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THEORETICAL AND EXPERIMENTAL INVESTIGATIONS OF THE SECOND SERVE OF ROOT CROP PILE COMPONENTS

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Fodder beet root crops in the autumn-winter period are one of the main types of juicy fodder for dairy livestock. Mechanized harvesting of fodder beet roots is a rather complex and energy-consuming technological process. The criteria that meet the requirements for the operation of root-harvesting machines are first of all the quality of digging and separation of impurities from root crops. The purpose of the work was improvement of the process of mechanized digging of fodder beets by an adapted digging-transport combined working body based on analytical and empirical research of the second feeds of constituent components of the dug pile of root crops. Based on the results of experimental studies, empirical regression equations were developed, which functionally describe the change in the second supply of the excavated components of the pile of root crops, depending on the speed of the root-harvesting machine and the rotation frequency of the drive shaft of the adapted digging-transport combined working body. Based on the comparative analysis, it was found that the discrepancy between the theoretical and approximated experimental values of second feeds is 5–10%. The results of the study are a further step in improving the method of optimizing the parameters of working bodies for digging and cleaning root crops from impurities.

Keywords: fodder beets; root-harvesting machine; adapted digging-transporting combined operating number; spherical disc; frequency of cleaning shaft rotation

Fodder beets as an important culture is a valuable component for feeding dairy herd. Currently in the country's agricultural sector, fodder beets cultivated areas have been decreased due to imperfections of root-harvesting machines and inconsistencies of the quality of their work to agrotechnical requirements (Herasymchuk et al., 2018; Pogorely and Tatyanko, 2004; Lord, 2015).

The analysis of the work of blade, fork, vibrating and two-disc digging devices revealed that they significantly damage large roots, a significant loss of small roots takes place. In addition, these types of diggers are constructively and technologically impossible to efficiently combine two technological operations of harvesting – digging of roots with simultaneous separation of residual tops of their heads (Herasymchuk, et al., 2018; Kozachenko, 2004).

One of the reserves to increase the technological indicators of work quality of root-harvesting machines is to improve the technological process of digging root crops using combined diggers that combine a passive spherical disc system and horizontally set above it a shaft that contains elastic cleaning elements. The intensification of the process of fodder beet digging takes place due to the specific kinematic and dynamic factors arising from the cleaning elements simultaneous interaction with the root head and dug out root heap (Herasymchuk et al., 2018; Holovach and Prysiazhny, 2012; Mileusnić et al., 2022).

The efficiency and operational parameters of the technological process of the work of root-harvesting machine during the harvesting of root crops are characterized first of all by its functional indicators of the quality of work and productivity (throughput) of the main transport and technological systems (Baranovsky, 2007; Hevko et al., 2017).

The ability to dig, transport and process an appropriate amount of heap without loading on the working surfaces of transport and technological systems depends on the speed of movement of the root-harvesting machine, agro-biological properties of root crops, and working conditions of the root-harvesting machine (Bulgakov et al., 2017; Baranovsky et al., 2017).

The corresponding amount of heap coming to the root-harvesting machine transportation and technological systems depends on an adequate total second supply of the constituent components of the heap – root crops and impurities (Bulgakov et al., 1999).

The secondary feed of the constituent components of impurities consists of the second supply of soil impurities and the second supply of plant impurities. In this case, the second feed of soil impurities consists of the second feed of impurities of free soil and the second feed of stuck soil (Bulgakov et al., 2019; Pogorely and Tatyanko, 2004). The second supply of vegetable impurities consists of the second supply of weeds and the second supply of residues of the hog on the heads of roots (Storozhuk and Pankiv, 2015).

As for the root crops digging operating number synthesis, adapted combined operating numbers

in particular, a scientific treatment of the root crops digging process, such a component in the gradient second serve of the picked up piles, should be taken into consideration, depending on the digging operating number parameters, root crop sizes, and the root-harvesting machine operation conditions (Baranovsky, 2007; Baranovsky and Ramsch, 2008; Baranovsky and Potapenko, 2017; Hevko et al., 2016).

The analysis of the latest investigations and publications confirmed that the problem of experimental investigations of the component ingredient second serve of the adapted digging-transporting combined operating number picked up piles had not been studied, beside the results of theoretical investigation of the scientific task in question (Špokas et al., 2016; Skalický, 2003).

The purpose of the work is the empirical substantiation of dependence of a change in the second feed of constituent components of the excavated pile of fodder beets from a change in the translational speed of the root-harvesting machine and the rotation frequency of the cleaning shaft of the adapted digging-transport combined working body.

The adequacy of developed theoretical models of the second feed of constituent components of the excavated pile of fodder beets is established based on comparison with the corresponding indicators obtained as a result of field experiments, or the process of digging fodder beets by an adapted excavation-transport combined working body.

Material and methods

Many created designs of working tools, digging tools assemblies, and layout schemes require a differentiated approach in the selection, calculation, design, research, and implementation of new developments into production.

Therefore, a classified approach taking into account peculiarities of working bodies, layout schemes, and methods of operation, provides the opportunity for analysis and synthesis of necessary structural and technological scheme of a combined digger for specific working conditions.

The variety of root digger design schemes is connected directly with the process of harvesting and with structural and technological requirements for digging quality, root cleaning, and transportation. Based on carried out identification (analysis and synthesis) of analogues of existing digging tools, the advanced designs of combined root diggers, combining simultaneously all the advantages and benefits of the existing spherical single plate digger and the possibility of use in excessive soil moisture and weed-infested crop conditions, were submitted, Fig. 1 (Herasymchuk et al., 2018).

