METHODOLOGY AND RESULTS OF EXPERIMENTAL STUDIES OF COMBINED UNIT FOR SUGAR BEET TOPS HARVESTING ON THE BASIS OF A ROW-CROP TRACTOR

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Abstract: *On the basis of an integrated wheel-type tractor (traction class 3.0), there was created the new combined machine and tractor unit carried out a continuous flat cutting of the sugar beet tops with a front mounted sugar beet tops cutting machine. To carry out this field experimental studies, a program and methodology was developed based on measurements of the remains of the tops on the heads of root crops after passing through the aggregate at a given rate of translational motion, the height of the installation of its rotary cutting mechanism above the level of the soil surface and the frequency of its rotation. The results of the study were statistically processed on a personal computer using regression and correlation analysis methods. Based on the developed methodology of the full-factor experiment, empirical mathematical models were constructed in the form of regression equations for the process of cutting the tops of sugar beet. According to the results of these calculations, it was found that the speed of the forward movement of the sugar beet tops cutting aggregate exerts the greatest influence on the mass of the remains of the tops on the spherical surfaces of the root heads, after a continuous main cut. In a lesser extent, this process is influenced by the rotational speed of the rotor of the sugar beet tops cutting machine and the height of the rotor installation above the soil surface level by means of two pneumatic copying wheels. According to the results of experimental studies, it has been established that the rational design and technological parameters of the process for harvesting sugar beet tops by a front mounted sugar beet tops harvesting machine with a rotary cutting apparatus is its rotation frequency equal to 960 rpm, the speed of the aggregate should not exceed 2.0 m.s^{-1}, and the height of the rotor installation should be as low as possible, not less than 0.02 m.*
KEY WORDS: SUGAR BEET TOPS, HARVEST, FLAT CUT, METHODOLOGY, EXPERIMENTAL RESEARCH.

1. Introduction

One of the key problems of the technological process of harvesting sugar beets is to remove and harvest the leaves and tops from the heads of sugar beet roots standing in the soil. Studies have shown that with modern technology harvesting of the leaves and tops of heads of sugar beet roots sometimes there is lost about 14-17% of the crop mass containing a sugar. Therefore, the problem of harvesting the tops and cleaning the heads of sugar beet roots from the remains of the tops without loss of the saccharіferous crop mass is an actual, economically justified scientific and technical problem. To solve this, it is necessary to develop a technique for experimental studies of such a combined machine-tractor unit that would allow cleaning the main sugar beet crop mass of the tops and cleaning the heads of sugar beet roots, while structural and technological implementation should ensure improved quality and technical and economic performance. The practical solution of this problem determines the relevance of this work.

The specified scientific and practical tasks of harvesting the main crop mass of the sugar beet tops and cleaning the heads of sugar beet roots standing in the soil can be solved by the development and application of combined machine and tractor units, the modular construction principle of which gives important advantages when used in production conditions [1].

The following scientific workers significantly contributed to the theory and practice of this issue in due time: Pogorevshshiy L.V., Bulgakov V.M., Toporovsky S.A., Gurchenko O.P., Tatyanko N.V. and other scientists [2-6].

At the same time, their theoretical studies, obtained dependencies and practical results are not sufficient to justify the design and technological parameters and operating modes of the combined sugar beet heads harvesting machine-tractor unit.

2. Preconditions and means for resolving the problem

2.1. Purpose of the study

The aim of the study is to develop a methodology for the experimental determination of rational parameters for cutting the sugar beet tops by a developed unit to ensure the required quality of harvesting the crop mass of sugar beet tops.

2.2 Solution of the examined problem

The subject of experimental studies are the sugar beet roots, tops and the working process of the cutting of the sugar beet root tops by a combined cutting machine.

The subject of experimental studies is the relationship between the quality indicators of the operation of the sugar beet tops harvester and its operating modes.

As a result of the processing of a priori information, theoretical studies and expert evaluation, it was established that the main input parameters for experimental studies (replaceable factors) are the rotor speed, the forward speed of movement of the aggregate and the position of the rotor above the soil surface. Other parameters that characterize the operation of the unit, as well as the characteristics of the research conditions, are unchanged, but controlled factors.

