EXPERIMENTAL STUDY OF OPERATION INDICATORS OF BEET TOPS HARVESTING MACHINE FOR SUGAR BEET TOPS CONTINUOUS CUTTING

Prof. Eng. Volodymyr Bulgakov[1] PhD., Prof. Eng. Valerii Adamchuk[2] PhD.,
Eng. Yevhen Ihnatiev[3], Prof. Eng. Hristo Beloev[4], Prof. Eng. Plamen Kangalov[4], PhD.,
Prof., Eng, Boris Borisov[4], PhD., Assos. prof. Eng. Georgi Mitev[4], PhD.

[1]National University of Life and Environmental Sciences of Ukraine, 15, Heroyiv Oborony Str., Kyiv, 03041, Ukraine;
[2]National Scientific Centre "Institute for Agricultural Engineering and Electrification" ?
11, Vokzalna Str., Glevakha-1, Vasylkiv District, Kiev Region, 08631, Ukraine
[3]Tavria State Agrotechnological University, 18, Khmelnytsky av., Melitopol, 72312, Zaporizhia region, Ukraine;
[4]"Angel Kanchev" University of Rousse, 8, Studentska Str., 7017 Ruse, Bulgaria
E-mail:vbugakov@meta.ua, yevhen.ihnatiev@tsatu.edu.ua

Abstract: *Field experimental studies of a new beet tops harvesting machine, which is front mounted on a wheeled tractor aggregating tractor, are carried out, carrying out a continuous non-sensing cut of the green massif of sugar beet tops. At the same time, a new laboratory-field installation was developed, which consists of a rotor type front mounted rotary type machine with a horizontal axis of rotation, a transverse screw for collecting the cutted leaves from all width, and a loading mechanism in the form of a paddlewheel and a loading nozzle. During the field experiments, the tractor moving with a specified speed regime fixed by track measuring wheel, the total cutting height was set in a predetermined interval by means of two pneumatic sensing wheels with adjustment mechanisms. The rotational speed of the rotary cutter, with arched knives mounted on the drive horizontal drum, was varied with the help of replacement asterisks. In the prepared area of sugar beet field, the beet tops was cut at various parameters of the harvesting process, which was then estimated by the size of the remaining tops remnants left on root crops heads and in the aisles. According to the developed program and methodology, statistical processing of the results of experimental studies with the help of a personal computer was subsequently carried out, which allowed obtaining graphical dependencies of the indicated tops residues on the root crops heads, which made it possible to establish performance of new harvesting machine for continuous cutting of sugar beet tops. The established dependencies made it possible to choose rational constructive and technological parameters for harvesting tops by front mounted harvesting machine.*
KEY WORDS: BEET TOPS, CLEANING, CONTINUOUS CUT, EXPERIMENTAL STUDIES.

1. Introduction

High-performance and high-quality harvesting of sugar beet tops remains a rather complex and urgent task for sugar beet growing. Recently, the most common in the world is the three-phase method of tops harvesting, which is based on a continuous main cutting of entire tops massif (at width of harvesting machine), its collection and transfer to a vehicle that moves side by side, and then using an individual copy of each head of root crop in a row, after-treatment or after-cutting (or simultaneously: and additional cleaning and pre-cutting with different working organs) heads of root crops from the tops remains. Since these operations are carried out sequentially for root crops of sugar beet in the soil (i.e., at the root) and the harvesting of the tops precedes the operation of digging out the beet roots from the soil, the tops harvesting machines, as independent agricultural machines, or tops harvesting modules, as integral units of sugar beet harvesters are located in the frontal position with respect to the power means (to the tractor – if it is a hinged tops harvesting machine or to the front part of the self-propelled frame beet root harvesters). However, our experimental studies have established that in the process of work, the front-mounted machine placed on the tractor carries out movements in space that are determined by the relief of the surface of the field, the translational speed of the tractor, placement of sensing wheels, relative to the suspension system of the machine, etc., affects the quality of this process. The use of pneumatic wheels as sensing causes the oscillating of cutting mechanism in the vertical plane, which significantly affects the quality of the process – uniform cutting of a tops of vegetable from heads of root crops on all width of cut, its fullest collecting and transportation without losses. The practical solution of this problem determines the relevance of this work.