A combined digger consists of two spherical discs [1] (Fig. 1) set at an angle α to the axis of root row. Discs [1] are installed on their axes of rotation [2]. The root directing device [3] is set on the front area of the working edge of each spherical disc [1].

Above the discs, perpendicular to the direction of the speed of motion of the digger V_M ($m \cdot s^{-1}$), there is a horizontal drive shaft [4]. The horizontal drive shaft includes a reel [5] that bears flanges [6]. The reel of the horizontal shaft is made of three sections.

The axes [7], [8], [9] are set adherently between the flanges of the reel on its axis range; the flat elastic blades [10], [11] are fixed on them. The axes [7] and [8] of the two end sections [12], [13] form a truncated cone, the end sections [12], [13] are directed to each other by smaller bases. The axis [9] of the intermediate section [14] forms a cylinder. The planes that pass through the axes [7], [9] or [8], [9] of the contiguous sections [12], [14] or [13], [14] are set at an obtuse angle.

When the digger moves, the root directing device [3] (Fig. 1) shifts knocked out of row roots to its centre, and the spherical disc [1] digs roots. Along with digging roots by rotating the drive shaft [4], the flat elastic blades [10], [11] of the two end sections [12], [13] interact with the heads of roots, while simultaneously cleaning the heads of roots from residue tops of two adjacent rows, and a destruction of the lumps of soil occurs.

In addition, the flat elastic elements of the intermediate section [14] simultaneously interact with roots and lumps of soil, purify the surface of roots of adhering soil, destroy the lumps of soil, and push heap, located in the space of spherical discs, which speeds up

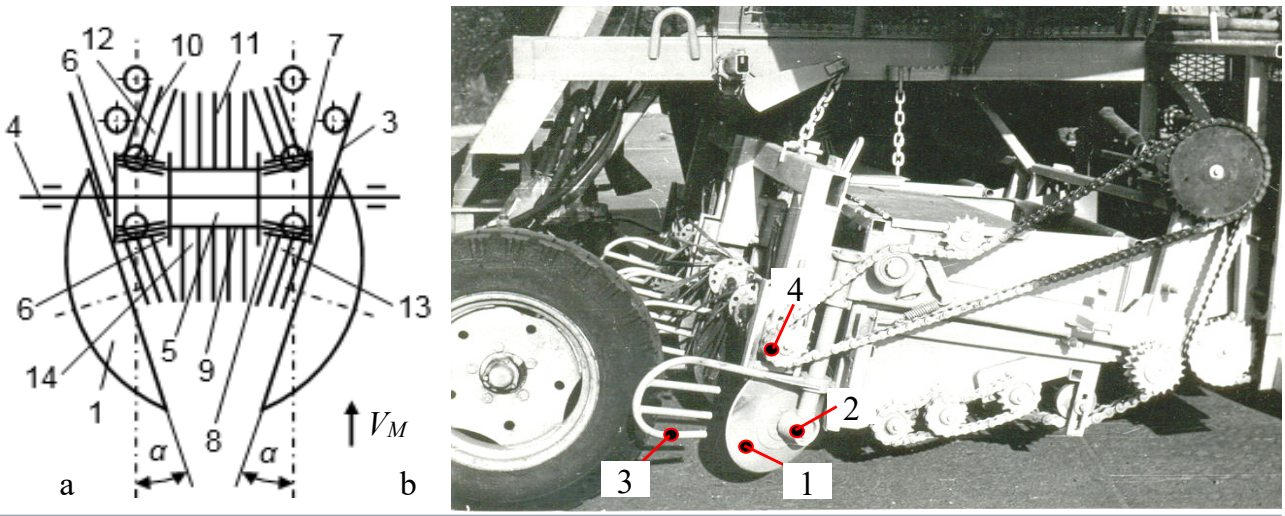


Fig. 1 Block diagram (a) and general view of the combined digger (b)

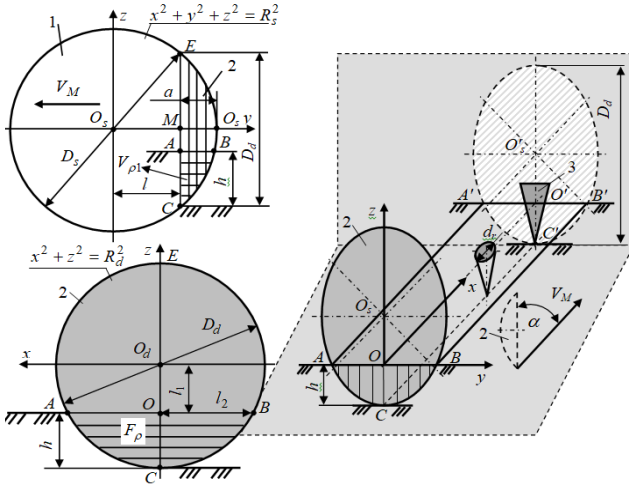


Fig. 2 Scheme for calculating the technological process of digging a pile of root crops
1 – sphere; 2 – spherical disc; 3 – root crop

its supply to the following transport technology systems of root-harvesting machines.

To substantiate the efficiency of the technological process of digging root crops by root-harvesting machine, a complex scheme (Fig. 2) is considered.

In the course of motion of the adapted digging-transporting combined operating number (Baranovsky et al., 2006) with a translational working speed V_M (m·s^{-1}) at time t (s), a spherical disc [2], the depth of which is h (m), passes the path OO' and cuts a groove in the soil $ACBB'C'A'A$, the profile of which at the level of the soil surface is formed by the contour of figure $ABB'A'A$. Within the space of the groove, there is soil, root crops [3], and vegetable impurities, which in the sum make up the total flow of heap.