As an initial parameter for this process is considered the mass of the remains of the sugar beet root tops per unit area of the field.

Experimental studies of the influence of the operating modes of the sugar beet rots tops harvesting machine for continuous sensing less cutting of the tops, which are front mounted on the wheeled tractor, on the qualitative parameters of the removal of the tops consist in determining the influence of each factor separately and their interaction on the initial parameter and determining the regression dependence of this influence, which will characterize the change in the reduced the mass of the remains of the sugar beet roots tops on the surface of the head of the sugar beet roots, from the indicated parameters in the form of empirical mathematicians process models.

As a result, the mathematical model (the regression equation) of the influence of variable factors on the amount of non-cut leaves from the heads of sugar beet root by a sugar beet heads harvesting machine has the following general form:

$$Y = f(X1, X2, X3), \quad (1)$$

where $X1$ – rotation frequency of the rotor; $X2$ – aggregate forward speed; $X3$ – height of the rotor above the soil surface level.

Experimental studies involve the use of both standard and partial techniques:

- the methodology for determining the conditions for conducting of the research;
- a methodology for conducting laboratory and field studies to determine the effect of parameters and operating conditions of the sugar beet tops harvester on the quality of leaves removal;
- the methodology of conducting field research to assess the quality of the operation of the harvesting machine in the field conditions.

The methodology of the experimental research also consists the selection of the necessary instruments, equipment, adaptation and techniques that will be used in the experiments.

The laboratory-field experimental setup (1) developed for this purpose makes it possible to carry out in full the experimental studies of a new sugar beet heads harvest combination unit (Figure 1), with the possibility of changing the factors within the specified limits: the rotor speed with the help of the drive mechanism and the control of the tachometer; forward speed of a machine by means of a gear box of a tractor and the control of its actual value by a passed distance measuring wheel; height of installation of a rotor by the lever mechanism by using of a scale.