2. Preconditions and means for resolving the problem

In spite of the large spread of front-mounted beet tops harvest modules of western production of beet harvesters, as well as some designs of domestic front-mounted tops harvesting machines, this almost did not lead to analytical and experimental studies of their oscillatory motion. However, in part, the task of studying the effect of constructive parameters on the movement along rows of sugar beet roots and the unevenness of the soil surface was tried in the following works [1-6].

2.1. Purpose of the study

The aim of the study is to experimentally determine the rational parameters of cutting the beet tops by developed unit to ensure the required quality of tops harvesting.

2.2. Methods of research

Experimental studies were conducted on the fields of the research farm "Olenovskoe" in the Fastovsky district of Kiev region. The object of experimental studies was the working process of tops cutting by developed unit. The conditions for carrying out the studies, which were determined according to known methods [7-10], are given in the table.

To implement the program of experimental research of the technological process of tops removal with the use of a tops harvesting machine, a laboratory-field experimental installation was developed (Fig. 1), which is front mounted on a tractor-type arable and row-crop wheeled tractor of drawbar category 3.0, and the cutter apparatus is made in the form of a horizontal rotor [5]. The machine makes it possible to realize a continuous, non-sensing cut of the main mass of beet tops with its further loading into the vehicle.

Laboratory-field experimental installation (Fig. 1) consists of a wheeled arable tractor I and front mounted topper II, which contains a frame 1, an attachment 2, a copying wheel 3, a rotary cutter apparatus 4, a transport device 5, a loading device 6 , as well as the drive 7.

The laboratory-field experimental setup [5] allows to carry out experimental researches of the given tops harvesting machine in full accordance with the adopted program and methodology (Fig. 1), with the possibility of changing the factors within the established boundaries: rotor speed with the drive mechanism and tachometer control; speed of movement of the harvester with the help of the tractor's gearbox and control of its actual value by track measurement wheel; The height of the rotor installation with a lever mechanism with the control by means of a ruler.

Table 1. *Conditions for carrying out laboratory-field experimental research of tops harvesting machine*

Index	Value
Soil type	Black soil with middle organic matter (OM), middle clay
Soil hardness in the rooting area, MPa	0.94…2.3
Soil moisture in the area of root crops,%	18.0... 21.6
Average beet root yield, t·ha^{-1}	46.4
Average yield of the tops, t·ha^{-1}	44.8
Average density of plantings of sugar beets, pcs· ha^{-1}	112000
Maximum deviation of position of sugar beet roots from the conventional line, mm	30…40
Position of sugar beet root heads above the soil surface, mm	0…70
The form of bundles of tops on the heads of root crops: – cones – a half-socket	there is a significant amount of dry and fallen stalks of the foliage) more than 90% 10%
Soil relief	flat
Maximum gradients of the relief, deg	Not more than 2...4

Laboratory-field experimental installation (Fig. 1) consists of a wheeled arable tractor I and front mounted topper II, which contains a frame 1, an attachment 2, a copying wheel 3, a rotary cutter apparatus 4, a transport device 5, a loading device 6 , as well as the drive 7.

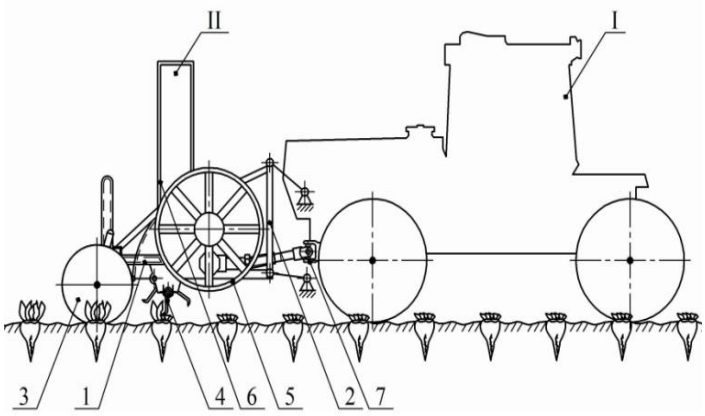

Fig. 1. *– The design diagram of the laboratory-field experimental installation:*

I – wheeled arable and row-crop tractor; II – front-mounted beet tops harvesting machine; 1 – frame; 2 – the hinged device; 3 – a sensing wheel; 4 – rotary cutter apparatus; 5 – transport device; 6 – the loading device; 7 – drive

The laboratory-field experimental setup [5] allows to carry out experimental researches of the given tops harvesting machine in full accordance with the adopted program and methodology (Fig. 1), with the possibility of changing the factors within the established boundaries: rotor speed with the drive mechanism and tachometer control; speed of movement of the harvester with the help of the tractor's gearbox and control of its actual value by track measurement wheel; The height of the rotor installation with a lever mechanism with the control by means of a ruler.