As a result of theoretical analysis of the technological process of root crops digging, taking advantage of adapted digging-transporting combined operating number (Fig. 1, Fig. 2), theoretical-calculation optimal mathematic models, which specify the change of the component ingredient second serve of the pile, depending on adapted digging-transporting combined operating number parameters (Baranovsky et al., 2006), agri-biological features of root crops planting (Jobbágy et al., 2011; Storozhuk and Pankiv, 2015) and root-harvesting machine operation conditions, have been obtained (Gurchenko et al., 2001; Baranovsky et al., 2014; Júnnyor et al., 2022):

– general root crop pile second serve W (kg·s^{-1}):

$$W = V_M N \sin\alpha \left\{ \frac{F_\rho \rho_s}{8} - \frac{U_r}{2V_M t \sin^2\alpha \sqrt{aD_d - a^2}} \left(\frac{\rho_s C_V}{\rho_r} - 1 \right) + \right. \quad (1)$$
$$\left. - + 2\sqrt{aD_d - a^2} \left[U_t (\mu + \eta) + \lambda \right] \right\}$$

– general admixture second serve W_a (kg·s^{-1}):

$$W_a = V_M N \sin\alpha \left\{ \frac{\rho_s}{8} \left(F_\rho - 4h \frac{U_r C_V}{V_M t \rho_r \sin^2\alpha \sqrt{aD_d - a^2}} \right) + \right. \quad (2)$$
$$\left. - + 2\sqrt{aD_d - a^2} \left[U_t (\mu + \eta) + \lambda \right] \right\}$$

– root crop second serve W_r (kg·s^{-1}):

$$W_r = \frac{2V_M N U_r \sin\alpha}{\sqrt{aD_d - a^2}} \quad (3)$$

– general soil admixture second serve W_s (kg·s^{-1}):

$$W_s = \frac{\rho_s V_M N \sin\alpha}{8} \left(F_\rho - 4h \frac{U_r C_V}{V_M t \rho_r \sin^2\alpha \sqrt{aD_d - a^2}} \right) \quad (4)$$

– general plant admixture second serve W_p (kg·s^{-1}):

$$W_p = 2V_M N \sin\alpha \sqrt{a(D_d - a)} \left[U_t (\mu + \eta) + \lambda \right] \quad (5)$$

– beet top remains second serve on the root crop tops W_{bt} (kg·s^{-1}):

$$W_{bt} = 2V_M U_t \mu_i \sin\alpha \sqrt{a(D_d - a)} \quad (6)$$

where:

$$F_\rho = \int_{R_d - a}^{R_d} (\sqrt{R_s^2 - z^2} - \sqrt{R_s^2 - R_d^2}) dz =$$

$$= \left(\frac{0.25D_d^2}{h} + h \right)^2 \left(\arcsin \frac{D_d h}{0.25D_d^2 + h^2} - \arcsin \frac{h(D_d - 2a)}{0.25D_d^2 + h^2} \right) +$$

$$+ (D_d - 4a)\left(0.25D_d^2 - h^2\right) -$$

$$- (D_d - 2a)\sqrt{\left(0.25D_d^2 - h^2\right)^2 - 4h^2 a(D_d - a)}$$

$$R_s = \frac{R_d^2 + a^2}{2a}$$

where: N – row number (number); α – fixing angle of the spherical disc relatively to the root crop row axis (degree); ρ_s, ρ_r – specific weight of soil and root crop (kg·m^{-3}); U_t, U_r – beet top and root crop productivity (kg·m^{-2}); C_V – a coefficient that takes into account the volume of the underground part of root crops diameter d_r; F_p – cross-sectional area $AOBC$ of the cutting edge of the spherical disc (m^2); D_d, a – diameter and depth of the spherical disc correspondingly (m); μ_i – the ratio of the remains of the tops of root crops in the area of 1 m^2; η_i – loss ratio of root crops in the area of 1 m^2; λ_i – specific weight of weeds in 1 m^2 (kg·m^{-2}); h – spherical disc depth (m); R_s – sphere radius (m)

For the initial conditions D_d = 0.45 m (Herasymchuk et al., 2018), a = 0.1 m, α = 30° (Herasymchuk et al., 2018; Špokas et al., 2016], ρ_s = 1500 kg·m^{-3}, ρ_r = 550 kg·m^{-3} (Storozhuk and Pankiv, 2015; Baranovsky and Potapenko, 2017; Gurchenko et al., 2001), and the maximum allowable values of the components μ = 0.1 (10%), η = 0.08 (8%), λ = 0.1 kg·m^{-2} (Pogorely and Tatyanko, 2004; Bulgakov et al., 1999; Baranovsky et al., 2014), according to the agrotechnical requirements for root harvesters, graphical dependences of the change in the second supply of the components of the heap of root crops on the speed of movement were plotted $W_i = f_{Wi}(V_M)$. At the same time, the yield of fodder beet roots was taken as U_r = 1.5, 3.5, and 5.5 kg·m^{-2}, and the beet tops as U_{bt} = 0.5, 1.5, and 2.5 kg·m^{-2} (Herasymchuk et al., 2017;

