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Theoretical study of altitude of coming out heads of root crops of beet above the surface of soil at their harvesting

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The purpose. To minimize losses of sacchariferous mass after continuous sensorless cutting off of haulm from heads of sugar-beet by theoretical justification of height of cutting off. **Methods**. Methods of higher mathematics, in particular geometrical simulation and mathematical statistics, and also analysis of the gained models. **Results**. According to results of experimental researches and service tests of process of harvesting of sugar-beet it is revealed that the newest models of beet combines, manufactured in Europe and America, cause significant losses of sacchariferous mass. A source of these losses is in the core the bad cutting of heads of root crops of sugar-beet, to be exact — excessively low point in which cops are sawed. That leads to straight loss of sacchariferous mass. Thus, there is a necessity of searching engineering decisions which will allow to avoid both losses of sacchariferous mass, and sticking of residues of haulm to root crops. Results of research in distribution of heights that root crowns protrude above the soil surface confirmed the hypothesis that it follows the normal distribution. **Conclusions**. On the basis of the gained results it is established that normal allocation has such statistical parameters: mean deviation s=20…30 mm, expectation m=40…60 mm. Also dependence of losses of sacchariferous mass on height of cutting of haulm from head of root crop of sugar-beet is gained.

Keywords: *sugar-beet, haulm, losses, sacchariferous mass, normal allocation.*

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Cultivation of sugar beet is a strategic branch of agriculture of leading agrarian countries of Europe, America and China [1-3]. Harvesting is one of the most critical operations in sugar beet production, because at this stage a significant part of the harvest can be lost [4, 5].

Taking into account the fact that root-crop harvesting includes operations on cutting the heads of root-crops, their digging and cleaning, loss of harvested crops is determined by a number of factors [6-8]. Therefore, the emphasis should be made on the most significant of them, namely the losses due to unsatisfactory performance of beet harvesters at the stages of root cropping and their further digging out of the soil [5, 7, 9]. The increase of contamination of sugar beet roots with green mass by only 1% of the established norm reduces the sugar yield by 0.1%, and for storage in the collars with the content of the canopy about 4% causes daily losses of sugar on average 0.02% [8, 12]. At the same time, modern beet harvesters produced in Europe and America cause significant losses due to undercutting of the heads of roots and, consequently, loss of sugar mass. Therefore, the actual task of this study is to find ways to reduce the above losses.

Analysis of the latest research and publications. There are many types of equipment developed to detect the surface of the root canal head, but beet harvesters, which perform a non-copy cut, have become the most common equipment that is now used [13]. Nowadays, modern sugar beet harvesters mainly use rotor units, cut the heads of root crops at the same height relative to the soil surface. The choice of height of cut heads is carried out according to generally accepted recommendations, but in practice they are often difficult to observe, given the probabilistic nature of the distribution of heights of beet root heads above the soil level [5]. However, users of sugar beet harvesting equipment are always faced with the problem of determining the height of the root canal heads in specific operating conditions. In most cases, the problem is solved by using the top finger method (including visual assessment of defoliator performance after several

test cycles). This operation is repeated several times, which is a waste of time, and therefore reduces cleaning productivity and does not guarantee a high level of precision over the entire area. In addition, it is possible to choose the wrong cutting height, which will result in significant sugar loss. Therefore, it is considered advisable to develop an automated controller, which would provide a solution to the problem of selecting the height of the cut, its automatic adjustment in the operation of the harvesting machine. In order to design this device, it is first necessary to find out the type of statistical distribution that describes the heights of the beet root heads protruding above the soil surface. This problem has been dealt with for many years by many researchers [7, 11, 12, 14], and their results are mainly indicative of the normal law of distribution. But the reliability of their results is doubtful because of the impossibility of obtaining sufficiently large volumes of samples by sampling and manual measurement. Attempts to solve these issues were made in the works [9, 12], but their results and methods are not sufficiently tested and should be clarified.

The purpose of the research. Minimize the loss of sugar mass after a continuous, non-copy cut of the canopy from the heads of sugar beet by theoretical justification of the cut height.