Based on the calculations performed, previous studies and analysis of a priori information, the levels of variation of factors were established:

– rotational speed of the machine rotor: 500, 750, 1000 rpm;

– speed of the movement of the harvester: 0.5, 1.5, 2.5 m·s^{-1};

– the height of the cut of the foliage: 0.02, 0.06, 0.10, 0.15 m.

The quality of the work, as indicated above, was taken by tops remnants on the root crops heads, in g·m^{-2}, which were determined by harvesting all residues (including those not cut off from the heads of the root parts of a part of the foliage) from the area of 1·m^2 after pass of experimental installation (Fig. 2) and weighing on electronic scales with an accuracy of 1.0 g.

Fig. 2. *– Determination of the quality of the removal of the tops by research beet tops harvesting machine*

The power tool (tractor), according to its technical characteristics, must provide operation of tops harvesting machine at the required working speeds and adjust to the corresponding track width [12].

The results of the experimental studies were processed according to the known method of statistical processing of the research data [7, 9, 11] with further presentation in the form of functional and graphical dependencies, and also with the application of applications for the PC.

3. Results and discussion

As a result of the experimental studies carried out according to the adopted methodology, the following dependencies were obtained.

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

– in natural form:

$$Q = -177{,}593 - 0{,}24224n + 530{,}8054V + 8680{,}805h + \\ + 0{,}000179nn - 109{,}767VV - 6795{,}18hh - \\ - 0{,}09602n - 1159{,}51Vh - 4{,}22748nh + 2{,}158437nVh, \quad (1)$$

– in coded form:

$$Y = 587{,}2724 - 50{,}5026X1 + 168{,}38335327X2 + 327{,}8374X3 + \\ + 11{,}18333X1X1 - 28{,}783X3X3 + 21{,}86292X1X2 + \\ + 29{,}85444X2X3 - 16{,}0845X1X3 + 35{,}07582X1X2X3. \quad (2)$$

where V – is the forward speed of the tractor, m·s^{-1}; n – is the rotational speed of cutting rotor, rpm; h – cutting height of tops, m.

Graphical interpretation of the indicated regression equations (1) and (2) presented in the form of response surfaces (Fig. 3 and Fig. 4).

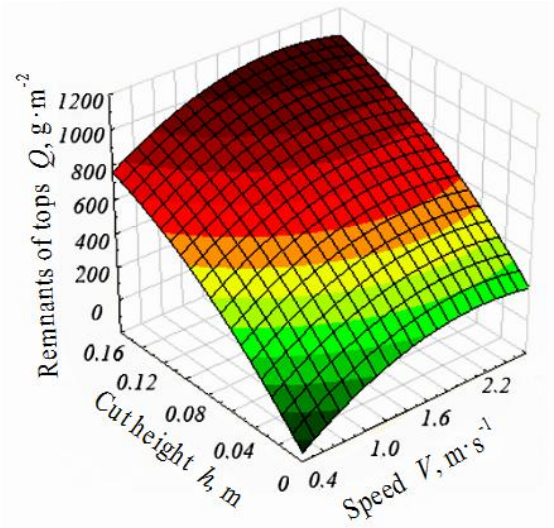

Fig. 3. *– The response surface of the dependence of tops remnants on root crop head surface on the speed of movement of tops harvesting machine and the cut height at a rotor speed of 500 rpm*

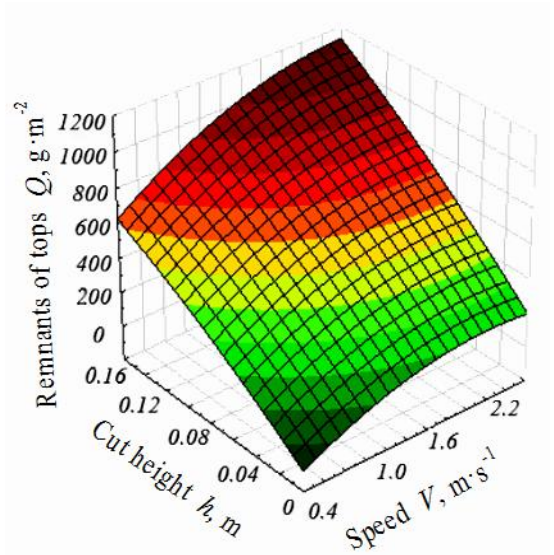

Fig. 4. *– The response surface of the dependence of tops remnants on root crop head surface on the speed of movement of tops harvesting machine and the cut height at a rotor speed of 1000 rpm*

On the basis of the factor analysis of regression equations (2), rational parameters of the process are determined, at which a qualitative removal of the tops by a rotary cutting apparatus will be achieved at the cuting height is 0.02 m, the speed of the machine is 1.5...2.0 m·s^{-1}, the rotor speed is 1000 rpm.