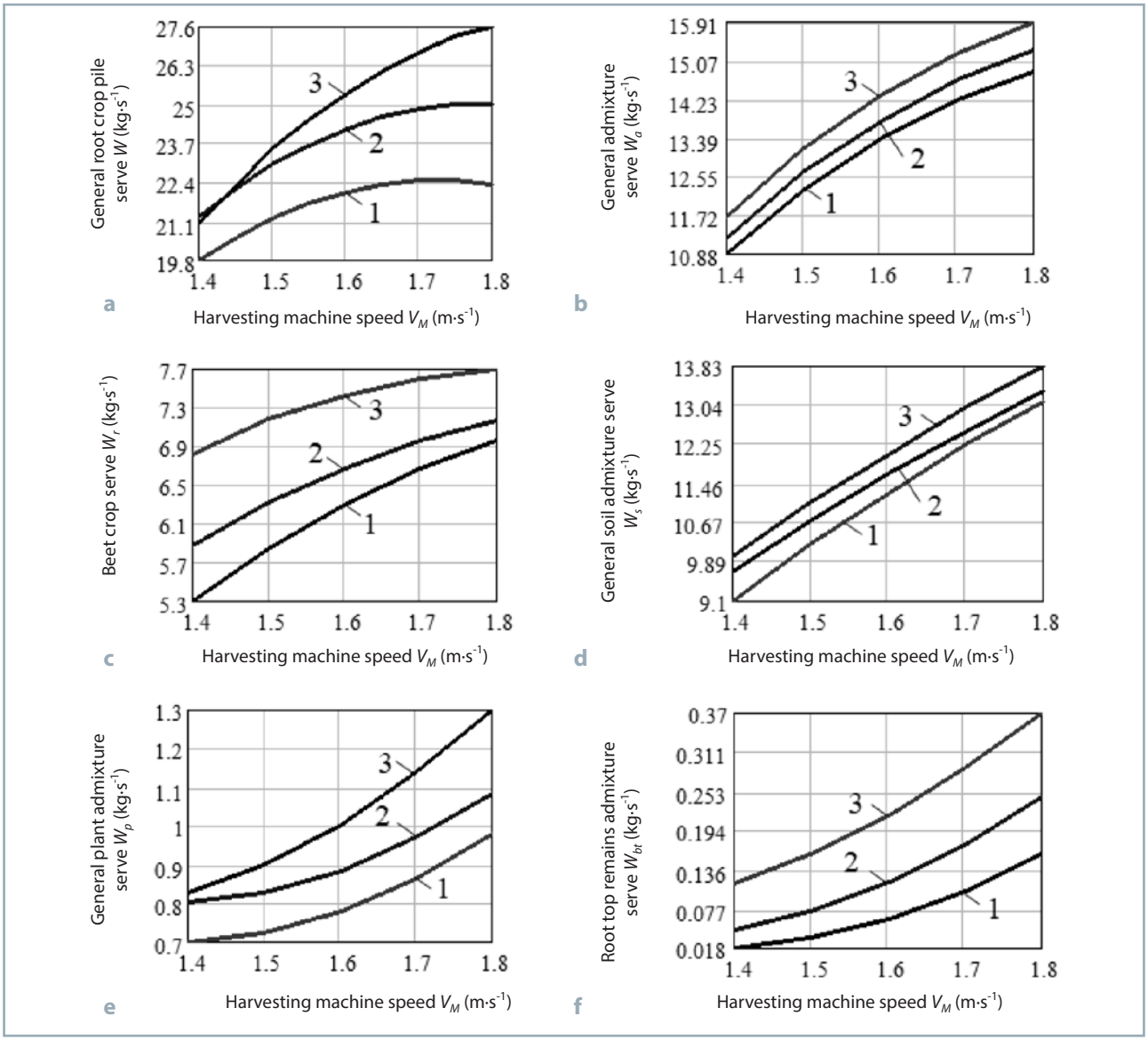


Fig. 3 The dependence of the heap feed on the speed of the harvester as a function: a – general root crop pile serve $W = f_W(V_M)$; b – general admixture serve $W_a = f_{Wa}(V_M)$; c – beet crop serve $W_r = f_{Wr}(V_M)$; d – general soil admixture serve $W_s = f_{Ws}(V_M)$; e – general plant admixture serve $W_p = f_{Wp}(V_M)$; f – root top remains admixture serve $W_{tr} = f_{Wtr}(V_M)$

Storozhuk and Pankiv, 2015), the number of rows of root crops dug out with a spherical disc was $K = 3$.

The graphical interpretation of the theoretical dependencies, which are constructed according to Eqs (1)–(6), is shown in Fig. 3.

The analysis of graphic constructions (Fig. 3) shows that: the total second feed of a heap varies from 19.8 to 27.6 kg·s^{-1} (Fig. 3a); the total supply of impurities of a heap varies from 10.9 to 15.9 kg·s^{-1} (Fig. 3b); root crops supply of a heap varies from 5.3 to 7.7 kg·s^{-1} (Fig. 3c); the total supply of soil impurities of a heap varies from 9.1 to 13.8 kg·s^{-1} (Fig. 3d); the total supply of plant impurities of a heap varies from 0.7 to 1.3 kg·s^{-1} (Fig. 3e); the supply of impurities of the tops of leaves on the heads of root crops of a heap varies from 0.2 to 0.37 kg·s^{-1} (Fig. 3f) within the range of the speed of movement of the root-harvesting machine from 1.4 to 1.8 m·s^{-1}.

To confirm theoretical ideas in terms of finding regulations of the second serve change of the component ingredients of root crop piles, experimental investigations of root crop digging have been made, taking advantage of adapted digging-transporting combined operating number as a part of improved three-row root-harvesting machine (Gurchenko et al., 2001; Baranovsky et al., 2014), based on construction of the plan-matrix and the implementation of planned factor experiment 3^2 (Sauro and Lewis, 2013).

Factors characteristics and their varying levels are presented in Table 1.

Table 1 Factor characteristics and their varying levels

Name of factor	Factor level value
Harvesting machine speed V_M (m·s^{-1})	1.4(-1)–1.6(0)–1.8(+1)
Frequency of cleaning shaft rotation n_o (rpm)	400(-1)–500(0)–600(+1)

Respond function (optimization parameter), that is, the component ingredient second serve of the root crop piles of half hybrid fodder beet "Kyivskyi", found experimentally, was determined as the mathematic model of the second level polynomial.

