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EXPERIMENTAL RESEARCH OF STRIPPING THE LEAVES FROM ROOT CROPS

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Modern trends in root crop machinery include the development and implementation of highly efficient, energy-saving and technologically reliable harvesting systems and facilities into agricultural production. The main criteria for meeting these demands are the digging quality and root crop impurities separation characteristics. The objective of research is the justification of design and kinematic parameters of cleaning tools. The paper provides description of the experimental unit and procedures for experimental research of the process of stripping the haulm residues from root crop heads. A histogram and polygon were plotted for probability density function of random variables of the length of leaf remnants on root crop heads. The differential law for a probability density function of length of leaf remnants after the stripping by cylindrical rollers was obtained. The approximate linear dependence was obtained as a regression equation, which describes a change in the length of leaf remnants on the root crop heads depending on the diameter and rotation speed of rollers. The aforementioned method and results obtained in experimental research can be used by specialists at design engineering bureaus for development of new or improvement of existing combined cleaning systems.

Keywords: length of leaf remnants; haulm stripping rollers; roller diameter; roller rotation speed; response surface

The mechanised harvesting of root crops of sugar and fodder beet is one of the most labour-intensive and energy intensive operations in the general framework of crop production, not only in Ukraine but also in highly developed world countries.

Considering the fact that Ukraine belongs to significant agricultural countries of Europe and the world which has the necessary capacity for production of strategic food products – sugar and food products of animal origin – domestic mechanical engineering should develop and purposefully introduce the improved root crop harvesting machinery into agriculture, which would be comparable to the best world equivalents in their functional and performance characteristics (Pogorely and Tatyanko, 2004).

The operation quality of existing cleaners separating the impurities from roots does not meet the parameters set by agrotechnical requirements for root crop harvesting due to the usage of imperfect processes and thus the tools for cleaning of root crop piles from impurities do not separate haulm remnants from root crop heads, which represents 5–10% (Baranovsky, 2014) of the weight of harvested root crops, and damage a significant amount of root crops (from 20% to 40%) (Dubchak, 2013; Bulgakov and Korenko, 2007).

One of the ways to improve the quality parameters of the root crop harvesting process, which is a complex scientific and technical task, is to search for new structural designs of tools and improved combined cleaning systems for root crop piles based on new structural designs and layout schemes of root crops harvesting machinery in general (Storozhuk and Pankiv, 2015).

In this regard, the development of new processes and tools for cleaning of root crop piles from various impurities and the study of influence of parameters and operation modes of combined cleaning systems in order to improve the quality parameters of root crops harvesting machinery are relevant national economic task.

Material and methods

The objective of research lies in the justification of design and kinematic parameters of tools of cleaner based on the analysis of the obtained regression equation, which describes a change in the lengths of leaf residues after their stripping by cylindrical rollers in comparison to their original parameters. The process efficiency of our improved combined cleaner of root crop piles (Baranovsky et al., 2011, Kravchenko et al., 2012, Baranovsky et al., 2013, Trukhanska et al., 2013) significantly depends on the degree of separation and the quality of stripping of haulm residues from root crop heads, except for separation of free soil and plant impurities (Jobbágy et al., 2011).

In order to establish empirical regularities characterising the dependence of change in the lengths of leaf stalk remnants h_z on root heads on their stripping using cylindrical rollers, we have conducted laboratory experiments by means of a laboratory unit. A diagram of the laboratory unit is presented in Fig. 1, and a main view of the laboratory unit is provided in Fig. 2.