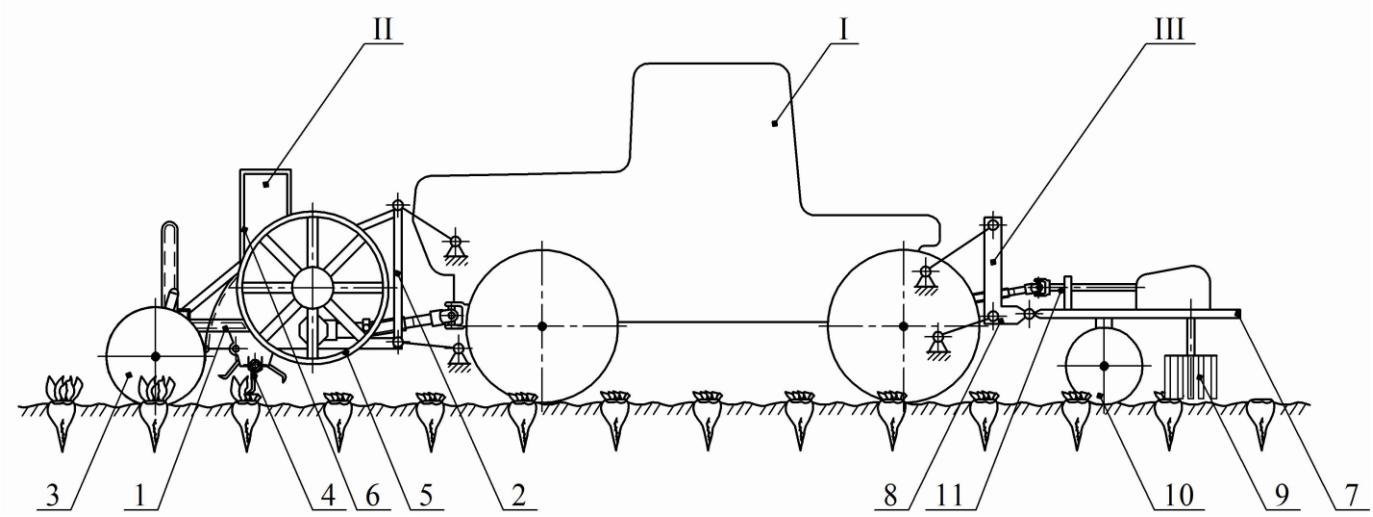

Fig. 1. *– Combined machine-tractor aggregate for the harvest of the sugar beet heads:*
I – tractor; II – front-mounted sugar beet head harvest machine: 1 – frame; 2 – carrying attachment; 3 – sensing wheel; 4 – rotary heads cutting mechanism; 5 – conveying-feeding working body; 6 – loading equipment; III – cleaner of the sugar beet heads from remains of the leaves: 7 – frame; 8 – carrying hitch; 9 – cleaning shaft; 10 – sensing wheel; 11 – drive

Table 1. Factors which have been studied on the front-mounted sugar beet root tops harvest mechine carried on universal wheel-type tractor

No.	Factor	Notation	Unit of measurement	The minimum value of the factor	The maximal value of the factor
1.	Forward speed of the tractor	*V*	$m \cdot s^{-1}$	0.5	2.5
2.	Speed of rotation of the cutting rotor	*n*	rpm	500	1000
3.	Height of the cutting of the sugar beet heads	*h*	m	0.02	0.15

The methodology for determining the conditions for carrying out the research of the sugar beet root tops harvesting machine is based on determination of the variety, yield and basic agrobiological characteristics of sugar beet, soil type, relief and micro relief, soil moisture content and hardness of the soil and other parameters that characterize the research site, according to the generally accepted method [7, 8]. From the point of view of high reliability of the results and their practical value, the research is conducted in the optimal agrotechnical terms for the harvesting of sugar beet.

So, for example, soil and climatic conditions (soil moisture content and hardness, soil type, including texture, relief and microroughness, clogging of the site) are determined according to the generally accepted methodology. Moisture content and hardness of the soil are determined in rows and rows between sugar beets in layers: from 0 to 10 cm, from 10 to 20 cm, from 20 to 30 cm.

The location of the heads of the sugar beet roots relative to the soil surface is determined from one side of the row by measuring the distance from the soil surface to the top of the head of the sugar beet root with a measurement error of ± 5 mm. Depending on the location of the heads, the measurement results may be with the «plus» sign or «minus» sign: the «plus» sign if the root crop is located above the soil surface level; a «minus» sign, if they are below the soil level.

The condition of the tops on the surface of the root head in the form of the layout of the leaves is determined in three test areas of 10 m in length on two adjacent rows. The leaf weight of the foliage is distributed by a visual survey of each plant in groups: cone, rosette, half-rosette. The data is processed to obtain a percentage of the amount of each of the groups from the total number of sugar beet roots.

The boundaries of variation of the main factors – the forward speed of the tractor; rotational speed of the rotary cutter; the height of the cutting of the tops (i.e., the height of the establishment of the sugar beet topper device above the soil surface) was determined on the basis of processing of literature sources and previous theoretical and experimental studies (Table 1).

Based on the calculations performed, previous studies and analysis of the aprioristic information, there was established levels of variation factors:

- speed of rotation of the cutting rotor: 500; 750; 1000 rpm;
- forward speed of the sugar beet heads harvester: 0.5; 1.5; 2.5 $m \cdot s^{-1}$;
- height of the cutting of the sugar beet heads: 0.02; 0.06; 0.10; 0.15 m.

As an indicators of the quality of the work, as indicated above, there were considered the remains of the tops on the heads of sugar beet roots, in $g \cdot m^{-2}$, which were determined by collecting all the residues (including those not cut off from the root heads of the part of the leaves) from the area of 1 m^2 after passage of the experimental mechanism and weighing on electronic scales with an accuracy of 1.0 g.

The power unit (tractor), in terms of its technical characteristics, must ensure the operation of the sugar beet heads harvester at the required operating speeds and at the level of adjustment of the running gear to the corresponding track width [12].

