# LABORATORY-FIELD RESEARCH RESULTS FOR ONION CLEANING
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# *РЕЗУЛЬТАТЫ ЛАБОРАТОРНО-ПОЛЕВЫХ ИССЛЕДОВАНИЙ МАШИНЫ ДЛЯ УБОРКИ ЛУКА*

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## ABSTRACT

*In the machine technology for cultivation and harvesting of root crops and onions, one of the most important quality indicators determining the duration of root crops storage is the presence of soil and plant impurities in the heap to be stored. The impossibility to separate soil lumps from the heap of root crops and onions is due to the fact that the majority of harvesters use slotted separating executive devices, while the inter-rod distance of the separating conveyor, in order to eliminate the loss of root crops, is made smaller than the minimum size of the separated root crop, which leads to the impossibility of their cleaning on the separating executive devices of harvesters, and, consequently, to the damage of a significant part of commercial products and loss of a significant part of the crop grown during storage. The modern technologies and technical means for harvesting root crops and onions are not capable of providing high-quality commercial products with minimal labour, due to falling behind or a lack of development of technological foundations, technologies and executive devices for harvesting root crops and onions, capable of reducing or excluding the content of soil lumps in commercial products under various soil and climatic conditions. Therefore, development of mechanization tools for harvesting root crops and onions, which would allow reducing or eliminating the content of mechanical impurities in commercial products under various soil and climatic conditions, is a scientific problem, the solution of which will contribute to the innovative development of the domestic agricultural market, Russia's stable position on the foreign market.*

## РЕЗЮМЕ

*В машинной технологии возделывания и уборки корнеплодов и лука одним из важнейших показателей качества, определяющего длительность хранения корнеплодов является наличие в закладываемом на хранение ворохе почвенных и растительных примесей. Невозможность отделения почвенных комков из вороха корнеплодов и лука обусловлена тем, что на большинстве уборочных машин применяют щелевые сепарирующие рабочие органы, при этом межпрутковое расстояние сепарирующего транспортера с целью исключения потерь корнеплодов выполнено меньше минимального размера сепарируемого корнеплода, что приводит к невозможности их очистки на сепарирующих рабочих органах уборочных машин, а следовательно, к травмированию значительной части товарной продукции и потерям при хранении значительной части выращенного урожая. Современные технологии и технические средства уборки корнеплодов и лука не способны обеспечить получение качественной товарной продукции при минимальных трудозатратах, что обусловлено отставанием или отсутствием в разработке технологических основ, технологий и рабочих органов уборки корнеплодов и лука, позволяющие снизить или исключить содержание почвенных комков в товарной продукции в различных почвенно-климатических условиях. Следовательно, разработка средств механизации для уборки корнеплодов и лука, позволяющих снизить или исключить содержание механических примесей в товарной продукции в различных почвенно-климатических условиях представляет научную проблему, решение которой будет способствовать инновационному развитию внутреннего рынка сельскохозяйственной продукции, устойчивому положения России на внешнем рынке.*

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## INTRODUCTION

Creation and implementation of machines of a new, intellectual type is the determining component of the agricultural engineering development strategy in the Russian Federation *(Aldoshin N.V. et al., 2015; Aldoshin N.V. et al., 2014; Kukharev O.N. et al., 2018; Kurdyumov V.I. et al., 2019; Kurdyumov V.I. et al., (2016))*. The harvesting productivity and efficiency depends on the optimal solution to the problem of controlling the technological process of machine harvesting of root crops and onions *(Bashkirtsev V.I. et al., 2017; Lobachevsky Ya.P. et al., 2016; Laryushin N.P. et al., 2015).*

When solving many problems related to the improvement of technological processes and executive devices of agricultural machines, the main goal is to increase crop yields and improve the harvesting quality of the grown crops *(Zykin E.S. et al., 2017; Kukharev O.N., 2006; Kalinin A.B. et al., 2015; Kalinin A.B. et al., 2016; Kukharev O.N. et al., 2018).*

The main task to be achieved by mechanized harvesting of root crops and onions, as well as other crops, is to increase the completeness of collection, reduce damage to the products, which can be achieved by creating higher-performance harvesters.

When harvesting root crops and onions, a large volume of soil passes through the separating devices of root and onion harvesters on each hectare, from which root crops and bulbs must be extracted with minimal damage. Because of this, the productivity of harvesters is determined mainly by the throughput capacity of the separating devices *(Kukharev O.N. et al., 2018; Sibirev A.V. et al., 2018).*

At the same time, separating devices, and in particular the most common ones - rod elevators, are unable to ensure the required completeness of separation and sufficient performance under various conditions of their use.

To eliminate these deficiencies, various intensifiers with various drive designs are used on harvesters.

The disadvantages of separation intensifiers of various designs include the fact that, as a result of force impact on the material being processed, the product is damaged, moreover, during harvesting, soil impurities come together with root crops and bulbs, which leads to the clogging of the product, so additional processing is required for its cleaning at the site, which entails additional costs.

