RESULTS OF LABORATORY INVESTIGATIONS OF SOIL SCREENING ABILITY OF A CHAIN DIGGER WITH ASYMMETRIC VIBRATOR ARRANGEMENT

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РЕЗУЛЬТАТЫ ЛАБОРАТОРНЫХ ИССЛЕДОВАНИЙ ПРОСЕВАЕМОСТИ ПОЧВЫ НА ПРУТКОВОМ ЭЛЕВАТОРЕ С АСИММЕТРИЧНЫМ РАСПОЛОЖЕНИЕМ ВСТРЯХИВАТЕЛЕЙ

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ABSTRACT

The increased yield of onion sets through the use of high-yielding hybrids as seed material entails an increase in weight and number of onion bulbs per one running meter. Consequently, the onion set heap supply from the surface of modern harvesters digging over the separating working parts is also increased. However, these harvesters do not ensure complete removal of soil impurities during onion set harvesting in the traditional onion set production conditions. In this regard, it is necessary to carry out investigations to identify areas on the surface of a chain digger with asymmetric vibrator arrangement and minimum value of soil screening, as well as to develop recommendations and proposals for their improvement.

The paper describes a procedure and results of laboratory tests of a chain digger with asymmetric vibrator arrangement to determine soil screening ability on its surface. It was found out that the greatest value of the screened soil mass, regardless of the supply of soil impurities, was observed at the wave length attenuation section of the loaded strand in the chain digger due to elliptical vibrator impact relevant to the length of the chain digger $L_{EL} = 1020$ mm.

The paper provides the results of laboratory tests of a chain digger with asymmetric vibrator arrangement and determines the length-width soil screening relationship.

РЕЗЮМЕ

В связи с увеличением урожайности лука-севка, в результате использования в качестве семенного материала высокоурожайных гибридов происходит увеличения массы и количества луковиц лука-севка на одном погонном метре. Следовательно, увеличивается подача вороха лука-севка с поверхности подкапывающих на сепарирующие рабочие органы современных лукоуборочных машин, которые не обеспечивают полноту выделения почвенных примесей при уборке лука-севка в современных условиях производства лука-севка. В связи с этим, необходимо проведение исследований по выявлению участков на поверхности пруткового элеватора с асимметричным расположением встряхивателей с минимальной величиной просеивания почвы и разработка рекомендаций и предложений по их повышению.

Описана методика проведения и результаты лабораторных исследований пруткового элеватора с асимметричным расположением встряхивателей по определению просеваемости почвы на его поверхности.

Определено, что наибольшее значение массы просеянной почвы вне зависимости от значения подачи почвенных примесей наблюдается на участке затухания длины волны рабочей ветви пруткового элеватора от воздействия эллиптического встряхивателя соответствующей длине пруткового элеватора $L_{EL} = 1020$ мм.

В статье приведены результаты лабораторных исследований пруткового элеватора с асимметричным расположением встряхивателей и определена зависимость просеивания почвы по длине и ширине.

INTRODUCTION

The continuing extensive investigations in the field of mechanized production technology of onion sets *(Aksenov A.G., Sibirev A.V., Emelianov P.A., 2018)* do not solve the problems associated with poor design of digging and separating parts of onion harvesters, as evidenced by the contents of the soil lumps commensurable with bulbs in the heap being separated *(Sibirev A.V., Aksenov A.G., Dorokhov A.S., 2018)*. To intensify separation of the onion set heap, the separating surface of the chain digger *(Tauseef Asghar M., Abdul Ghafoor, Anjum Munir, Muhammad Iqbal, Manzoor Ahmad, 2014)* is made with rods *2* located on chains *1* (Fig 1).
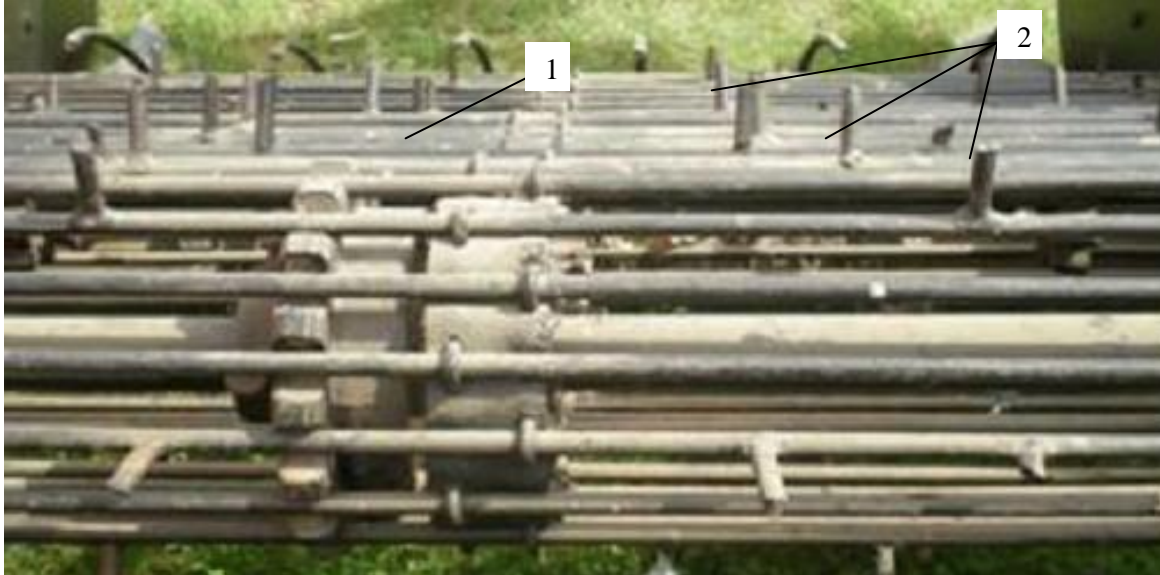

