as well as cleaners of the heap from admixtures. Perspective are the root crop harvesting machines, built according to the modular principle, where, depending on the state of the beet plantation, the composition of the cleaning tools, and the kinematic and technological modes of their operation are determined. To carry out experimental studies, experimental equipment was made which, under laboratory and field conditions, made it possible to obtain qualitative separation indicators of the heaps of sugar beet roots with wide variation in the range of kinematic and design parameters of the improved cleaner. As the results of the laboratory and field experimental studies showed, in each of the two stages of cleaning the beet heap, a sufficiently high degree of removal of the soil admixtures and plant residues is ensured. Thus, at the first, preliminary stage of cleaning, the removal of admixtures amounted to 65.5–75.8%. After the second, basic stage of cleaning, the transported heap contained no more than 1.9% of admixtures. The results of the laboratory and field tests indicate that the proposed design of an improved sugar beet root cleaner from admixtures is prospective.

Key words: sugar beet, harvesting, cleaning, admixtures.

INTRODUCTION

One of the ways to raise the quality of sugar beet harvesting is the development of new trailed (or semi-trailed) root harvesting machines that would be equipped with digging tools suitable for different soil and climatic conditions, equipped with such improved cleaning implements that provide high-quality cleaning of root crops under any conditions of the beet plantation and that are designed according to the so-called modular principle (Halemendik, 2001; Pogorely & Tatyanko, 2004).

Separators of the beet heap should provide steady and qualitative technological process under heavy harvesting conditions, and at various characteristics of the material to be processed. The systems of the separating tools, often used in the sugar beet harvesters and root harvesting machines, do not always ensure a sufficient level of separation of soil and the plant residues from the beet raw materials (Ivančan et al., 2002; Lilleboe, 2014; Bulgakov et al., 2015). This is due to clogging or sticking of the surfaces of the cleaning tools with moist soil and green plant residues (Lammers et al., 2010; Bulgakov et al., 2014).

Many researchers and designers have worked in order to solve the problem of creating reliable and efficient machines for cleaning beet heap (Smith, 1991; Gevko, 1999; Linnik, 2014). However, in spite of a large number of separate works on the improvement of some technological processes of cleaning the beet and potato heaps (Bulgakov et al., 2017) during harvesting – there are no practical studies on the development and operational testing of the separators of a modular design. Consequently, investigations are necessary in this area for the beet harvesting industry and for solving the problem of cleaning the heap of root crops, in general.

The aim of the study is to determine the quality indicators of cleaning heaps of sugar beet root crops after passing through stages 1 and 2 of the improved cleaner of a modular type, and to evaluate the impact of the rotation speed of the screw upon the soil separation quality from the root crop.

MATERIALS AND METHODS

A new design of improved cleaning and transportation implements was developed, which were installed on the trailed root-harvesting machine MKP-6 (the test samples of which were made according to our drawings at the Ternopil Combine Plant (Zykov, 2010). New cleaning and transportation implements were installed (according to the modular principle) in the middle of the self-propelled root harvesting machine.

As can be seen from the presented diagram of the root harvesting machine, the basic cleaning of the sugar beet roots from the soil admixtures and plant residues takes place inside the cleaning drum formed by the driven auger-type or bar rolls, inside of which there is installed with clearance either a transverse screw conveyor, or a drum with arch-shaped cells.

In order to estimate the cleaning efficiency of the sugar beet roots from admixtures during digging, field equipment was designed and manufactured under factory conditions (see Fig. 1). The main components of this experimental equipment are disk diggers 1 with beaters 2, which are installed on serial root crop harvesters, on the improved cleaning device 3–5 and the loading elevator 6 of a new design. The cleaning device consists of 80 mm diameter screw rollers which form an S-shaped cleaning surface, in the cavity of which there is a transverse screw with a diameter of 650–850 mm conveying the beet roots in the axial direction to the discharge conveyor.

After the experimental installation was made, it was tested under field conditions. The economic tests showed positive results (Bulgakov et al., 2014), which made it possible to make equipment in the future with improved cleaning and transportation implements for carrying out experimental tests in order to find out the quality indicators of the cleaning and transportation devices under various harvesting conditions.