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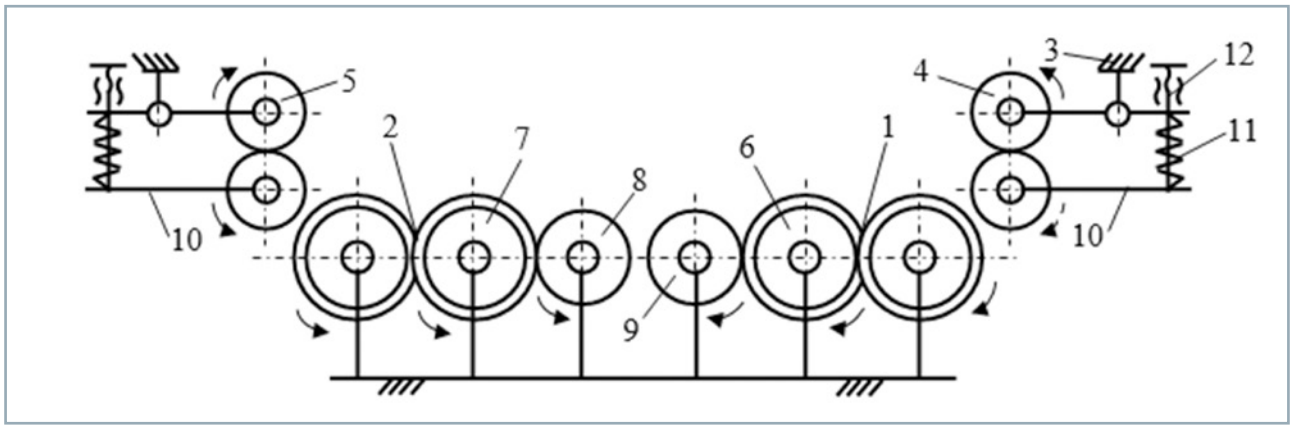

Fig. 1 Structural diagram of the laboratory unit
1 – right stripping system; 2 – left stripping system; 3 – frame; 4, 5 – stripping roller; 6, 7 – auger; 8, 9 – smooth roller; 10 – bracket; 11 – spring; 12 – pair of screws

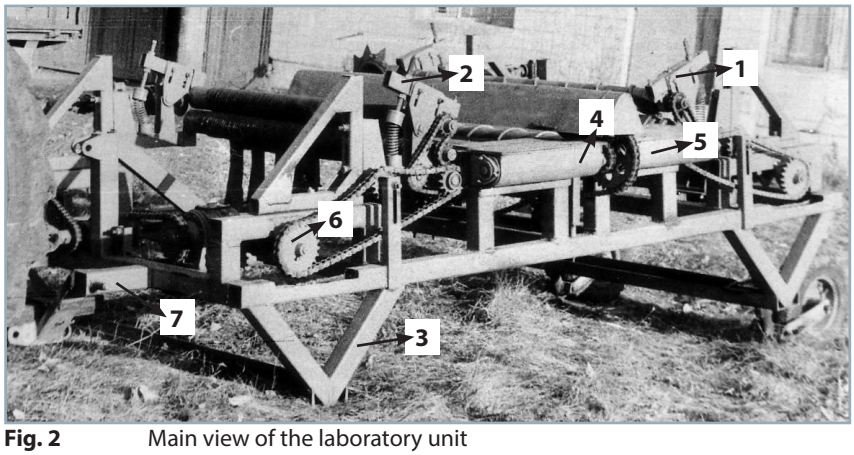

Fig. 2 Main view of the laboratory unit
1, 2 – right and left stripping systems; 3 – frame of the unit; 4, 5 – gear; 6 – chain drive; 7 – hitch tongue

The laboratory unit is a ombination of the right [1] (Fig. 1) and the left [2] systems for stripping of haulm remnants. Each system consists of two pairs of cylindrical stripping rollers [4, 5]; two pairs of screws [6, 7]; and two smooth cylindrical rollers [8, 9] mounted on the frame [3]. Each stripping roller is mounted on the bracket [10], and stripping rollers of each pair are spring-loaded to each other by a spring [11] and a pair of screws [12].

The pressure force between the stripping rollers of each pair was adjusted by compression or extension of the spring by a screw pair. Two haulm remnant stripping systems (Fig. 2) are driven by the right [4] and the left [5] side bevel gears and chain drives [6] respectively.