Fig. 1 – Separating chain digger
1 – chain; 2 – rod

The main purpose of rods *2* located on chains *1* is the destruction of soil lumps coming from the digging part of the harvester. However, in addition to the process of destruction of the soil lumps themselves, intensive force action of rods *2* on the root crops occurs, which increases the damage to the separated products.

There is a known design of separating chain digger (Fig. 2), wherein a passive two-plate vibrator *4* located under the upper strand of the chain digger apron *3* intensifies the separation process (*Natenadze N., 2016).*
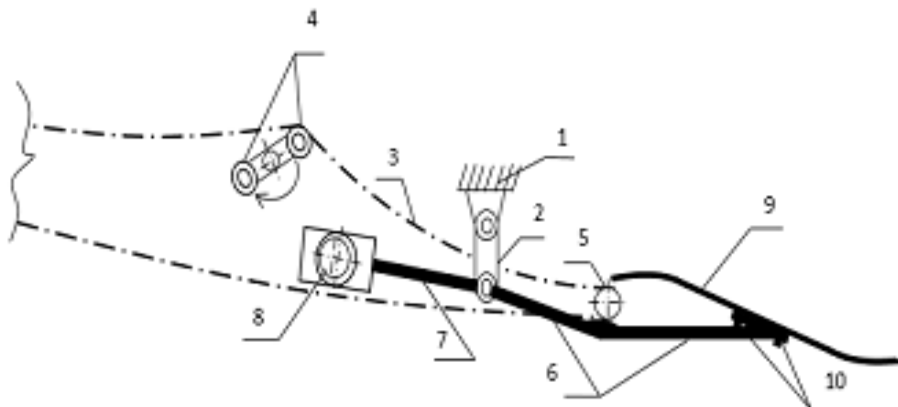

Fig. 2 – Separating chain digger
1 – frame; 2 – draft; 3 – chain digger; 4 – two-plate vibrator; 5 – supporting roller; 6 – mounting bracket;
7 – intermediate bracket; 8 – wobbler shaft; 9 – digging shovel; 10 – shovel bracket

In addition, the front part of the chain digger apron from the side of digging shovel *9* oscillates in the vertical plane when bracket *6* of digging shovel *9* acts on supporting roller *5*, which provides additional force to the soil layer, and thereby intensifies the process of separation of soil-vegetative impurities.

The disadvantages of this known design of the chain digger include increased damage to root crops during the transition from one cascade to another, and also the impossibility of dispersing a heap of onion sets along the entire width of the conveyor.

Analysis of the mechanized harvest machinery suggests that the operating elements of the harvester with different types of separation intensifiers do not provide quality indicators of root crops harvesting on such indicators as the completeness of separation and damage to root crops *(Aniket U. Dongre, Rahul Battase, Sarthak Dudhale, Vipul R. Patil, Deepak Chavan, 2017)*.

This is because after digging the soil layer together with the bulbs, a significant amount of soil lumps enters the separating working parts, which are difficult to separate on the working parts and are not always subjected to dynamic destruction under the influence of different types of separation intensifiers *(Farhadi R., Sakenian N., Azizi P., 2012)*. As a result, it causes damage to the bulbs due to the interaction with soil lumps during transportation of the onion heap to post-harvest processing *(Sibirev A.V., Aksenov A.G., Mosyakov M.A., 2018)*. This circumstance is caused by unsatisfactory process of soil impurities screening on the most widespread working part of primary separation – the chain digger *(Natenadze N., 2016)*.

In this regard, it is necessary to conduct investigations to identify areas with a minimum value of soil screening on the chain digger surface with an asymmetric vibrator arrangement, and to develop recommendations and proposals for their improvement. The outcome of the research will make it possible to design working parts of the devices for both primary and secondary separation at the known values of the release of the onion heap from digging and separating working parts, as well as at known values of the separation rate of the chain digger and its translational speed.