To conduct laboratory and field experimental tests, a methodology was developed for conducting field experiments, including the following:

1. The cleaner was conditionally divided into the first and the second stage of cleaning. The first stage of cleaning consists of auger-type rolls 3 (Fig. 1) that rotate in one direction, the second stage consists of screw rolls 4 that have counter-rotational movement and are located inside an S-shaped (in the longitudinally vertical plane) surface of the large-diameter auger 5.

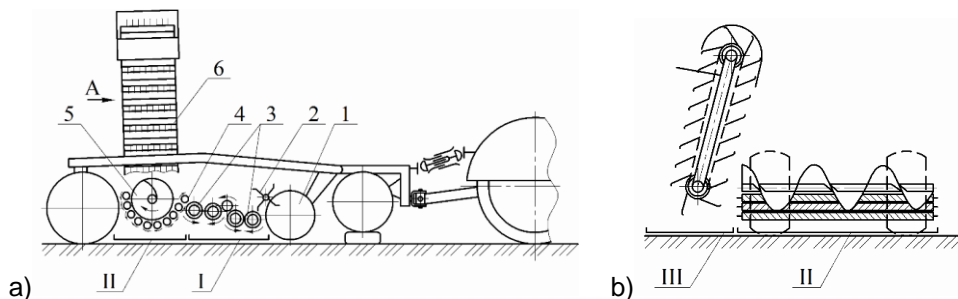


Figure 1. The technological scheme of the laboratory and field experimental equipment (a) and its view A according to arrow (b).

2. The experimental equipment was installed in a stationary manner so that the first stage of cleaning I occupied a horizontal position (see Fig. 1). This was because the root crop of sugar beet, fed as a single specimen, will have a chaotic nature of its movement along the surface of the cleaner (if there is no support for the entire heap), but it needs to be directed along the cleaner to the loading elevator, as it occurs at volume feeding of a heap of root crops to be cleaned. The drive of the operating tools of the experimental equipment was from the power take-off shaft of the tractor which provided conditions for its stable operation.

3. For step-by-step investigation of the cleaning and transportation devices three storage bins (I, II and III) were made (for the first stage of cleaning, for the second stage, as well as for the common discharge of the beet roots from the cleaner) and placed under the cleaning unit. During the laboratory tests, the loading elevator was disconnected from the root-harvesting machine.

4. Massive amounts of soil, together with the root crops, were excavated manually and weighed.

5. When the drive of the root harvester was switched on, the soil masses with the root crops were fed to the first stage of cleaning, opposite the first digger. When the root crops on the cleaner reached the loading elevator, the drive of the operating tools of the machine was switched off. From the storage bins I, II and III, soil and other residues were removed and divided into fractions, each of them being carefully weighed with accuracy to 1 gram, and the measurement data were recorded in a table for their further statistical processing. Further, measurement was made of the cleaning degree of the root crops, fed from the other five diggers.

For laboratory studies the massifs of soil, together with the root crops, were dug out manually, and preliminarily weighed. During these studies, the amount of the screened soil and its remains in the heap were determined.

6. Further investigations were carried out changing the rotation speed of the transverse screw conveyor, which was achieved by means of replacement sprockets of the chain drive.

Experimental field tests of the improved root-harvesting machine were carried out in autumn 2016 at the Ukrainian Scientific Research Institute for Prognostication and Testing of Machinery and Technologies (Kiev Region, Ukraine). During the field tests only the amount of unseparated soil and its quantity on the surface of the root crops were determined.

The necessary number of replications of experiments (N) was determined from the following dependence (Nalimov & Chernova, 1975):

$$N = \text{Integer} \left(\frac{t \cdot v}{\rho} \right)^2 \quad (1)$$

where t – the normalised value of Student's t-test. With a confidence level of 95% ($t = 1.96$); v , ρ – the coefficients of variation and the allowed deviation (the accuracy factor) of the measured parameter.

It is known that for most technical problems it is not necessary to determine the measurement error with accuracy greater than 10% (Venikov, 1986). Proceeding from this, we assumed in the calculations that $\rho = 0.1$.

Previous studies (Halemendik, 2001) have shown that the variation coefficient of the soil screened off during its separation usually does not exceed 12%, that is, the variability of the process is low. Therefore we assumed that $v = 0.12$. As a result, the obtained the following value of the necessary amount of replications of experiments $N = 6$. Thus the investigations were conducted in with a 6-fold replication. At the same time, for each of the six diggers, a pre-weighed mass of the soil with the sugar beet roots was supplied.