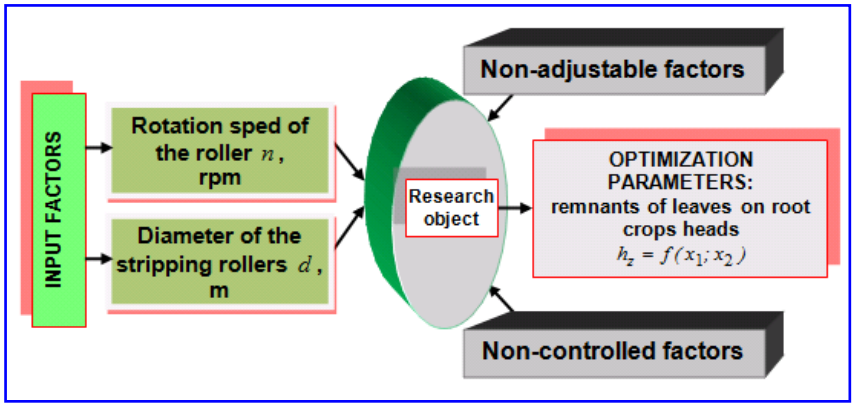

Fig. 3 Structural model of research

The rotation speed of the stripping rollers, which were manufactured smoothly cylindrically shaped and were rubberised, was changed by moving of the sprocket on the drive shaft of the chain drive; the diameter of the stripping rollers was changed by moving of the roller with corresponding diameter in brackets. The laboratory unit is attached to a hitch of the tractor MTZ-80 using a hitch tongue [7].

Root crops with the remnants of leaf stalks on their heads are manually loaded onto augers, which transport root crops to the stripping rollers. The remnants of leaf stalks are dragged by counter-rotation of the stripping rollers between the working surfaces and further stripped.

The root crops of half-hybrid fodder beet "Kyivskyi" manually dug with the remnants of leaf stalks on their heads of the length of at least 10 cm were delivered to the experimental site. The time interval between digging and cutting of the majority of leaves on root crop heads did not exceed 10 minutes. The structural model of experimental research with determination of the length of haulm remnants on root crop heads is presented in Fig. 3.

Results

In order to obtain a regression equation describing a change in the length of leaf remnants on root crop heads depending on the process parameters, we opted for a plan of two-factor experiment at three levels of factor variation. The following parameters were taken as independent variables:

the diameter of the rollers *d* marked as index x_1; the rotation speed of the rollers *n* marked as index x_2.

Considering the fact that the independent variables are heterogeneous during the experiments and have different units, and the numbers expressing values of these factors have different orders, they were brought to a unified system of calculation by transition from real numbers to introduced symbols.

When plotting a design matrix of experiments' marked notations, upper, zero and lower-varying factors were introduced respectively (+1), (0), (-1). The results of marking of variables and levels of their variation are given in Table 1. The relationship between x_1, x_2 and natural *d*, *n* values of the variables was established for dependence according to Lystopad (1998). The design matrix was plotted for the two-factor experiment of CFE 3^2 type (complete factorial experiment), and experiments were conducted in triplicate.

Implementing the plotted design matrix in order to eliminate the impact of non-controlled (NCF) and non-adjustable (NAF) factors (Fig. 3) on the optimisation parameter, it was randomised by applying the method of random balance, which was implemented by taking the sequence numbers of experiments out of the box (Lystopad, 1998).

The sequence, conditions for selection of root crops and determination of the length of leaf remnants on root crop heads were determined by means of standard methods (KD 46.16.01.005-93, 1993). The obtained calculation results were summarised in the table of conditions and results of experimental research. The processing of obtained experimental data array was carried out by well-known techniques and methods of statistical processing using the correlation and regression analysis of the approximating mathematical model $h_z = f(x_1; x_2)$ in order to obtain empirical regression equation (Spirin and Lavrov, 2004).

The determination of the functional distribution law of random variables of the length of leaf remnants h_z on root crop heads was conducted in accordance with standard procedures (KD 46.16.01.005-93, 1993) during the first phase of research processing of experimental data array of the general sample.

Division into classes of experimental data array obtained in general sampling of a continuous random process of dimensional values of the length of leaf remnants h_z on root crop heads was carried out on the basis of Sturgis rule (Royzman and Goroshko, 2012).