4. Conclusions

1. On the basis of the analysis of the empirical mathematical model in the form of the regression equation of the haulm removal process, it is established that the height of the cut has the greatest influence on the mass of the tops of the tops on the surface of the root heads of the root crops, while the lowest is the rotor speed of the cutter apparatus. With an increase in the speed of the machine and the height of the cut, the mass of the remains of the tops on the head of the root crops will also increase, while increasing the rotor speed will, on the contrary, reduce the mass of the remains of the tops.

2. It has been established that the rational values of process parameters at which qualitative tops removal will be achieved by a rotary cutter apparatus is the cutoff height is 0.02 m, the speed of the machine is 1.5...2.0 m·s^{-1}, the frequency rotor rotation – 1000 rpm.

3. Based on the results of field experimental studies of the operation of tops harvesting machine, which is front-mounted on the arable and row-crop tractor, when harvesting the tops with a continuous cutting, it can be concluded that machine performance indicators meet the agrotechnical requirements, and therefore the expediency of its application in production conditions is proved.

5. References

1. Pogoreliy L.V., Beet harvesters: (design and calculation) / L.V. Pogoreliy, N.V. Tat'yanko, V.V. Bray and others; Under the Society. Ed. L.V. Pogorelogo. - K.: Technique, 1983. – 168 with.

2. Bulgakov V.M., Properties of the sugar beet tops during the harvest / V.M. Bulgakov V.V. Adamchuk, L. Nozdrovicky, M. M. Boris, Ye. I. Ihnatiev, // Proceeding of the 6th International Conference on Trends in Agricultural Engineering 2016. – 7-9 September 2016. – Prague, Czech Republic. p.p. 102-108.

3. Gurchenko O.P., Substantiation of the main parameters of the shovel head cleaner beet from the remains of the tops / OP Gurchenko // Agricultural machines. Collection of scientific works. – Lutsk, 1997, Issue 3. – P. 30-37.

4. Toporovsky S.A., The substantiation of the technological process and the main parameters of the working organ for harvesting sugar beet tops without copying root heads / S.A. Toporovsky // Diss. Cand. tech. sciences. – Kiev, 1988. - 202 with.

5. Ihnatiev Ye.I., Development of a new constructive technological scheme for harvesting sugar beet tops using arable and row-crop tractors / Ihnatiev Ye.I // Bulletin of Agrarian Science. – 2016. – № 8. – P. 67-71.

6. Bulgakov V.M., Beet harvesters. Monograph / V.M. Bulgakov. – Kiev: Agrarian Science, 2011. – 351 p.

7. Vedenyapin S.V., The general method of experimental studies and processing of experimental data / S.V. Vedenyapin // – M.: Kolos, 1967. – 159 p.

8. Dospekhov B.A., Methodology of field experience (with the basics of statistical processing of research results) / B.A. Dospekhov // – M.: Agropromizdat, 1985. – 351 p.

9. Maslov G.G., Didmanidze O.N., Tsybulevsky V.V. Optimization of parameters and operating modes of machines by methods of experiment planning. Textbook for agricultural universities. – G.: OOO "Publishing House" Triada", 2007. – 292 p.

10. Zavalishin F.S., Methods of research on mechanization of agricultural production / F.S. Zavalishin, I.G. Mantsev // – Moscow: Kolos, 1982. – 228 p.

11. Kalosha V.K., Mathematical processing of experimental results / V.K. Kalosha, S.I. Lobko, T.S. Chikova // – Minsk: Vysheyshaya shkola, 1982. – 105 p.

12. Adamchuk V., Theoretical research into the power and energy performance of agricultural tractors / V. Adamchuk, V. Bulgakov, V. Nadykto, Y. Ihnatiev, J. Olt // Agronomy Research. 2016. Volume 14. No 5, p.p. 1511–1518.