The technical parameters of the process of implementing field experiments (the process of digging fodder beets) were as follows: the average yield of root crops was 34.5 t·ha^{-1}; the average yield of beet tops – 13.5 t·ha^{-1}; row spacing – 0.45 m; the diameter of the spherical disc – 0.45 m; disc travel depth – 0.09 ±0.015 m; angle of "attack" – 30°; the external diameter of the drive shaft – 0.65 m; the length of the experimental plot of root crops of one repetition – 0.25 m; the number of repetitions of one planned experiment – 3.

The procedure for implementing experiments and processing experimental data was carried out according to a well-known technique.

After the passage of the test plot by the root harvester (digging out of roots), the dug-out heap was divided into its constituent components (parts) – roots, soil, and plant impurities.

The components of the heap were weighed alternately on a scale with an accuracy: root crops and free soil ±0.1 kg; all others ±0.05 kg.

The numerical values of the second supply of the compound component Wi were determined by the formula $W_i = M_i/t_{Ni}$, where M_i is the mass of the i-th component (kg), and t_{Ni} is the time of digging out the root crops of the test length of a section 25 m long at the i-th speed of the root harvester (s).

The obtained values of the second supply of components of the heap of root crops were recorded in the corresponding columns of the plan-matrix of 3^2 experiment.

In this case, the total number of experiments of one repetition was $3^2 = 9$.

Results and discussion

The type of the empirical model (polynomial of the 2nd degree) was taken as the highest value of the coefficient of multiple determination D (Sauro and Lewis, 2013).

At the same time, the adequacy of the model was checked using the Fisher F-test, and the significance of the coefficients of regression equation was checked using the Student's t-alpha test (Sauro and Lewis, 2013).

For the probability level $P = 0.95$, the following values were obtained: the coefficient of multiple determination $D = 0.997$, while D is significant with a probability $p = 0.995$; multiple correlation coefficient $R = 0.998$; standard deviation $s = 1.014$; Fisher F-test $F = 180.285$; Student's t-alpha test $t = 2.305$, while all the calculated coefficients of regression equation are significant.

The results of the implementation of planning matrix for planning an experiment of type 3^2 are shown in Table 2.

According to the indicators of the second feed of components of the heap when digging out the roots of fodder beets (Table 2) and the corresponding theoretical indicators of the second feed (Fig. 3, curve 2, U_r =3.5 kg·m^{-2}, U_{bt} =1.5 kg·m^{-2}), comparative diagrams were built, Fig. 4.

It has been established that the values of the second feeds W_i (Fig. 2), which are obtained from the results of theoretical studies according to Eqs (1)–(6), do not differ significantly from the corresponding results of experimental studies, which are shown in Table 2.

At the same time, the difference between the theoretical indicators and non-approximated experimental values of the second feeds W_i is 5–15%.

The regression equation of fodder beet picked up pile second serve change, taking advantage of adapted digging-transporting combined operating number, has been obtained in code and real values depending on the velocity of movement V_M of root-harvesting machine and the frequency of cleaning shaft rotation n_o as a function $W_i = f_{Wi}(V_M)$:

– general beet crop pile second serve W (kg·s^{-1}):

$$W = -38.87 + 58.29\,V_{M1} - 0.01\,n_o - 26.25\,V_M^2 + 0.07\,V_M n_o - 0.1 \cdot 10^{-3} n_o^2 \quad (7)$$

– general admixture second serve W_a (kg·s^{-1}):

$$W_a = -37.84 + 54.88\,V_{M1} - 0.004\,n_o - 13.33\,V_M^2 - 0.004\,V_M n_o + 6.66 \cdot 10^{-6} n_o^2 \quad (8)$$

Table 2 Indicators of the second feeds of components of the heap when digging out of fodder beet roots

Experiment number	V_M (m·s^{-1})	n_o (rpm)	Average value of triplicates					
			W (kg·s^{-1})	W_a (kg·s^{-1})	W_r (kg·s^{-1})	W_s (kg·s^{-1})	W_p (kg·s^{-1})	W_{bt} (kg·s^{-1})
1	1.4	400	17.3	9.8	8.2	8.5	0.64	0.14
2	1.6	400	19.4	9.5	7.5	8.9	0.53	0.11
3	1.8	400	18.9	9.2	7.8	8.7	0.61	0.04
4	1.4	500	17.1	12.6	8.8	9.8	0.60	0.18
5	1.6	500	21.3	12.2	9.1	11.8	0.55	0.21
6	1.8	500	22.5	11.9	8.0	11.1	0.59	0.16
7	1.4	600	17.1	14.3	9.3	12.2	0.63	0.44
8	1.6	600	20.2	12.0	9.0	12.9	0.71	0.24
9	1.8	600	23.4	13.2	10.1	12.3	0.81	0.21