Research methods. The methods of higher mathematics, in particular geometric modeling and mathematical statistics, as well as the analysis of the obtained models were used in this study.

Research results. To model the defoliation process of the root canal head, a geometric model developed in [11] was used. The essence of the model was to determine the volume and mass of the head of one root-crop with the use of geometric ratios presented in Figs. 1, 2, 3. In the case of a known distribution of heights, the protrusion of the root-crop heads of the lost mass and the remnants of the haulm in relation to the height of the cut can be predicted by the method [12]. In order to move from one root to an entire root sample in accordance with the above technique, the enlargement was carried out over the entire height range of the head protrusion, taking into account the probability of occurrence of each value. The algorithm for determining the loss of sugar mass and haulm residues on roots, depending on their position relative to the soil surface and the cutting plane, was implemented in the form of a computer program for the MatLab environment.

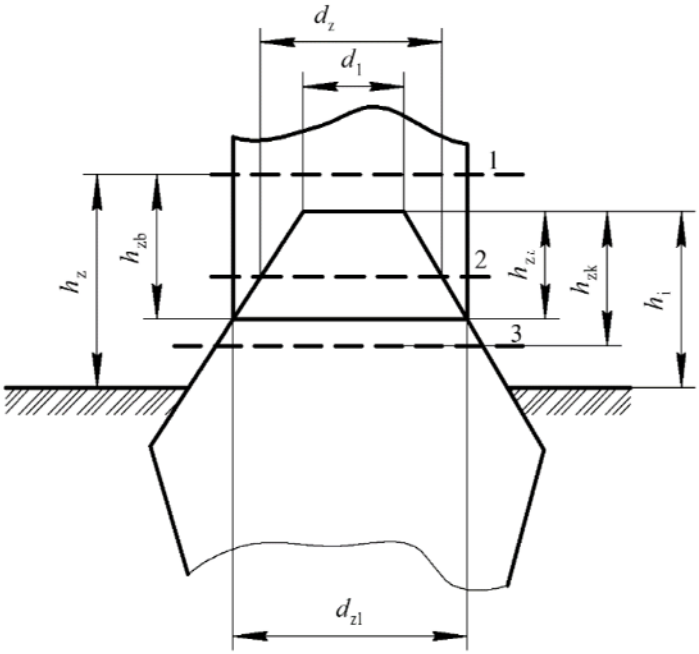

Fig. 1. The geometric model of the sugar beet root head with the lower cut line above the ground floor:

h_i – height of root protrusion, mm; h_{ZL} – distance from the top of the root head to the bottom of the haulm, mm; h_z – height of the non-copy haulm cut, mm; h_{zk} – distance from the top of the root canopy head to the surface of the non-copy haulm cut, mm; h_{zb} – distance from the plane of the non-copy cut of the haulm to the bottom line of the haulm, mm; d_1 – diameter of the upper part of the root head, mm;

d_z – diameter of the root head in the plane of the non-copy cut of the haulm, mm; d_{zl} – diameter of the root head in the plane of the lower haulm line, mm

The trimming plane 1 is above the root head, in which case there is no loss of sugar mass, but the root head has the haulm remaining :

$$h_{zk} = 0. \quad (1)$$

$$h_{zb} = h_{ZL} - h_{zk} + h_z. \quad (2)$$

$$B = 0, \quad (3)$$

$$G = \frac{\pi \cdot h_{zk} \cdot \rho_b \cdot d_{z1}^2}{4} - \frac{\pi \cdot \rho_b \cdot h_{ZL}\left(d_1^2 + d_1 \cdot d_{z1} + d_{z1}^2\right)}{12}, \quad (4)$$

where G – remains of haulm on the root, kg; B – loss of sugar mass, kg; $_b$ and $_k$ – density, respectively, of haulm and root, kg m $^{-3}$.