MATERIALS AND METHODS

Determination of the regularity of the soil impurities separation on a chain digger with an asymmetrically installed elliptical digger and supporting roller, as in *Patent No. 2638190 Russia, IPC A01 D33/00. (Sibirev A.V., Aksenov A.G., Kolchin N.N., Ponomarev A.G., 2017)* was performed on a laboratory installation (Fig. 3, 4).
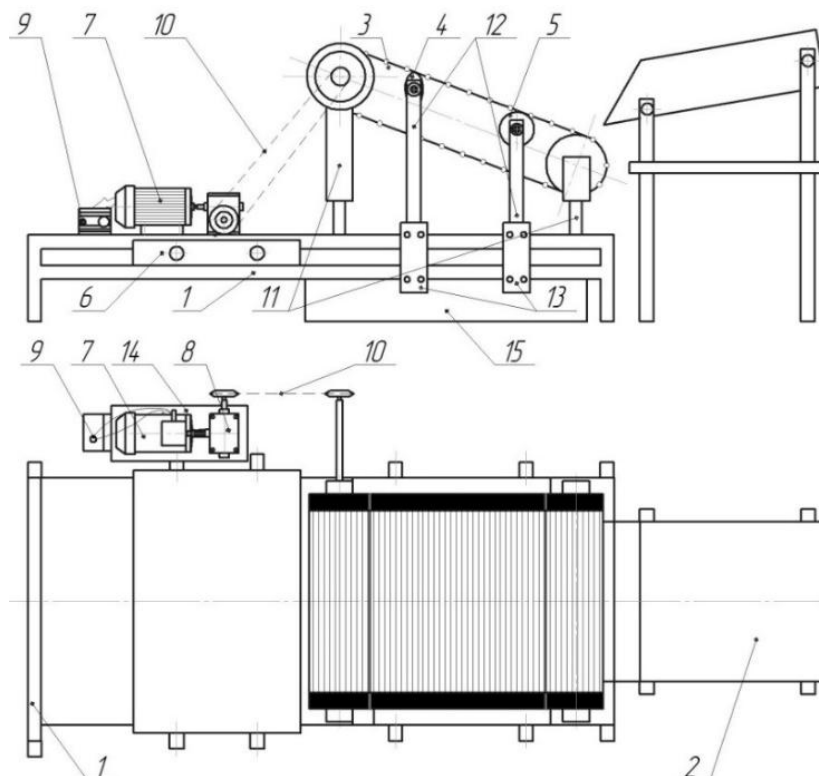

Fig. 3 – Laboratory installation for determining the impact of the process parameters of the chain digger on the quality of onion set heap separation

1 – frame; 2 – container for preliminary heap placement; 3 – chain digger; 4 – elliptical vibrator; 5— cylindrical roller; 6 – tarpaulin of separated products; 7 – electric motor; 8 – single-stage gearbox; 9 – frequency converter; 10 – chain transmission; 11 – support posts; 12 – vibrator and support roller posts; 13 – connecting bracket; 14 – support plate; 15 – impurity collector
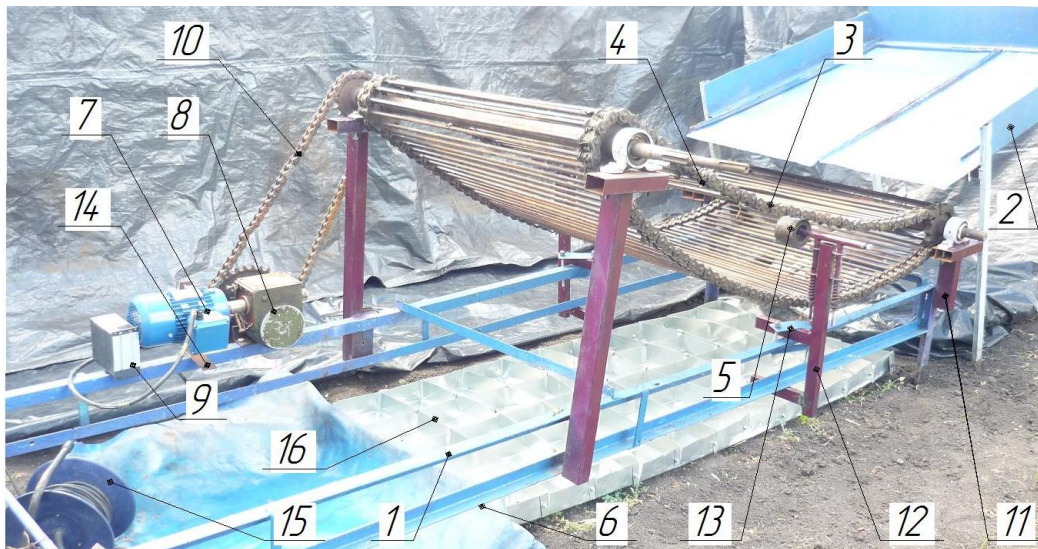
Fig. 4 – Laboratory installation for determining the impact of the process parameters of the separating chain digger on the quality of onion set heap separation

1 – frame; 2 – container for preliminary heap placement; 3 – chain digger; 4 – elliptical vibrator; 5 – supporting roller; 6 – tarpaulin of separated products; 7 – electric motor; 8 – single-stage gearbox; 9 – frequency converter; 10 – chain transmission; 11 – support posts; 12 – vibrator posts; 13 – connecting bracket; 14 – support plate; 15 – impurity collector

The laboratory installation consists of a container *2* for the preliminary placement of a heap, a separating chain digger *3* (working length 1.9 m and width 0.94 m) installed on support posts *11* of frame *1* *(Sibirev A.V., Aksenov A.G., Mosyakov M.A., 2018)*.