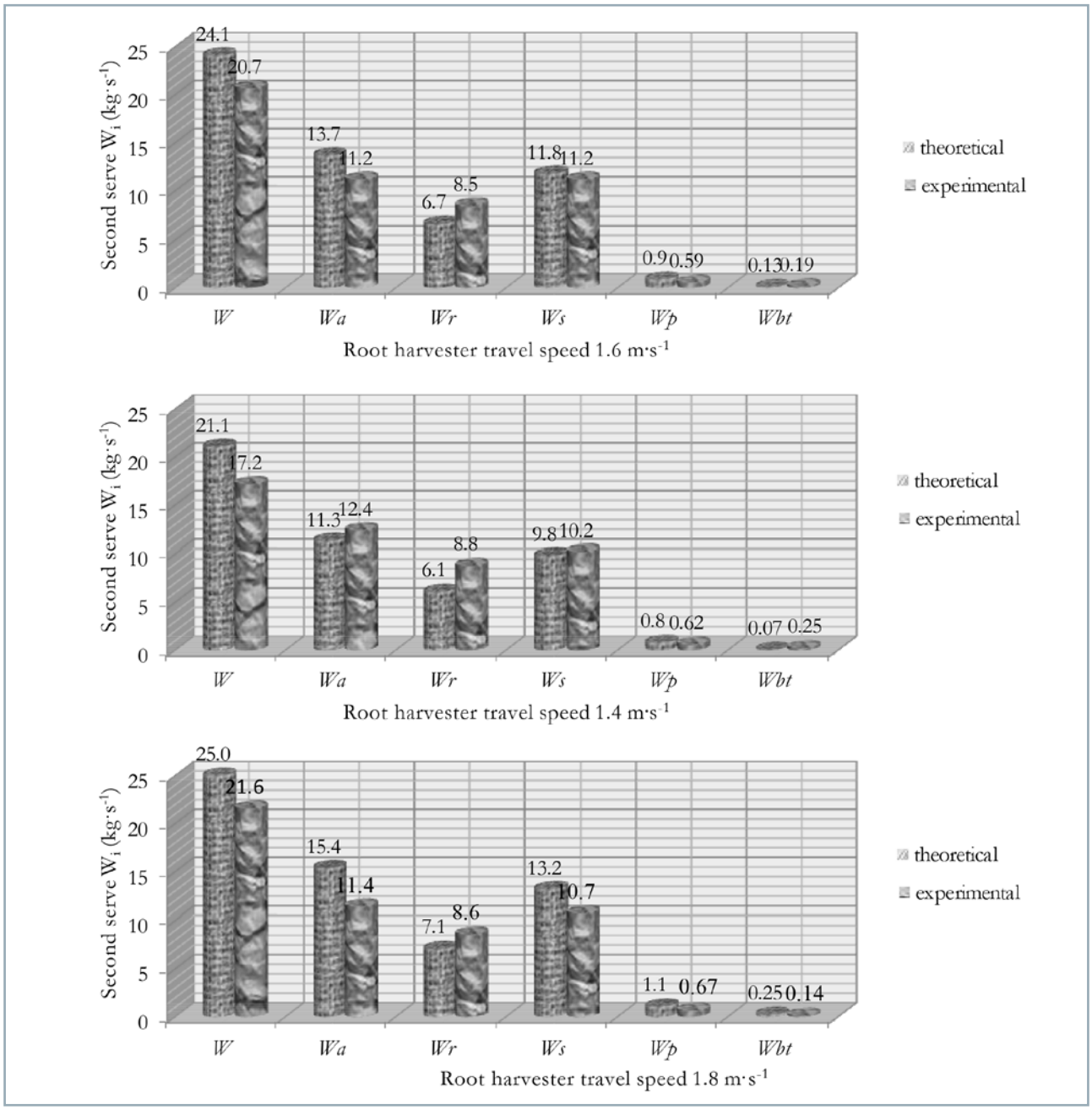


Fig. 4 Diagram of the second feeds of components of the heap of fodder beet

– beet crop second serve W_r (kg·s^{-1}):

$$W_r = 5.31 + 11.54\,V_{M1} - 0.04\,n_o - \\ - 4.17\,V_M^2 + 0.01\,V_M n_o + 1.83 \cdot 10^{-5} n_o^2 \quad (9)$$

– general soil admixture second serve W_s (kg·s^{-1}):

$$W_s = -34.51 + 24.89\,V_{M1} + 0.07\,n_o - \\ - 4\,V_M^2 - 0.005\,V_M n_o - 6 \cdot 10^{-5} n_o^2 \quad (10)$$

– general plant admixture second serve W_p (kg·s^{-1}):

$$W_p = 8.76 - 6.71\,V_{M1} - 0.01\,n_o + \\ + 1.54\,V_M^2 + 0.005\,V_M n_o + 5.66 \cdot 10^{-6} n_o^2 \quad (11)$$

– root top remains admixture second serve on the root crop tops W_{tr} (kg·s^{-1}):

$$W_{tr} = 0.85 - 0.95\,V_{M1} - 0.0007\,n_o + \\ + 0.67\,V_M^2 - 0.002\,V_M n_o + 2.17 \cdot 10^{-6} n_o^2 \quad (12)$$

Regression Eqs (7)–(12) can be applied for finding the second serve of pile component ingredients depending on the change of V_M and n_o of adapted digging-transporting combined operating number within such limits: the speed of movement of the root harvester on a section of the headland length of 25 m $1.4 \leq V_M \leq 1.8$ m·s^{-1}; the frequency of growing the drive shaft of the adapted digging-transport combined working body $400 \leq n_o \leq 600$ rpm.