Trim plane 2 below the tops of the root heads:

$$h_{zk} = h_i - h_z. \quad (5)$$

$$h_{zb} = h_{ZL} - h_i + h_z. \quad (6)$$

$$B = \frac{\pi \cdot h_{zk} \cdot \rho_k \left(d_1^2 + d_1 \cdot d_{z1} + d_{z1}^2\right)}{12}. \quad (7)$$

$$G = \frac{\pi \cdot h_{zb} \cdot \rho_b \cdot d_{z1}^2}{4} - \frac{\pi\left(h_{zl} - h_{zk}\right)\left(d_1^2 + d_1 \cdot d_{z1} + d_{z1}^2\right)}{12}. \quad (8)$$

The trimming plane of the root heads 3 is below the level of the haulm stems:

$$h_{zk} = h_i - h_z. \quad (9)$$

$$h_{zb} = 0. \quad (10)$$

$$B = \frac{\pi \cdot h_{zk} \cdot \rho_k \left(d_{z1}^2 + d_z \cdot d_{z1} + d_z^2\right)}{12}. \quad (11)$$

$$G = 0. \quad (12)$$

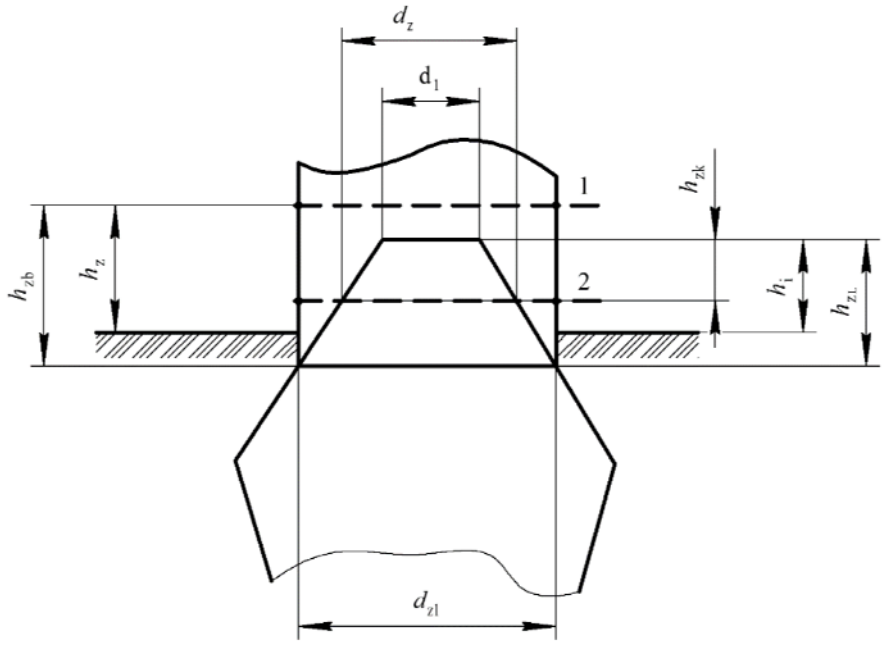

Fig. 2. Geometric model of the head of the root crop of sugar beet, in which the lower line of the stems is located below the soil surface

The plane of roots heads cutting 1:

$$h_{zk} = 0. \quad (13)$$

$$h_{zb} = h_{ZL} - h_{zk} + h_z. \quad (14)$$

$$B = 0. \quad (15)$$

$$G = \frac{\pi \cdot h_{zb} \cdot \rho_b \cdot d_{zl}^2}{4} - \frac{\pi \cdot \rho_b \cdot h_{ZL} \left(d_1^2 + d_1 \cdot d_{zl} + d_{zl}^2 \right)}{12}. \quad (16)$$

The plane of roots heads cutting 2:

$$h_{zk} = h_i - h_z. \quad (17)$$

$$h_{zb} = h_{ZL} - h_i + h_z. \quad (18)$$

$$B = \frac{\pi \cdot h_{zk} \cdot \rho_k \left(d_1^2 + d_1 \cdot d_{z1} + d_{z1}^2 \right)}{12}. \quad (19)$$

$$G = \frac{\pi \cdot h_{zb} \cdot \rho_b \cdot d_{z1}^2}{4} - \frac{\pi \left(h_{ZL} - h_{zk} \right) \cdot \left(d_1^2 + d_1 \cdot d_{z1} + d_{z1}^2 \right)}{12}. \quad (20)$$

