UDC 631.356.02

Experimental investigation of the statistical distribution of the height of the prediction of beef root heads above the soil surface

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The purpose. Reduction of losses of sugarcane mass and amount of residues of the hives after carrying out a continuous copyless cut of the hives from the heads of the root crops of sugar beets on the root by experimental justification of the statistical distribution of the height of the projection of the heads of the roots above the soil surface and the height of the cut. **Methods.** The researches were carried out using the methods of conducting field experimental researches and statistical processing of the obtained results on PC. **Results.** Experimental studies and operational tests of the latest models of beet harvesters in Europe and America, the results of which are covered in many scientific papers by domestic and foreign scientists, indicate a significant loss of sugar mass in the process of sugar beet harvesting. Moreover, the main source of these losses is the unsatisfactory pruning of the root heads on the root. Therefore, there is a need for scientific research to substantiate the necessary engineering solutions that will reduce the loss of sugar mass and the presence of residues of hives on the heads of roots. The result of the studies of this work is an experimental confirmation of the hypothesis about the normal height distribution of the heads of the roots above the soil surface. **Conclusions.** The statistical parameters of the specified normal distribution were determined: mathematical expectation m = 40...60 mm, standard deviation σ = 20...30 mm. The laboratory facility for conducting experiments and the field studies conducted with its help have created sufficient prerequisites for the development of a new system for automatic control of the cutting height of the heads of root crops on modern beet harvesters, which will ensure minimal losses of sugarcane mass.

Key words: *sugar beet, harvesting, losses, sugar mass, height control.*

DOI: https://doi.org/10.31073/agrovisnyk201912-07

One of the most important operations in sugar beet growing technology is their harvesting, because at this stage a significant part of the harvest can be lost [1, 2]. In particular, significant yield losses are possible when cutting root heads before digging, and these losses are determined by a number of different factors [3]. Therefore, it is necessary to pay attention to the unsatisfactory operation of beet harvesters at the stages of root cropping and their further digging out of the soil [2]. It should be noted that it has a negative effect on the production of the required amount of sugar, both too high and too low cut of the heads of roots. As the results of scientific works [5, 9] show, the increase of contamination of the root-crop gully of sugar beet with green mass by only 1% of the established norm reduces the sugar yield by 0.1%, and when stored in the burrs with the content of the canopy about 4% causes everyday loss of sugar on average by 0.02%. At the same time, modern sugar beet harvesters produced in the world's leading sugar beet-growing countries cause significant losses of sugar mass due to the underestimated cut of root-crop heads on the root. Therefore, the search for ways to reduce the above losses is an urgent task today.

Analysis of the latest research and publications. First of all, it should be noted that beet harvesters, which perform a copyleaf cut, have purchased the most common use at the present time [11, 12]. In this case, most often used rotary pruners that cut the heads of root crops at the same height relative to the surface of the soil. Thus, in the roots located high above the soil surface, a significant part of the sugar mass is cut off, and the lowlands are observed significant remnants of the haulm on their heads. This is

explained by the probabilistic nature of the distribution of beet root crown heights over the soil surface [4]. Therefore, when harvesting sugar beet, they face the problem of determining the height of the placement of root cane heads for specific operating conditions. Therefore, it is advisable to develop an automated controller, which would ensure automatic adjustment of the cutting height during the operation of the harvesting machine. But for such a development it is necessary to find out the type of statistical distribution of the height of the root crops' heads protrusion over the soil surface. The results of the works [4] indicate the normal law of distribution. But the reliability of their results is doubtful because of the insufficient volume of statistical samples and manual measurement. Attempts to prove that the distribution law is really normal were conducted in the works [4, 5], but their results and methods are not sufficiently tested and should be clarified.

The purpose of the research. Decrease of sugar mass losses and the quantity of boot residue after carrying out of continuous non-copy cuttings of the canopy from the heads of sugar beet roots on a root by an experimental substantiation of statistical distribution of height of protrusion of heads of roots over a soil surface and height of a cut.