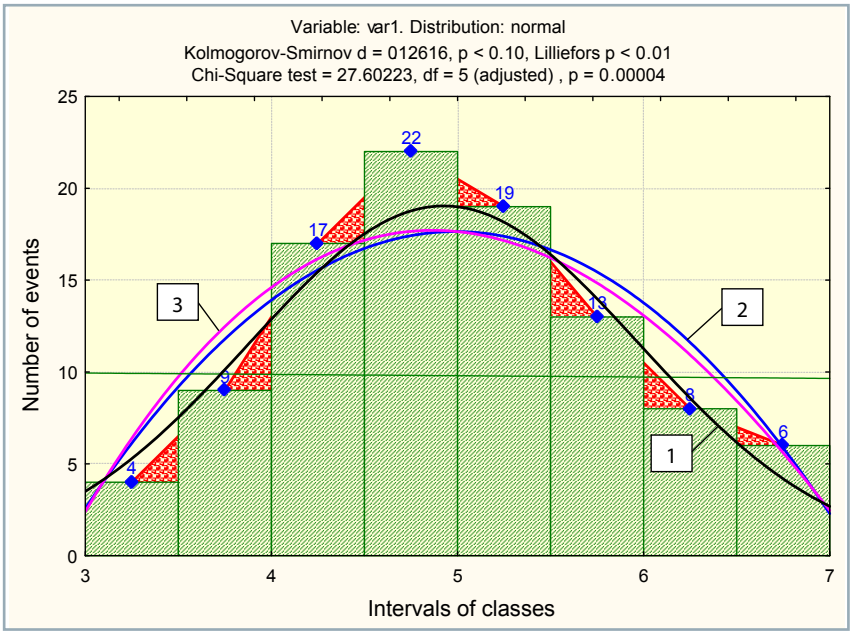

Fig. 4 Histogram and polygon plotted for probability density function h_z
1 – normal distribution law; 2 – square distribution law; 3 – cube distribution law

As a result of general sample processing, histogram and polygon were plotted for the probability density function of dimensional variables of the length of leaf remnants $f(h_z)$ on root crop heads (Fig. 4), each of which reflects a differential law of distribution of random variables or the probability density function of $h_z(x)$.

The analysis of the histogram and polygon plotted for probability density function of random process (Fig. 4) shows that (Pogorely and Tatyanko, 2004):

$$h_z(x) = f(h_z) = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{1}{2}\left(\frac{h_z-\mu}{\sigma}\right)^2} \quad (1)$$

where:
σ – standard deviation
μ – expectation

The numerical values of σ and μ for the probability density function law $h_z(x)$ are presented in Table 2.

Table 1 Results of marking the factors and levels of their variation

Input factors	Notation factor		Varying the spacing factor	Variation level factor (natural/marked)		
	natural	marked				
Diameter of the roller *d* (cm)	*d*	x_1	0.02	10/(-1)	12/(0)	14/(+1)
Rotation speed of the roller *n* (rpm)	*n*	x_2	200	400/(-1)	600/(0)	800/(+1)

Table 2 Numerical values of σ and μ

Function	Value σ	Value μ
$h_z(x)$	4.93	1.05

Then, the differential law of probability density function has the following form:

$$h_z(x) = \frac{1}{4.93\sqrt{2\pi}} e^{\frac{1}{2}\left(\frac{h_z - 1.05}{4.93}\right)^2} \quad (2)$$

The hypothesis of a normal distribution of a sample of random variables is necessary for confirming or rejecting the null hypothesis considering the distribution of random variables. The relation of a random sample of random variables to the general sample is also verified. The fitness of distribution of random variables to the normal distribution law for correction factor λ_s was verified using Kolmogorov-Smirnov "goodness of fit test" K (λ).

In order to build an empirical mathematical model describing the changes in dimensional values of the length of leaf remnants h_z on root crop heads depending on the diameter of the stripping rollers d and rotation speed of the stripping rollers n, a table of the results obtained for points of the composite design of two-factor experiment of CFE 3^2 type was compiled.