Under chain digger apron *2*, there are passive elliptical vibrators *4* and supporting rollers *5* with the possibility of moving along frame *1* on the posts *12* by fixing the position of bracket *13* on frame *1* with the bolted connection. The electric drive of chain digger *3* is carried out from the electric motor *7* of asynchronous brand 4A180U3 GOST 1050-88 (N = 0.6 kW, n = 920/1,200 rpm) and frequency converter *9* Tecorp Group (N = 0.75 kW; U_{EN} = 220 V, U_{OUT} = 220 V) through single-stage gearbox *8* (models 1-TsU-160-2-23) which are installed on base plate *14*.

To determine the amount of soil screened through the slots of chain digger *2*, under its surface, there is an impurity collector *16*, the diagram of which is presented in Figure 3.

The impurity collector (Fig. 5) represents a metal tray 1 with a length L_y and width B_y exceeding the length L_{EL} and width B_{EL} of the chain digger. This involves: L_y =2040 mm, B_y =1020 mm.
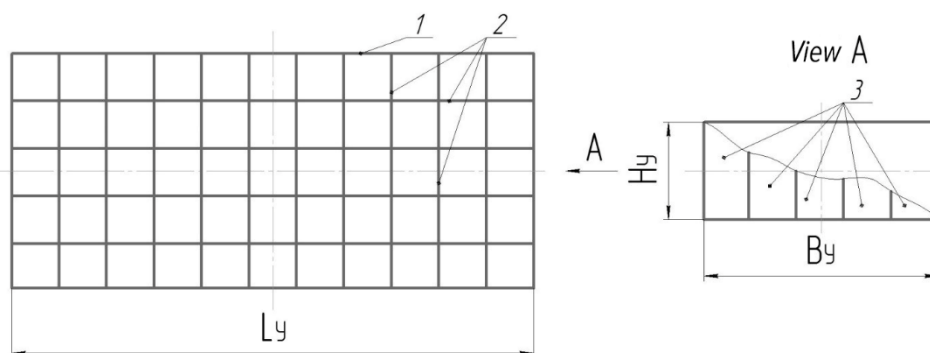

Fig. 5 – General view of the impurity collector
1 – metal tray; 2 – partition; 3 – cell

The surface of metal tray *1* is divided by partitions *2* along the length and width, forming cells *3* in height H_y, with dimensions of 170 × 170 × 100 (mm).

Each cell that determines the location of soil screening on the chain digger surface has its own serial number. The investigations to determine the regularity of the soil impurities separation *(Sibirev A.V., Aksenov A.G., Dorokhov A.S., 2018)* on a chain digger with an asymmetric digger arrangement were carried out with a minimum feed of onion sets Q_{Vp} = 10 kg/s, with an increase in the limit value Q_{Vp} = 50 kg/s and a variation interval of 10 kg/s for different values of the translational v_{EL} speed of the chain digger and the interaxial S_5

distance between passive elliptical vibrator *4* and supporting roller *5*. The lower limit of the range of translational speed variation v_{EL} was 1.4 m/s and then changed in 0.2 m/s increments to a limiting value of 1.8 m/s. An elliptical vibrator was installed at a distance of 350 mm from the rotation axis of the chain digger barrel. Interaxial S_5 distance between the passive elliptical vibrator and the supporting roller was set equal to 0.4 m in accordance with the results of the laboratory tests, ensuring, at a given quantitative value of the process parameter, the maximum separation completeness. The procedure of investigations was as follows.

A soil sample with a certain weight and moisture was placed on the surface of container *2* for the preliminary heap placement. The required soil moisture for the investigations was provided by superficial watering of the soil sample, then, it was maintained for several hours to achieve the required humidity in accordance with the research plan. An impurity collector was installed under the apron of chain digger *3*.

The optimal values of the translational v_{EL} speed of the chain digger and the interaxial S_5 distance between passive elliptical vibrator *4* and supporting roll *5* were set, in accordance with the results of the laboratory tests.

Fig. 6 – Electronic desktop scales MK-15.2-A21
1 – a glass bulb; 2 – electronic table scales

Then, frequency converter *9* and electric motor *7* were successively turned on.
In the steady regime of the apron movement of chain digger *3*, a soil impurity sample was fed from container *2* for the preliminary heap placement. After soil impurities passing through the separating surface of chain digger *2*, electric motor *7* was switched off at the investigated value of the Q_{Vp} supply of soil impurities.

Further from each cell of impurity collector *16*, soil was extracted and weighed on scales of the MK-15.2-A21 model (Fig. 6).

Based on the results of weighing the screened soil taken from each cell of the impurity collector that passed through the slit openings of the chain digger, the dependence of the mass of the screened soil impurities of soil K_P along the length L_{EL} and width B_{EL} of the chain digger was determined, i.e.:

$$f(K_p) = Q_{Vp}, v_{EL} = const; S_5 = const. \qquad (1)$$

In addition, the separation coefficient K_C of soil impurities was determined on the chain digger with an asymmetric vibrator arrangement along its length L_{EL} and width B_{EL}:

$$K_C = \frac{m_P}{m_{CONST}} \cdot 100\% \qquad (2)$$

where m_P − is the mass of screened soil impurities (in the impurity collector), kg;

m_{CONST} − is the mass of incoming soil impurities, kg.