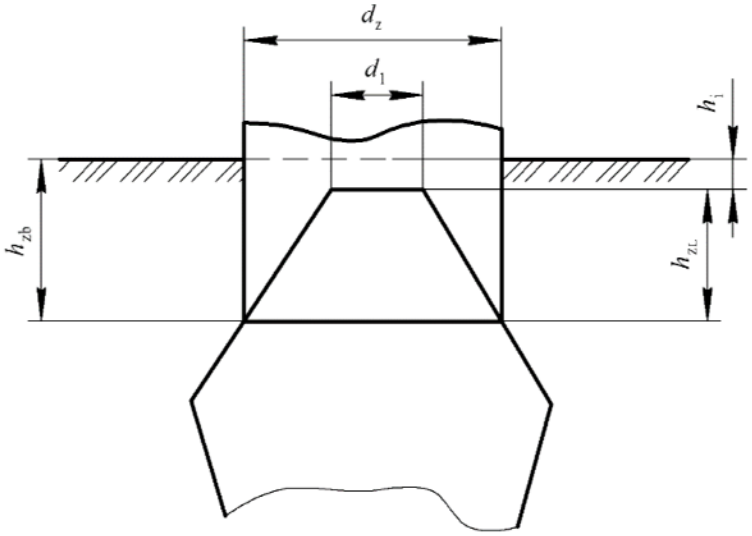

Fig. 3. Geometric model of the head of the sugar beet root, which is located below the soil surface

The plane of roots heads cutting 1:

$$h_{zk} = 0. \quad (21)$$

$$h_{zb} = h_{ZL} - h_{zk} + h_z. \quad (22)$$

$$B = 0. \quad (23)$$

$$G = \frac{\pi \cdot h_{zb} \cdot \rho_b \cdot d_{z1}^2}{4} - \frac{\pi \cdot \rho_b \cdot h_{ZL} \left(d_1^2 + d_1 \cdot d_{z1} + d_{z1}^2 \right)}{12}. \quad (24)$$

The results of the calculation on the PC of sugar mass losses on the basis of the obtained geometric models are shown in Fig. 4.

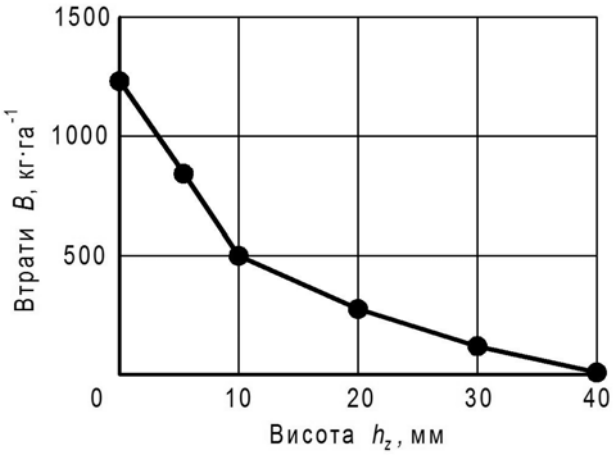

Fig. 4. The relationship between the loss of sugar mass B and the height h_z of the copyless cut of a branch of the heads of roots

On the graphic shown in Fig. 4, the dependence of sugar beet mass losses in specific conditions, after determining the statistical parameters of distribution (*m*,), using a mathematical model [12]. This, in turn, makes it possible to create an automated system for evaluating the parameters of sugar beet roots in order to quickly adjust the cutting height of the haulm in order to reduce the loss of sugar mass.

Conclusions

The results of the study on the distribution of heights, the protrusion of sugar beet root fruit heads over the soil surface confirms the hypothesis of their distribution according to the normal law.

Based on the results obtained, it is established that this distribution has the following statistical parameters: average deviation = 20…30 mm, mathematical expectation *m* = 40…60 mm.