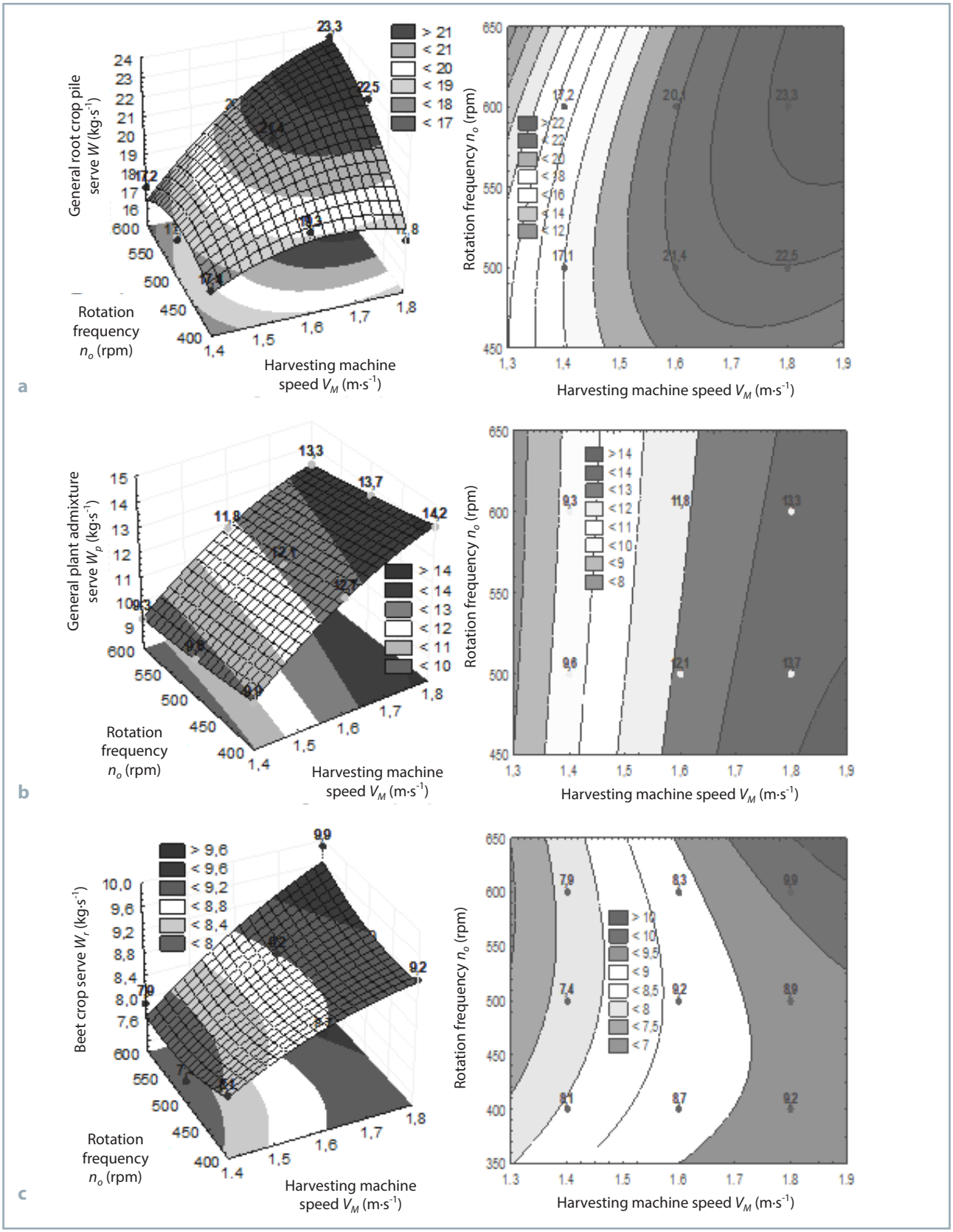


Fig. 5 Respond surface and its two-dimensional cross-section of the second serve of beet root crops pile component ingredient change depending on root-harvesting machine movement velocity V_M and adapted digging-transporting combined operating number cleaning shaft rotation frequency n_o
a – general root crop pile serve W; b – general admixture serve W_a; c – beet crop serve W_r