The research results were recorded in the observation log.

Further, the studied factors were changed and the experiment was repeated in accordance with the chosen research plan.

The experiments repetition during the research of the influence of the chain digger process parameters with an asymmetric vibrator arrangement on the size of the soil screening ability is fivefold.

RESULTS
The results of the conducted research were recorded in the observations log and are presented in Tables 1-4.

Table 1

Results of research to determine the mass of screened soil impurities of soil K_P along the chain digger surface at Q_{Vp} =10 kg/s, v_{EL} =1.6 m/s, S_5 =0.4 m

Chain Digger Width V_{EL}, mm	Chain Digger Length L_{EL}, mm												Total, kg
	170	340	510	680	850	1,020	1,190	1,360	1,530	1,700	1,870	2,040	
170	0.03	0.04	0.13	0.15	0.13	0.16	0.06	0.07	0.08	0.09	0.1	0.08	
340	0.05	0.07	0.15	0.18	0.15	0.17	0.07	0.07	0.07	0.06	0.06	0.05	
510	0.06	0.07	0.24	0.25	0.32	0.28	0.16	0.15	0.14	0.14	0.13	0.12	9.93
680	0.07	0.08	0.26	0.28	0.33	0.29	0.16	0.15	0.13	0.12	0.11	0.09	
850	0.06	0.08	0.25	0.27	0.33	0.29	0.15	0.14	0.13	0.12	0.11	0.1	
1020	0.05	0.06	0.18	0.2	0.21	0.2	0.13	0.12	0.11	0.09	0.08	0.07	

Table 2

Results of research to determine the mass of screened soil impurities of soil K_P along the chain digger surface at Q_{Vp} =20 kg/s, v_{EL} =1.6 m/s, S_5 =0.4 m

Chain Digger Width V_{EL}, mm	Chain Digger Length L_{EL}, mm												Total, kg
	170	340	510	680	850	1,020	1,190	1,360	1,530	1,700	1,870	2,040	
170	0.08	0.11	0.23	0.35	0.43	0.36	0.09	0.11	0.11	0.12	0.1	0.09	
340	0.08	0.1	0.23	0.36	0.42	0.37	0.12	0.13	0.12	0.11	0.09	0.09	
510	0.11	0.15	0.38	0.59	0.68	0.64	0.28	0.26	0.23	0.21	0.18	0.15	19.68
680	0.11	0.15	0.41	0.64	0.71	0.75	0.3	0.27	0.24	0.22	0.21	0.17	
850	0.12	0.14	0.48	0.57	0.68	0.69	0.28	0.26	0.21	0.19	0.18	0.16	
1,020	0.11	0.15	0.38	0.43	0.52	0.54	0.24	0.23	0.21	0.22	0.13	0.12	

Table 3

Results of research to determine the mass of screened soil impurities of soil K_P along the chain digger surface at Q_{Vp} =30 kg/s, v_{EL} =1.6 m/s, S_5 =0.4 m

Chain Digger Width V_{EL}, mm	Chain Digger Length L_{EL}, mm												Total, kg
	170	340	510	680	850	1,020	1,190	1,360	1,530	1,700	1,870	2,040	
170	0.09	0.11	0.46	0.57	0.68	0.75	0.21	0.18	0.15	0.11	0.12	0.1	
340	0.09	0.12	0.58	0.65	0.71	0.84	0.28	0.25	0.22	0.15	0.14	0.12	
510	0.11	0.12	0.71	0.78	0.83	0.93	0.31	0.27	0.24	0.17	0.16	0.15	29.16
680	0.11	0.15	0.78	0.88	0.97	0.92	0.46	0.39	0.38	0.36	0.32	0.26	
850	0.1	0.14	0.79	0.87	0.94	0.92	0.45	0.37	0.35	0.33	0.32	0.28	
1,020	0.1	0.11	0.76	0.79	0.88	0.96	0.31	0.28	0.23	0.16	0.15	0.13	

Table 4

Results of research to determine the mass of screened soil impurities of soil K_P along the chain digger surface at Q_{Vp} =40 kg/s, v_{EL} =1.6 m/s, S_5 =0.4 m

Chain Digger Width V_{EL}, mm	Chain Digger Length L_{EL}, mm												Total, kg
	170	340	510	680	850	1,020	1,190	1,360	1,530	1,700	1,870	2,040	
170	0.11	0.12	0.87	0.96	0.98	1.58	0.29	0.25	0.23	0.19	0.17	0.12	
340	0.11	0.13	0.89	0.94	1.02	1.43	0.31	0.28	0.25	0.21	0.18	0.13	
510	0.12	0.14	0.88	0.98	1.32	1.76	0.37	0.35	0.28	0.26	0.23	0.15	38.56
680	0.12	0.14	0.96	1.12	1.38	1.68	0.38	0.37	0.29	0.28	0.24	0.16	
850	0.12	0.14	0.87	1.07	1.37	1.64	0.36	0.36	0.27	0.25	0.25	0.17	
1,020	0.11	0.13	0.88	0.94	0.92	1.21	0.43	0.38	0.32	0.28	0.21	0.17	