For the data obtained during the laboratory-field experimental studies the following statistical characteristics were calculated: the mean value H , g; the mean square deviation σ , g; the coefficient of variation K , %. In this paper approximation of the obtained data by a polynomial of the second degree was carried out, and the Pearson correlation coefficient (R) was calculated (Benjamin & Cornell, 1970; Dospehov, 1985; Tamm et al., 2016).

The data obtained during the laboratory and field experimental tests were statistically processed and presented in the form of graphs.

RESULTS AND DISCUSSION

The results of the efficiency determination of the beetroot cleaner from admixtures are presented in the form of graphs (Fig. 2 and Fig. 3), where the angular speed of the screw rotation is plotted along one axis, the screened and the unscreened soil – along the second axis, which is expressed as percentage of the total soil quantity fed for cleaning and transport devices.

As we can see from the graphs (Fig. 2), the largest mass of residues (65–75%) is separated in the first stage of cleaning. In this case, there is no doubt that the angular speed of rotation of the transverse screw does not significantly affect the cleaning process.

Fig. 3 shows the impact of the angular speed of the screw rotation upon the final quality of cleaning of the sugar beet roots by improved cleaning and transportation implements. These graphs are constructed by measuring the weight of the soil residues that have remained on the heads and bodies of the sugar beet roots at the output of the cleaner.

Figs 2 and 3 showed that, maximum weight of the soil and plant residues after cleaning did not exceed 1.9%. The amount of soil firmly bound with the surface of the sugar beet root did not exceed 2.2% of its total mass. Increasing the angular speed of rotation of the transverse screw reduced the amount of the free soil at the outlet the cleaner. However, increase in the angular speed of the screw, did not lead to improved cleaning of the lateral surfaces of the sugar beet root from the bound soil. Thus, at an angular speed of 22.3 s^{-1} , the amount of the bound soil is only 1.7%, and, increasing the angular speed of rotation to 28.7 s^{-1} , the amount of soil is 2.2%.

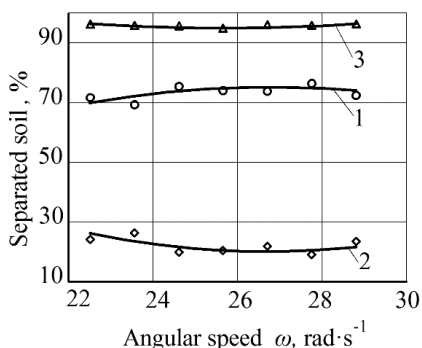


Figure 2. Dependence of the soil sifted off during its separation on the angular speed of rotation of the screw: 1 – the first stage of cleaning ($R = 0.64$); 2 – the second stage of cleaning ($R = 0.68$); 3 – total amount of the separated soil ($R = 0.75$).

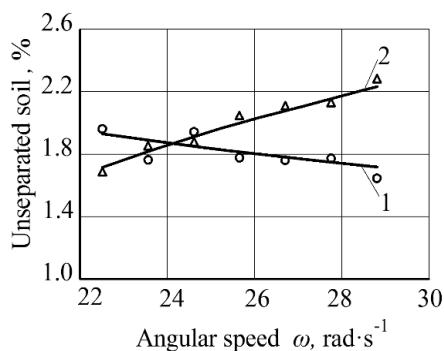


Figure 3. Impact of screw rotation speed upon the separation quality of the soil from the root crop: 1 – the free soil ($R = 0.71$); 2 – the soil bound with the root crop ($R = 0.67$).

The conducted analysis and comparison of the research results under similar conditions of work (Gevko, 1999; Zykov, 2010; Nikitin, 2018) of the root harvesting machines KSP-6; MKP-6, etc. (made in Russia) and the West European firms Holmer, Franz Klein, Agrifak, etc. showed that the quality indicators of their work often do not meet the agrotechnical requirements. For instance, in heavy waterlogged soils (humidity more than 22%), the content of the soil admixtures in the gathered heap reaches 20%. Besides, more than 70% of the soil is in a cohesive state.