After determination of coefficients, the verification of the selected model and evaluation of the statistical significance of coefficients of regression equation using the corresponding *T*- and *F*-tests, the final form of the regression equation for changes in dimensional values of the length of remnants of leaf stalks h_z on root crop heads depending on the diameter of the stripping rollers d and the rotation speed of the stripping rollers n expressed in natural values as a functional $h_z = f(d; n)$ was obtained:

$$h_z = 10.26 - 76.54 / d + 805.72 / n \quad (3)$$

where:
d – diameter of the roller (m)
n – rotation speed of the roller (rpm)

The analysis of the above response surface (Fig. 5) shows that the dimensional values of the length of remnants of leaf

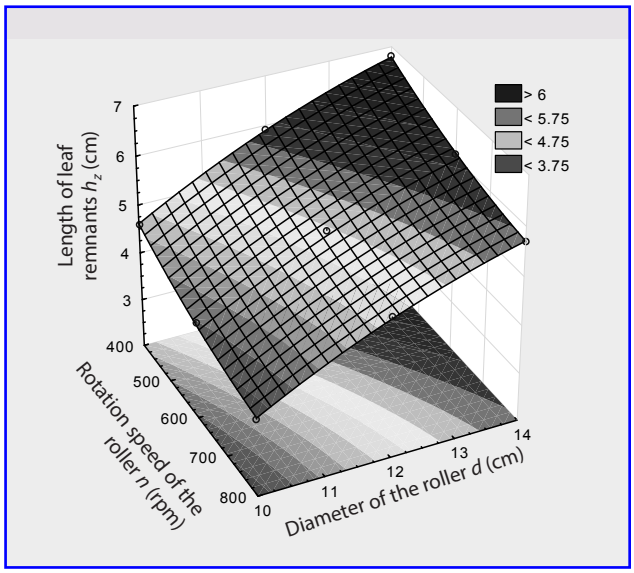

Fig. 5 Response surface of a change in the length of leaf remnants as a functional $h_z = f(d; n)$

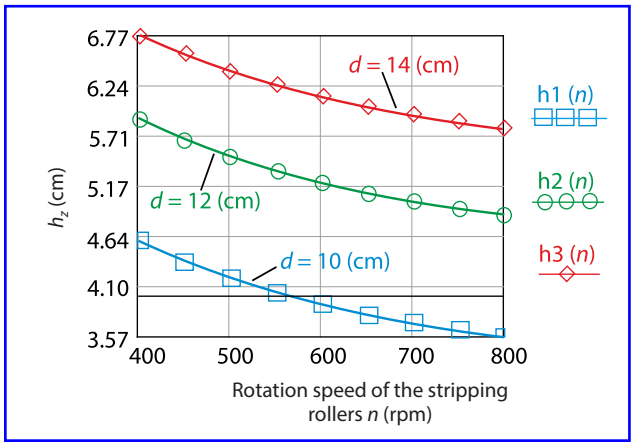

Fig. 6 Dependence of the length of leaf remnants as a functional $h_z = f(n)$

stalks h_z on root crop heads vary in the range of 3.5–6.7 cm, while the dominant factor regulating parameter h_z is the diameter of the stripping rollers – with increasing d within the range of factor variation, there is an increment in the length of leaf remnants h_z from 2.1 cm to 2.3 cm.

The change depending on the rotation speed of the stripping rollers n is inverse – with increase in n within the range of factor variation, there is a decrease in the length of remnants of leaf stalks; but this decrease (approximately from 0.9 cm to 1.2 cm) is significantly lower than the increment of h_z caused by changes in d. These statements are fully supported by the curves presented in Fig. 6.

According to the original requirements for root crop harvesting machinery, the dimensional values of the length of remnants of leaf stalks on root crop heads should not exceed 4 cm, i.e. $[h_z] \leq 4$ (cm) (DSTU, 1993). Then, according to the presented curves and Fig. 5, this condition is provided for values of the diameter of the stripping rollers of $10 \leq d \leq 11$ (cm) and the rotation speed of the stripping rollers of $n \geq 550$ (rpm).

Conclusion

On the basis of the regression equation obtained, the dependence of the changes in the length of crop root leaf remnants h_z on the diameter d and rotation speed n of the stripping rollers was established. It was found that within the limits of the changes $10 \leq d \leq 14$ (cm) and $400 \leq n \leq 800$ (rpm), the length of leaf remnants ranges from 3.5 cm to 6.7 cm. The obtained research results make it possible to optimise the constructive-kinematic parameters of the working bodies – in the form of cylindrical stripping rolls – for kneading of root crop tops. It is established that the most suitable condition for values of the diameter of the stripping rollers of $10 \leq d \leq 11$ (cm) was $[h_z] \leq 4$ (cm), and the most suitable condition for values of the rotation speed of the stripping rollers was $n \geq 550$ (rpm).