According to the established agrotechnical requirements, in the harvesting of sugar beet, the sugar beet root tops harvesting machines must ensure that the tops are not cut off from the level of green leaves and not more than 2 cm from the top of the head of the root, the number of roots with uncut tops should not exceed 8% of the total number, the number of roots with an oblique cut – up to 10%, the presence of parts of the heads of roots in the tops – up to 5%, and the maximum allowable contamination of the cut tops by soil is 0.5% [9].

To verify the quality of the process performed by the sugar beet root tops sampler studied, field experiments were carried out at rational values of the forward machine speed, rotor speed and shear height, which were established on the basis of the analysis of the obtained results of studies, according to the generally accepted methods [10].

The losses of the sugar beet tops, which are associated with the sugar beet roots from the test site after the passage of the sugar beet root harvester, is determined by cutting them manually.

The results of the experimental studies were processed according to the known method of statistical processing of research data [11] with further presentation in the form of functional and graphical dependencies, and also with the application of the adequate PC software.

3. Results and discussion

In accordance with the program and in according to the developed methodology, laboratory-field experimental studies of the effect of the parameters of the sugar beet tops harvester on the quality of root leaves removal were carried out in full.

Evaluation of the quality of the process performed by the sugar beet tops machine was carried out by cutting the remains of the tops from the sugar beet root and weighing them.

In general, during the research it was established that the experimental sugar beet top root harvesting machine provides a fairly high-quality and stable performance of the technological process, without clogging the working mechanism.

In order to assess the influence of the factors and the nature of their influence on the qualitative index of the work, we obtained dependencies in the form of a regression equation:

- in the simple form:

$$y = 49.39992 - 0.19953n + 167.3833V + 5035.927h, \quad (1)$$

- in encoded form:

$$Y = 578.8905 - 49.8833\,X1 + 167.3833\,X2 + 327.3136\,X3. \quad (2)$$

where V – forward speed of the tractor motion, $m \cdot s^{-1}$; n – speed of rotation of the cutting rotor, rpm; h – height of the cutting of the sugar beet heads, m.

It can be seen from equation (2) that the height of the cut has the greatest influence on the mass of the remains of the tops on the surface of the sugar beet heads when using a rotary sugar beet tops harvesting machine. the height of the installation of the rotary topping mechanism above the level of the soil surface, and the lowest is the rotor speed of the topping mechanism (cutter apparatus). In addition, an increase in the speed of the machine and the height of the cut will lead to an increase in the mass of the remains of the tops on the sugar beet root head, and the rotor speed, on the contrary, to a decrease, since for the factors in the equations, the «plus» sign (with the speed of the machine and the height of the cut) that with the increase of these parameters, the quantity of tops on the sugar beet root head will also increase, and the minus sign (at the rotor speed), on the contrary – with the increase in the factor, the quality of the removal of the sugar beet leaves will decrease.

Measurement of the field surface profile irregularities with the using of a profilograph showed that they have a high-frequency character with a period of approximately 0.7 m and an average amplitude of oscillations of 0.08 m. Similar results were obtained by other scientists in the studies, when the goal was to determine the state of the field surface profile [13].

For a more complete description of the process of removing the tops of a rotary sugar beet tops harvesting machine, due to the processing of the results of a multifactor experiment, a mathematical model is obtained in the form of a regression equation of the second degree:

$$\begin{aligned} Q = &-177.593 - 0.24224n + 530.8054V + 8680.805h + \\ &+ 0.000179nn - 109.767VV - 6795.18hh - \\ &- 0.09602n - 1159.51Vh - 4.22748nh + 2.158437nVh, \end{aligned} \quad (3)$$

Since the optimal values could not be determined unambiguously during the solution of the problem, an additional series of experiments was performed with a sugar beet head top height cut of 0.02 m and a rotor speed of 1000 rpm and with a change in the forward machine speed from 0.5 to 3.0 $m \cdot s^{-1}$ in increments of 0.5 $m \cdot s^{-1}$. The results of the study are shown in Fig. 2. According to the analysis, the results obtained are established that the rational values of the speed of movement of the sugar beet root tops harvester will be from 1.5 to 2.0 $m \cdot s^{-1}$.