It is known that the separating ability of a rod elevator depends on the inclination angle $\alpha_1$ and the elevator speed $v_{\mathrm{EL}}$.

The separation coefficient $\varepsilon$ at any inclination angle $\alpha_1$ increases as the speed of the rod elevator $\mathrm{v_{EL}}$ increases, to a certain maximum value, after which it starts decreasing. The optimal movement speed $\mathrm{v_{EL}}$ of a rod elevator is an interval between 2 m/s and 2.5 m/s.

Moreover, to avoid unloading a heap of root crops and onions on the surface of the rod elevator, the following conditions must be met (*Sorokin A.A., 2006*):

$$\mathrm{v_{EL}} = \mathrm{v_{Me}} = \mathrm{v_K} \cdot \mathrm{A} \tag{1}$$

where $\mathrm{v_K}$ – is the progressive speed of the harvester movement, m/s; $\mathrm{A}$ – coefficient (A=1.3).

Therefore, an increase in the productivity of the technological process of harvesting root crops and onions will lead to a decrease in the separation quality and increase in the damage to commercial products.

## MATERIALS AND METHODS

Based on the functional diagram of the control system with a perturbation control principle, an intelligent technology for harvesting root crops and onions was developed, with the development of a separating rod elevator with an adjustable blade inclination angle.

The separating rod elevator with an adjustable inclination angle (RF patent No. 2679734) ensures damage reduction and improves the quality of the separated products by minimizing the impact of the vertical component of the gravity of root crops and bulbs, while also increasing the uniformity of distribution of the heap of root crops and bulbs across the separating surface when changing angle α of the rod elevator inclination as a result of changes in soil and climatic conditions of harvesting root crops and onions *(Sibirev A.V. et al., 2019).* To adjust the inclination angle of the blade of rod elevator *1*, weight sensors *2* mounted on digging plough share *3* (Figure 1) are used.

Weight sensors *2* measure the weight of the incoming heap of root crops on digging plough share *3* and send the readings to microcontroller *4* during the root crops and onion heap separation and bar elevator *1* inclination angle $\alpha_1$ adjustment.

The linear drive, represented by electric cylinders *5*, moves the linear drive rod to the required distance $S_1$or $S_2$changes the $\alpha_1$inclination angle of the blade of rod elevator *1* depending on the readings of weight sensors *2* after receiving a signal from microcontroller *4*.

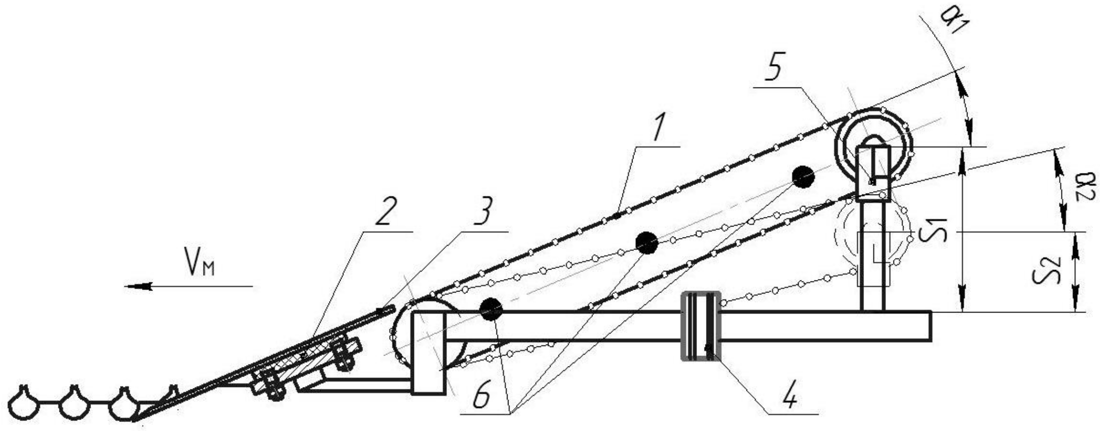


**Fig. 1 – Diagram of changes in the inclination angle of the rod elevator:**
*1 – rod elevator; 2 – digging plough share weight sensor; 3 – digging plough share; 4 – microcontroller; 5 – electric cylinder; 6 – inertial sensor*

When a heap of root crops passes across the surface of rod elevator *1*, the soil is screened through slotted holes formed by adjacent rods of the blade (Figure 2). The screened soil is registered by means of inertial sensors *6* installed along the length of rod elevator *1*. When evaluating the efficiency of separation by inertial sensor 6, the oscillation frequency will also be characterized by the movement speed of rod elevator *1* (interchanging gaps and rods above the sensor).
However, the amount of the screened soil will be characterized by peak amplitude values. Therefore, the separation efficiency of the elevator is estimated according to the amplitude values *(Sibiryov A.V. et al., 2019).*

If the soil is screened on the rod elevator below the required value set by microcontroller *4*, inclination angle$\alpha_1$ of rod elevator *1* is adjusted in the specified range of values. After determining the mass of the root crop and onion heap on the digging plough share, the controller, with time delay *T*, along with the movement of the rod elevator, sends a control signal to move the actuator rod.