3. Obtained dependence of sugar mass losses on the height of the copyless cut of the haulm from the root heads.

References

1. Spiess, E., & Diserens, E. (2001). Zuckerr ben: Erntetechnik und Bodenschutz – viel-seitige Wechselbeziehungen zwischen. *Technik, Erntequalit t und kologie. FAT-Berichte T nikon, 567,* 20.

2. Jansen, R., & Stibbe, G. (2007). Impact of plant breeding on the profitability of sugar beet production. *International Sugar J., 109 (1300),* 227-233.

3. Wu, H., Hu, Z., Peng, B., Wang, H., & Wang, B. (2013). Development of auto-follow row system employed in pull-type beet combine harvester. *Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering, 29 (12),* 17-24.

4. Lammers, P.S., & Schmittmann, O. (2012). Testing of sugar beet harvesters in Germany *International Sugar J., 115 (1370),* 100-106.

5. Zang, G., Xu, W., & Fan S. (2013). Analysis and parameter optimization of adjustable beet top cutting mechanism. *Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering*, *29 (18),* 26-33. https://doi.org/10.3969/ j.issn.1002-6819.2013.18.004.

6. Smith, J. A., Yonts, C. D., & Palm, K. L. (2013). Field loss from sugar beet harvest operations. *Applied Engineering in Agriculture*, *15 (6),* 627-631. https://doi.org/10.13031/2013.5828.

7. Bulgakov, V. M., Adamchuk, V., Nozdrovicky, L., Boris, M. M., & Ihnatiev, Ye. I. (2016). Properties of the sugar beet tops during the harvest. In *Trends in Agricultural Engineering.* (pp. 102-108). Prague.

8. Bulgakov, V., Adamchuk, V., Ivanovs, S., & Ihnatiev, Y. (2017). Theoretical investigation of aggregation of top removal machine frontally mounted on wheeled tractor. *Engineering for rural development*. *Jelgava, 16,* 273-280. https:// doi.org/10.22616/erdev2017.16.n053.

9. Adamchuk, V. V., Boris, A. M., Bulgakov, V. M., & Boris, M. M. (2015). Mekhaniko-tekhnolohichni peredumovy zmenshennia vtrat masy koreneplodiv v protsesi yikhzbyrannia [Mechanical and technological prerequisites for reduction of root mass loss during their harvesting]. In Konstruiuvannia, vyrobnytstvo ta ekspluatatsiia silskohospodarskykh mashyn: zahalnoderzh. mizhvid. nauk.-tekhn. zb. [Construction, production and operation of agricultural machinery: nationwide. intern. scientific-technical coll.]. (Vol. 45, Part 1, pp. 3-10). Kropyvnytskyi: KNTU. [In Ukrainian].

10. Bulgakov V. M., Adamchuk V. V., & Ihnatiev E. I. (2017). Teoriia vertykalnykh kolyvan frontalno navishenoi hychkozbyralnoi mashyny [Theory of vertical oscillations of the front mounted pickup machine]. *Bulletin of Agricultural Science*, *2,* 36-42. [In Ukrainian].

11. Bulgakov, V., Boris, M., & Boris, A. (2013). Theoretical investigations of leaf stripper heads of roots. *Agricultural Engineering, Research Papers*, *45 (2),* 46-53.

12. Bulgakov, V. M., Boris, A. M., & Boris, M. M. (2015). Doslidzhennia rozpodilennia vysoty vystupannia holovok koreneplodiv buriakiv tsukrovykh nad poverkhneiu gruntu [Investigation of the height of the projection of the root heads crops of sugar beet above the soil surface]. *Bulletin of Agricultural Science, 5,* 41-44. [In Ukrainian].

13. Bulgakov, V., Pascuzzi, S., Arak, M., Santoro, M., Anifantis, F., Ihnatiev, Y., & Olt, J. (2019). An experimental investigation of performance levels in a new root crown cleaner. *Agronomy Research, 17(2),* 358-370. https://doi.org/10.15159/AR.19.132.

14. Ihnatiev Ye. (2016). Theoretical substantiation of topping parameters without sugar beet head copying. *IV International scientific Congress "Agricultural machinery"*. (Issue 18(181), Vol. 1, pp. 55-58). Varna.