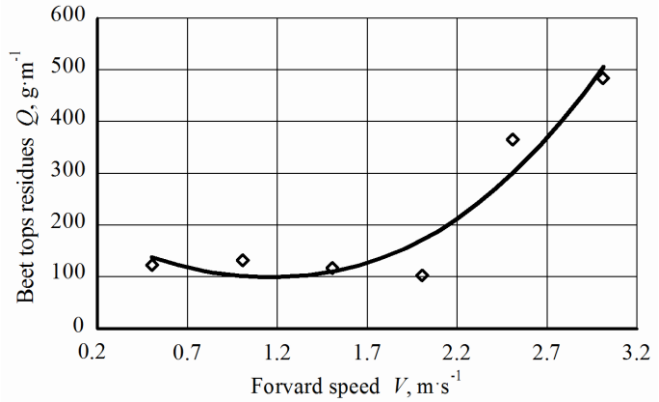

Fig. 2. *– Effect of the forward speed of the machine at a rotor speed of 1000 rpm and a height of cut of 0.02 m on a amount of the residues of the sugar beet root tops on the head of roots*

On the basis of the results obtained, field experiments were carried out on a sugar beet root tops harvest machine to assess the quality of its operation under production conditions at rational values of the process parameters.

To assess the quality of the work of the sugar beet root tops harvest machine in the production environment, the field studies of the machine were carried out at rational process parameters with the determination of the number of leaves tops on a root, roots with normal, high and low-cut tops, general and strong mechanical damage of the root, loss of sugar content and rooting out of sugar beet roots from the soil.

Based on the results of the field experimental studies that were carried out in the fivefold repetition shown in Table 2, it can be concluded that for these performance indicators, the sugar beet root tops harvest machine meets the agrotechnical requirements set for the root tops removal process. Especially, this applies to severe damage and knocking out sugar beet roots from the soil, since there were no such facts on the research sites.

Table 2. *Quality indicators of the function of a sugar beet root tops harvest machine*

No.	Indicators	Value according to the agrodemand	Values from experiments
1	Amount of leaves on the sugar beet roots, %	not more than 1.5	0,6
2	Correctly cutted sugar beet roots, %	not less than 85	95.3
3	Too low cutted sugar beet roots, %	not more than 5	3.2
4	Too high cutted sugar beet roots, %	not more than 10	1.5
5	Strongly mechanicaly damaged sugar beet roots, %	not more than 5	not occured
6	General damages of the sugar beet roots, %	not more than 20	1.5
7	Loss of sacchariferous mass, %	not more than 2	0.4
8	Knocking out sugar beet roots from the soil, %		not occured
9	Completeness of harvesting of sugar beet top leaves, %		96

Thus, according to the results of field experimental studies of the operation of the sugar beet root tops harvest machine in the field, when harvesting the tops with a continuous cutting, it can be concluded that the quality of the work corresponds to the agrotechnical requirements [9], and hence the expediency of using such an aggregate in production conditions.

4. Conclusions

1. The method of experimental researches of a sugar beet root tops harvest machine is carried out, which implements a continuous, uncopied cut of the main mass of the tops and the loading of the crop material into the vehicle, which involves: investigating the influence of the operating modes of the sugar beet root tops harvest machine on the quality of root tops removal; experimental determination in the field conditions of the main qualitative performance indicators.

2. It has been proved that the developed sugar beet root tops harvest combined unit in terms of performance in the field meets the qualitative indicators of work and agrotechnical requirements.

3. It has been established that the rational values of the process parameters at which qualitative removal of the tops will be achieved by the rotary cutter apparatus is the cut-off height of 0.02 m, the forward speed of the machine is from 1.5 to 2.0 $m \cdot s^{-1}$, the frequency rotor rotation is 1000 rpm.

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