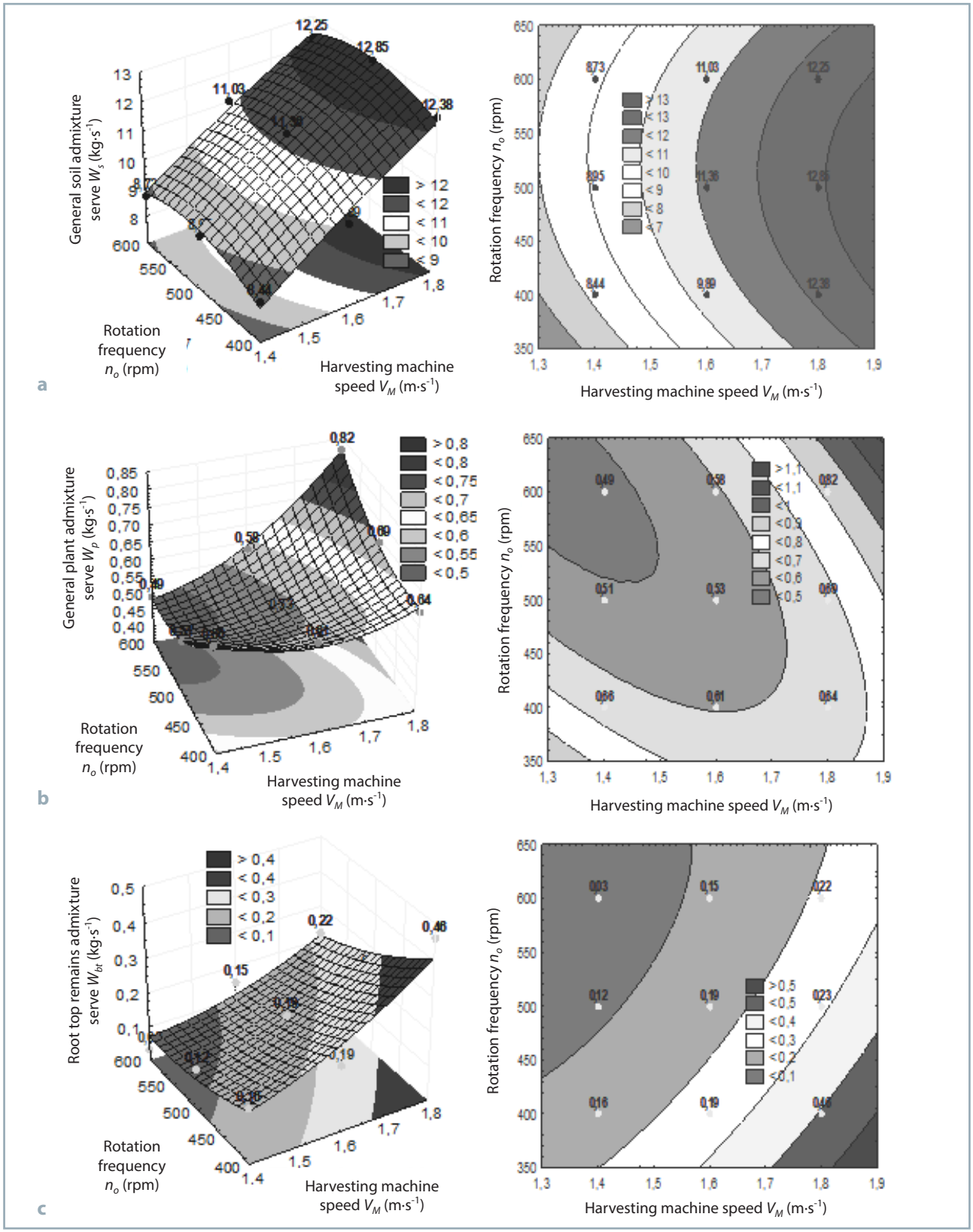


Fig. 6 Respond surface and its two-dimensional cross-section of the second serve of beet root crops pile component ingredient change depending on root-harvesting machine movement velocity V_M and adapted digging-transporting combined operating number cleaning shaft rotation frequency n_o

a – general soil admixture serve W_s; b – general plant admixture serve W_p; c – root top remains admixture serve W_{tr}

According to regression equation, the surface and two-dimensional cross-section correspondingly of the respond surface second serve of root crop pile component ingredients, have been built, and they are presented in Figs 5 and 6.

The analysis of presented graphic dependences (Figs 5 and 6) shows that there is close dependence of the seconds feed change of root crop piles admixture component ingredients on the change of root-harvesting machine operation velocity V_M and rotation frequency of cleaning shaft of the digger. Here, the root-harvesting machine operation speed of movement V_M being increased, results in the increase of the seconds feed W_i of root crop pile component admixtures in proportion, and vice versa, except those of the seconds feed of root crops themselves (Fig. 5c).

Function optimum $W_{i(\max;\ \min)} = f_{Wi}(V_M;\ n_o)$ is obtained under the maximum values of mentioned factors.

Based on the response surfaces (Figs 5 and 6), it was found that the approximated values of the second feeds of components of heap vary in the range: general beet crop pile second serve W from 17.1 to 23.3 kg·s^{-1} (Fig. 5a); general admixture second serve W_a from 9.6 to 14.2 kg·s^{-1} (Fig. 5b); beet crop second serve W_r from 7.6 to 9.9 kg·s^{-1} (Fig. 5c); general soil admixture second serve W_s from 8.5 to 12.9 kg·s^{-1} (Fig. 6a); general plant admixture second serve W_p from 0.3 to 0.8 kg·s^{-1} (Fig. 6b); beet top remains second serve on root crop tops W_{bt} from 0.12 to 0.22 kg·s^{-1} (Fig. 6c).

The divergence of the corresponding theoretical (Fig. 3) and approximated experimental (Figs 5 and 6) values of the second feeds of constituent components of heap is on average 5–10%.

Thus, it can be stated that the developed theoretical models (1)–(6) are adequate to the empirical regression equations (7)–(12).

The developed theoretical (1)–(6) and empirical (7)–(12) models make it possible to determine the second feed of heap components in the process of digging out root crops only with a spherical single-disc digger.

To determine the second feed when digging out root crops with another type of digger, for example, a vibration or disc digger, it is necessary to clarify the contact area F_ρ of the working body with the soil. The component F_ρ depends on the design and parameters of digger's working bodies and the depth of digging out of root crops by this type of digger.

In addition, the physical and mechanical parameters of the soil, the type of soil, and the climatic conditions of operation of the root harvester have a significant effect on the indicators of the second supply of impurities components (soil, plant residues, and tops).

The second supply of root crops will also significantly depend on the agro-biological characteristics and physical and mechanical properties of root crops (variety, yield and density of root crops, an indicator of the volume density of root crops and other properties).

Thus, it is possible to compare the obtained results of second feeds with the results of other researchers only by comparing them with the results obtained for a specific type of digger and specific conditions for operation of the root harvester.

Conclusion

Obtained theoretical dependencies (1)–(6) and the regression equations (7)–(12) as a result of carried out experimental investigations can be applied to find the second serve of root crop pile component ingredients depending on the parameters of the digging operating number, root crop sizes, and technological conditions of root-harvesting machine operation.

Besides, they can be used for calculation of the construction-technological parameters of other root-harvesting machine transporting-cleaning operating numbers.

The obtained experimental data of the second supply of components of impurities are the initial data for substantiating the parameters of the working bodies of root-harvesting machines cleaning systems. At the same time, on the basis of comparison of the results of the second supply of components of impurities study with and without the use of a cleaning shaft, it is possible to justify the correction factor. This will make it possible to clarify the developed mathematical models (1)–(6), which describe the technological process of digging root crops with the proposed digger.

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