Research methods. The research was carried out using the method of field experimental research and statistical processing of the results obtained on a PC.

Research results. So, for a reliable estimation of the distribution of the height of the sugar beet heads protrusion in the field (the distribution of plants in a row, the distribution of the height of the root crops heads protrusion over the soil and losses during harvest) was projected and made a special laboratory field installation for the study of this process in real conditions. This developed device was used in this study in order to find ways to reduce the loss of sugar masses arising in the process of cutting the heads of sugar beet roots, as well as to develop the theoretical prerequisites for the creation of an automated system of correction of the cutting height.

The results of the measurements were processed using statistical methods on PCs. The main purpose of the statistical processing was to find out the dependences of the distribution of heights of the protrusion of root-crop heads over the soil surface and its statistical characteristics: mathematical expectation m and standard square deviation σ. After that, according to the established dependencies, it is possible to make a prediction of sugar mass loss and the amount of haulm residue on the roots in relation to the height of uncopy haulm pruning. The input parameters of the model were related to the characteristics of the root vegetables as they were harvested during the harvesting operations. The main root-crop parameters are the upper part of the root-crop head diameter d_1 and the height of the root-crop head protrusion over the soil surface h_i. Other parameters were dependent and could be calculated using the regularities given in [4, 12]. The main parameters of the field are: m and σ – mathematical expectation and standard square deviation of heights of root heads protrusion over the soil surface (if this distribution corresponds to the normal law); Q – yield of root crops per unit area ($t \cdot ga^{-1}$); N – number of root crops per hectare, pcs. The process parameters also include the height of the carbonless cut h_z. The output parameters in the model were direct process parameters: sugar loss B and the number of haulm residues on the roots G or their value as a percentage of the total weight of the roots. To model the defoliation process of the root canal head, a geometric model developed in [13] was used.

As a first step, the functional structure of such an experimental block has been developed, using a schematic measurement model, which includes data input and output modules, a measuring block, a control module, a converter module to record the parameters of the placement of sugar beet roots in a row. Further, an original algorithm was developed to control the process of measuring the height of the placement of root-crop heads above the soil level.

Structural scheme of the developed laboratory block for field experiments includes a system of gyroscopes and accelerometers installed to study the influence of beet harvester vibrations on the stability of the harvesting modules of corneal machines.

The authors also developed a structural diagram of the laboratory installation and manufactured an electronic module to control the process of measuring the position of the sugar beet head above the soil surface. The measuring device included devices for the detection of sugar beet roots and other sensors that detect the position of the wheelbase of the machine and the height of the protrusion of sugar beet roots over

the soil surface. The height of the root canal head protrusion over the soil surface is measured by a copier, which deviates by an angle α, when interacting with the root canal, which protrudes by a height h_i. The angle of deflection of the copier was recorded by an encoder containing a magnetic disc and two Hall sensors A3144. As the magnet passes through the sensor area, digital pulses are generated, the number of which is proportional to the copier deflection angle. The encoder signals were transmitted to the E-14-440 module of the digital input/output board manufactured by LCard. The E-14-440 module was connected to a PC via USB connection and processed by LGraf software. In the process of measurement, the program generated a file with the data on the protrusion of root-crop heads over the soil surface. After obtaining a sufficient number of measurements (more than 50 thousand), the data were exported by the Octave 4.0 software and the dependences of sugar mass losses and haulm residues on the heads of root crops on the established height of the non-copy cut were obtained. Field researches were carried out by the specified laboratory and field experimental installation connected to the wheeled tractor for reduction in forward movement and maintenance of a food supply (Fig. 1).