Consequently, the improved cleaning and transportation operating tools of the MKP-6 root crop harvesting machine point to a significant advantage over the existing cleaning devices of serially produced root crop harvesting machines because the total number of residues in the heap of the collected root crops did not exceed 3.9%.

Such a combination of the cleaning and transportation tools made it possible to efficiently perform cleaning of the heap of root crops, both from the soil and plant admixtures. So, the counterrotating rolls effectively seize and remove from the heads of root crops the residues of the haulm. They also grab and separate other plant residues. A large-diameter auger, which conveys the root crops in an axial direction, provides

effective cleaning of the lateral surfaces of the root crops from the stuck soil. Together with the small-diameter screw conveyors it creates significant relative movements for sugar beet roots, which essentially affects the duration of their contact with the surfaces of the cleaning operating tools.

CONCLUSIONS

Operational tests and field studies of the experimental sugar beet root cleaner from admixtures (according to the developed program and methodology) showed a higher efficiency of the machine in contrast to the existing commercial machines. The majority of the residues (65–75%) was separated in the first stage of cleaning while the total amount of residues in the heap of the collected root crops did not exceed 3.9%.

REFERENCES

- Benjamin, J.R. & Cornell, C.A. 1970. Probability, Statistics and Decision for Civil Engineers, McGraw-Hill, New York, 121 pp.
- Bulgakov V., Zykov P., Bereziviy M. 2010. Root harvesting machine. Ukrainian patent No. UA30845, A 01 D 27/04.
- Bulgakov, V., Ivanovs, S., Adamchuk, V. & Boris, A. 2014. Experimental laboratory investigations of the operating element for sugar beet top removal. *Engineering for Rural Development* **13**, 24–30.
- Bulgakov, V., Adamchuk, V., Arak, M., Olt, J. 2015. Theory of vibration-assisted sugar beet root lifting. *Agronomy Research* **13**(5), 1165–1192.
- 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. *Agronomy Research* **15**(1), 44–54.
- Gevko, R. 1999. *Directions for improving beet harvesters*. Luck, 170 pp. (in Ukrainian).
- Dospehov, B. 1985. *Methodology of field experiments*. Moscow, 351 pp. (in Russian).
- Halemendik, N. 2001. *Increasing the Mechanical and Technological Efficiency of the Labour Consuming Processes in Beet Growing*. Ternopol, 48 pp. (in Ukrainian).
- Ivančan, S., Sito, S. & Fabijanić, G. 2002. Factors of the quality of performance of sugar beet combine harvesters. *Bodenkultur* **53**(3), 161–166.
- Lammers, S. Olaf, P. & Olaf, R. 2010. Defoliation of sugar beets – assessment of quality and gain in delivered beet mass, *Landtechnik* **3**, 464–467.
- Lilleboe, D. 2014. Optimizing defoliator & harvester performance. *The sugar beet grower* **53**(6), 6–13.
- Linnik, A. 2014. Determination of dynamic parameters of a rigid cleaner interacting with a root crop). *Bulletin of Ternopil National Technical University* **73**(1), 165–171. (in Ukrainian).
- Nalimov, V. & Chernova, N. 1975. Statistical methods for planning extreme experiments. Moscow, 206 pp. (in Russian).
- Nikitin, A. 2018. Sugar beet harvesting. <http://mcx-consult.ru/page1508072009>. Accessed 7.01.2018.
- Pogorely, L. & Tatyanko, N. 2004. Beet Harvesting Machines, Kyiv, 2004, 232 pp. (in Ukrainian).
- Smith, L. 1991. The effect of defoliator flail configuration, speed and crown removal on sugar beet yield, quality and profitability. *Sugar beet Research and Extension Reports* **22**, 222–227.
- Tamm, K., Nugis, E., Edesi, L., Lauringson, E., Talgre, L., Viil, P., Plakk, T., Võsa, T., Vettik, R. & Penu, P. 2016. Impact of cultivation method on the soil properties in cereal production. *Agronomy Research* **14**(1), 280–289.
- Venikov, B. 1986. Theory of similarity. Moscow, 479 pp. (in Russian).
- Zykov, P. 2010. Trailed root harvesting machine MKP-6. *Tractors and agricultural machinery* **6**, Moscow, pp. 12–14 (in Russian).