　　　Graphical display of the investigation results to determine the pattern of soil impurities separation is shown in Figures 7-10.
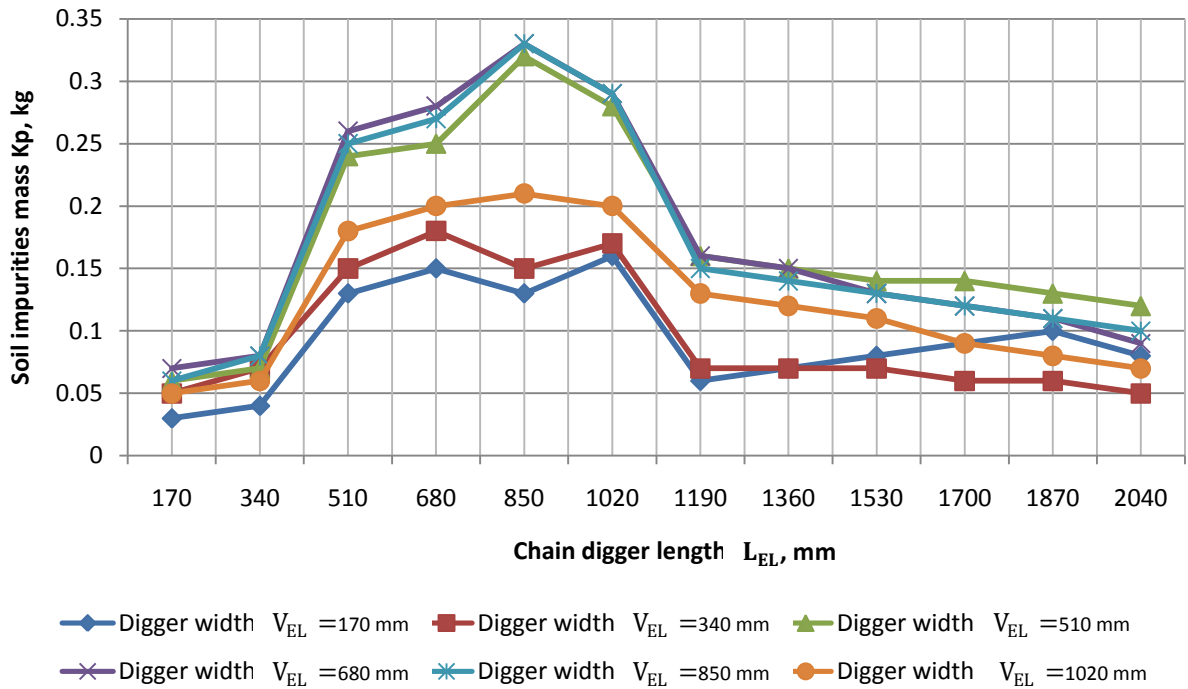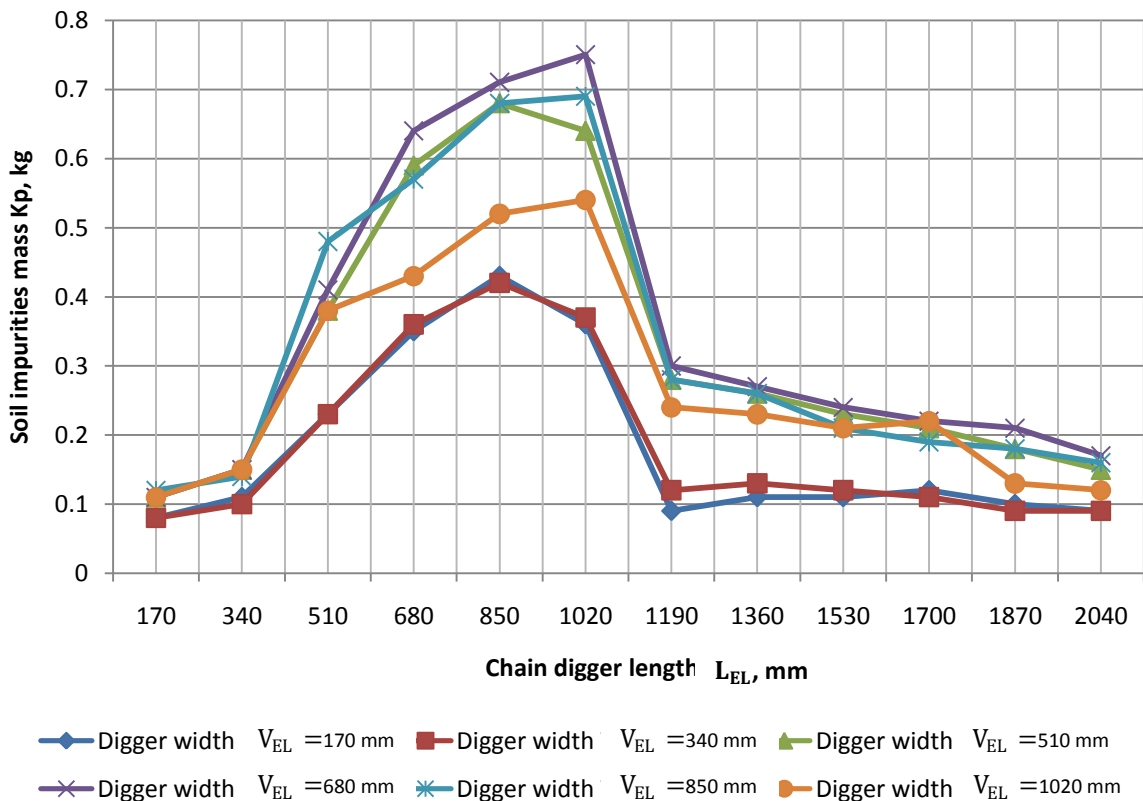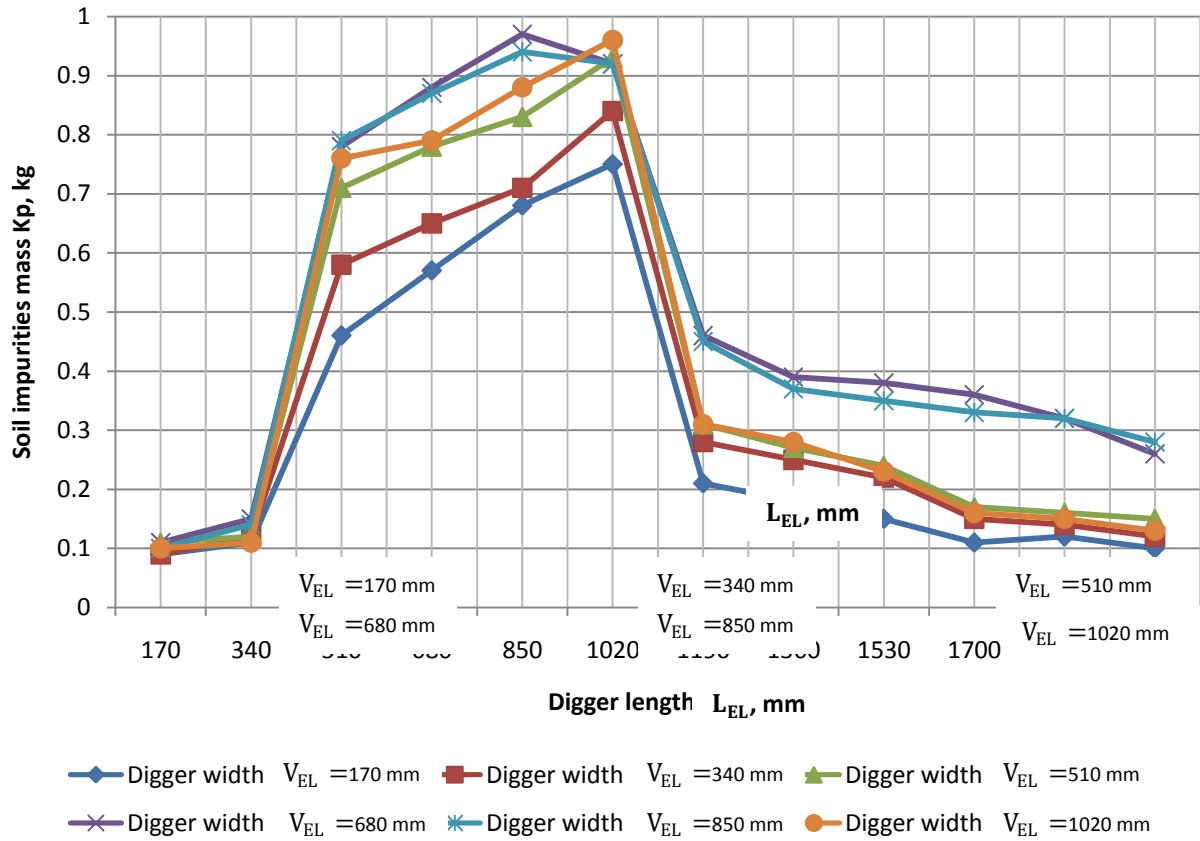