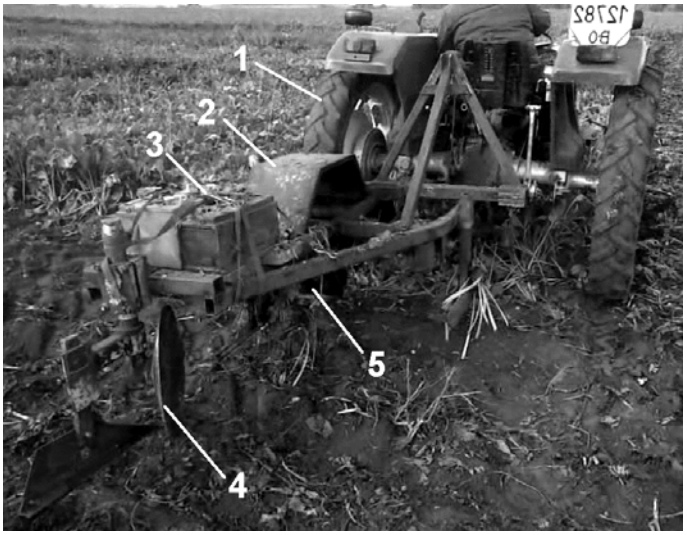

Fig. 1. Field experimental installation for measuring the height of the protrusion of sugar beet root heads over the soil surface: 1 – energetic means; 2 – experimental installation; 3 – control and data recording unit; 4 – sensor for detection of root-crop presence and its position in the line; 5 – copier for measuring the height of protrusion

The research was carried out on several beet plots with different biological yields of root crops and table beet, different geometry of the field surface, mechanical and physical properties of the soil. Graphs based on the results of processing on a large sample PC (50 thousand measurements) with the use of a specialized package MatLab.

The results of studying the parameters of root crops depending on the height of the protrusion of sugar beet root crops heads over the soil surface are shown in Fig. 3.

hese diagrams show a high degree of dependence on each other and show the distribution of sugar beet head parameters depending on the height of their protrusion over the soil surface h_i, indicated on the axis x. Also in Fig. 1 shows the amount of sugar mass above the ground (curves 3, 4) and the amount of sugar mass containing the remains of the haulm that must be removed (curves 5, 6). Further, based on the data presented in Fig. 3, and using the obtained mathematical dependencies and data from previous studies [13], the relationship between sugar mass losses and the height of the carbon-free cut of the sugar beet cane was obtained. Fig. 1 shows the loss of sugar beet mass and the height of the uncoated sugar beet cut. 4, an example of a calculation (for one specific case) based on the following distribution parameters is presented: m = 40 mm and σ = 20 mm. However, we can see that these parameters do change within the limits defined in the dependencies shown in Fig. 2. Thus, we can conclude that the statistical parameters of the distribution of heights of the root canals should be controlled and monitored in the dynamics.

Fig. 2. Parameters of heads of root crops, depending on their height of projection at the soil level at* m *= 40 mm: 1 – number of root crops* N *at σ = 10 mm; 2 – number of root crops* N *at σ = 20 mm; 3 – sugar mass above ground level* Ц₃ *at σ = 10 mm; 4 – sugar mass above ground level* Ц₃ *at σ = 20 mm; 5 – sugar mass above ground level, which has the remnants of a hillock* Цг *at σ = 10 mm; 6 – sugar mass above ground level, which has the remnants of a hillock* Цг *at σ = 20 mm

Because when this parameter is changed, the loss of sugar mass, as well as the optimal value of h_z of the canopy-free cut height, respectively, also change.

On the chart shown in Fig. 4, we see the dependence of sugar beet mass loss in specific conditions, after determining the statistical parameters of distribution (m, σ), using a mathematical model [13]. 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 canopy in order to reduce the loss of sugar mass.

Conclusions

Experimental studies of the distribution of heights of the protrusion of the heads of sugar beet roots over the soil surface confirm the hypothesis of their distribution according to the normal law.

On the basis of the results of experimental studies and their statistical processing it was established that this distribution has the following statistical parameters: standard square deviation σ = 20…30 mm, mathematical expectation m = 40…60 mm.

Experimental studies carried out on the developed field laboratory unit have created prerequisites for designing the system of automatic determination of the haulm height from the root-crop heads in modern root-breeding machines and combines.

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