The aforementioned methods and results obtained in experimental research can be used by specialists at design engineering bureaus for the development of new or improvement of existing combined cleaning systems of root crop harvesting machinery.

References

BARANOVSKY, V. M. – PIDHURSKY, M. I. – TRUKHANSKA, O. O. – PANKIV, M. R. 2011. Unit for separating dirt of tuberous root. Patent No 65050 UA.

BARANOVSKY, V. M. – PIDHURSKY, M. I. – TRUKHANSKA, O. O. – PANKIV, M. R. 2013. Unit for separating dirt of tuberous root. Patent No 77981 UA.

BARANOVSKY, V. M. 2014. A mathematical model of intensification of separation of impurities from root crops. In Scientific Bulletin of National University of Life and Environmental Sciences of Ukraine, pp. 196–204. (In Ukrainian: Matematychna model intensyfikatsiyi vidokremlennya domishok vid koreneplodiv).

BULGAKOV, V – KORENKO, N. 2007. Mathematical model of sugar beet vibratory digging up. In Acta Technologica Agriculturae, vol. 10, no. 4, pp. 61–65.

DUBCHAK, N. 2013. The resultant speed of the process of root crops contact interaction. In Bulletin of the Ternopil Ivan Puluj National Technical University, vol. 69, pp. 154–161. (In Ukrainian: Rezultuyucha shvydkist protsesu kontaktnoyi vzayemodiyi koreneplodiv).

DSTU 2258-93. Beet harvesters. Kiev: State Standard of Ukraine, 18 pp. (In Ukrainian: Mashyny buryakozbyralni).

JOBBÁGY, J. – GABAJ, D. – ÁRVAY, J. 2011. Evaluation of selected agro-physical properties of a root vegetable. In Acta Technologica Agriculturae, vol. 14, no. 3, pp. 61–65.

KD 46.16.01.005-93. Testing of agricultural machinery. General provisions. Kiev, 34 pp. (In Ukrainian: Vyprobuvannia silskohospodarskoi tekhniky. Osnovni Prykladnaya statystyka).

KRAVCHENKO, I. Ye. – TRUKHANSKA, O. O. – BARANOVSKY, V. M. – PIDHURSKY, M. I. – PANKIV, M. R. 2012. Unit for separating dirt of tuberous root. Patent No 74625 UA.

LYSTOPAD, I. A. 1998. Planning the experiment in studies on agricultural production mechanization. Moscow: Agropromizdat, 88 pp. (In Russian: Planyrovanye эksperymenta v yssledovanyyakh po mekhanyzatsyy selskokhozyaystvennoho proyzvodstva).

POGORELY, L. V. – TATYANKO, M. V. 2004. Sugar beet harvesting machinery: history, construction, theory, forecast. Kiev: Feniks, 232 pp. ISBN 966-651-166-5. (In Ukrainian: Sveklouborochnye mashiny: istorija, konstrukcija, teorija, prognoz).

ROYZMAN, V. – GOROSHKO, A. 2012. Multiple inverse problem. In Journal of Vibroengineering, vol. 14, pp. 1417–1424.

SPIRIN, N. A. – LAVROV, V. V. 2004. Methods of planning and process engineering experiment results. Yekaterinburg: SEI HPE Ural State Technical University, 257 pp. (In Russian: Metodye planyrovanyya y obrabotky rezultatov ynzhenernoho эksperymenta).

STOROZHUK, I. M. – PANKIV, V. R. 2015. Research results of harvesting haulm remnants of root crops. In INMATEH-Agricultural, INMA Bucharest, vol. 46. no. 2, pp. 101–108.

TRUKHANSKA, O. O. – BARANOVSKY, V. M. – KRAVCHENKO, I. Ye. – PANKIV, M. R. – DUBCHAK, N. A. 2013. Unit for separating dirt of tuberous root. Patent No 80478 UA.