Fig. 7 – Dependence of soil screening along the length and width of the chain digger with an asymmetric vibrator arrangement at Q_{Vp} =10 kg/s, v_{EL} =1.6 m/s, S_5 =0.4 m

Fig. 8 – Dependence of soil screening along the length and width of the chain digger with an asymmetric vibrator arrangement at Q_{Vp} =20 kg/s, v_{EL} =1.6 m/s, S_5 =0.4 m

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Fig. 9 – Dependence of soil screening along the length and width of the chain digger with an asymmetric vibrator arrangement at Q_{Vp} =30 kg/s, v_{EL} =1.6 m/s, S_5 =0.4 m
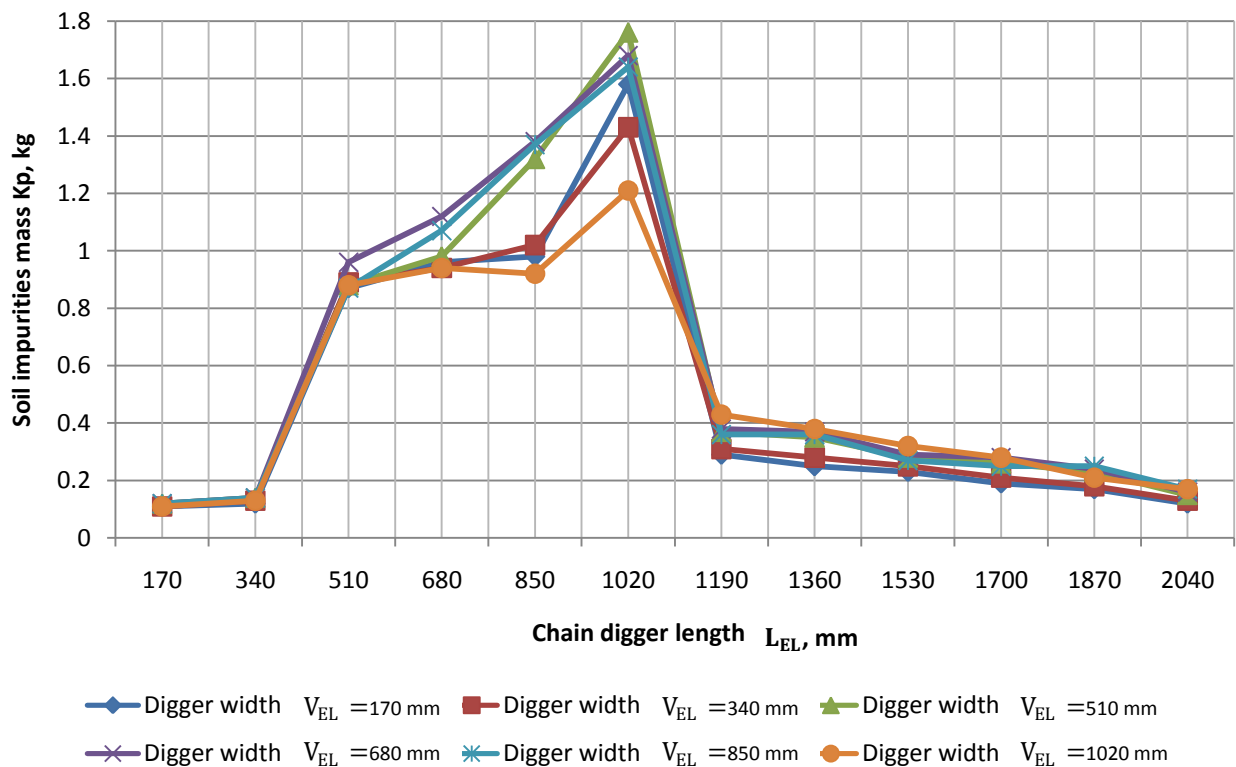

Fig. 10 – Dependence of soil screening along the length and width of the chain digger with an asymmetric vibrator arrangement at Q_{Vp} =40 kg/s, v_{EL} =1.6 m/s, S_5 =0.4 m

Using the presented graphical dependencies, it is possible to determine the mass of screened soil impurities through the slots of the chain digger with the asymmetric vibrator arrangement during feed change of $Q_{B\pi}$ soil impurities with constant values of process parameters $v_{EL} = const$; $S_5 = const$.

For this, after determining the appropriate area along the length of the chain digger, it is necessary to draw a straight line parallel to the y-axis, before crossing with the graph.

The variable length of the chain digger is indicated along the x-axis, along the y-axis—the mass of screened soil impurities.

The presented graphical dependencies show that the soil screening intensity on the chain digger with an asymmetric vibrator arrangement is provided with an increase in the soil impurities supply from 10 to 40 kg/s.

This circumstance is explained by the fact that when a soil impurities mass moves along the chain digger surface, there occurs the process of wedging of large particles in the soil mass.

Since in the soil sample of a larger mass there is a content of large soil particles exceeding their presence in a sample of a lesser mass, the soil particles screening occurs more intensively with an increase in the soil impurities supply to the chain digger surface.

And the greatest value of the K_P screened soil mass, regardless of the supply of soil impurities, is observed at the attenuation section of the wave length of the chain digger loaded strand from the action of an elliptical vibrator corresponding to the chain digger length L_{EL} =1020 mm.

With further movement of the soil mass along the chain digger length, there is a decrease in the intensity of soil impurities screening as a result of the attenuation of the wave length of the chain digger loaded strand from the action of an elliptical vibrator.

CONCLUSIONS

The investigation results show that most of the soil impurities are screened at the section of vibrators forming the vibrating wavelength, which during the research was established in the range of values $S_5 = 0.4$ m.

The results obtained will allow an intensified separation of root crops and bulbs from soil impurities by the optimal vibrator arrangement along the chain digger length at known values of maximum soil impurity penetration.

The results of the experiments indicate a high intensity of soil screening in the area of the chain digger with the vibrator arrangement.

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