**Fig. 2 – General view of the machine for harvesting root crops and onions, equipped with a separating rod elevator with adjustable blade inclination angle and receiving plough share for digging/collecting root crops and bulbs**
*1-– frame; 2 – receiving plough share for digging/collecting root crops and bulbs; 3 – supporting wheels; 4 – main separating rod elevator; 5 – additional rod elevator; 6 – bed-forming roller; 7 – shaker adjusting plate; 8 – narrowing tray; 9 – electric cylinders; 10 – weight sensor of the digging plough share; 11 – microcontroller*

The aim of the studies was to substantiate the possibility of using a separating rod elevator with an adjustable blade inclination angle for harvesting root crops and onions, as well as to establish the optimal values of its process parameters under laboratory and field conditions, ensuring high-quality separation of onion heaps from soil and plant impurities.


**Fig. 3 – General view of the harvester for root crops and onions, equipped with separating rod elevator with an adjustable blade inclination angle and receiving plough share for digging/collecting root crops and bulbs**
*1 – Tractor MTZ 1221; 2 – root and onion harvester*

Field studies of a separating rod elevator with adjustable blade inclination angle of root and onion harvester (Figure 3) were carried out on the fields owned by Tsirulev E.P. peasant farm enterprise in the Samara region in 2019, when harvesting Stuttgarter Riesen breed onions.

Production studies were carried out in accordance with STO AIST 8.7-2013 “Machines for harvesting vegetables and gourds. Methods for assessing functional indicators".

When conducting studies of separating rod elevator with an adjustable blade inclination angle installed on a UKL-1.3 root and onion harvester, the physical and mechanical properties of the soil were determined, as well as the onion heap separation quality indicators. The soil in the plot selected for the studies is medium loamy black earth soil, the field relief is flat, the field contour is close to a rectangular shape, the pass (furrow) length is 350 m.

The quality of the technological process performance was assessed according to the following indicators:

– damage $P$ to the bulbs;

– separation completeness $\nu$ of an onion heap *(Sibirev A.V. et al., 2018; Sibirev A.V. et al., 2019).*

When determining the optimal value of the studied factor during production studies, the other factors remained unchanged, i.e. equal to the optimal values determined during laboratory and field studies. In the process of laboratory and field studies of a root and onion harvester equipped with separating rod elevator with an adjustable blade inclination angle, process parameters were set in the above specified range of values.

Progressive speed $v_{EL}$ of the rod elevator blade varied from 1.0 m/s to 1.8 m/s with a variation interval of 0.2 m/s.

The only exceptions are the factors, the optimal values of which could not be investigated under laboratory conditions; these factors include depth $h_L$ of immersion into the soil of the digging plough share and progressive $v_K$ speed of the root and onion harvester. In addition, in order to study the influence of the amount of onion heap supply $Q_{BEL}$ on the quality of separation of the rod elevator with an adjustable blade inclination angle, the progressive speed $v_P$ of the root and onion harvester, as well as the depth $h_L$ of immersion of the digging plough share into the soil, were changed.

The progressive speed $v_K$ of the root and onion harvester varied from 1.0 m/s to 1.8 m/s with a variation interval of 0.2 m/s, the immersion depth $h_L$ of the digging plough share into the soil varied in the range of 0.02 m to 0.06 m, in increments of 0.01 m.

The performance quality of the rod elevator with an adjustable blade inclination angle was determined as follows. At the start of the registration plot, with self-propelled combine *1* moving non-stop (Figure 3), canvas was placed under the separating rod elevator upon a signal, in which all the harvested mass was collected.

In the process of passing the plot, canvas was unrolled behind the harvester, on which the heap dropped after separation.

Then samples were taken from the canvas surface from the entire territory of the registration plot.
In so doing, the fractional composition of the heap was determined, taking into account: bulbs, loose soil and soil attached to bulbs.

## RESULTS AND DISCUSSION

When conducting laboratory studies of a rod elevator with adjustable blade inclination angle, the optimal values of the studied factors were determined, to be investigated for quality indicators of work in a production environment. The study of the technological process of the work of a rod elevator with adjustable blade inclination angle under laboratory field conditions was carried out with factors varying within (Figure 4):

– depth of the digging plough share immersion into the soil $h_L =$ was 0.02 m to 0.06 m;
– progressive speed of the root and onion harvester $v_K =$ was 1.0 m/s to 1.8 m/s;
– the progressive speed of the rod elevator blade $v_{EL}$ = 1.55 m/s to 1.67 m/s.

According to the results of processing the experimental data, dependence graphs were plotted with regard to the completeness of separation of onion heap v in % and damage to bulbs *D* in % vs. the operating and process parameters of the harvester ($h_L$ and $v_P$) and the separating rod elevator ($v_{EL}$) with an adjustable blade inclination angle.

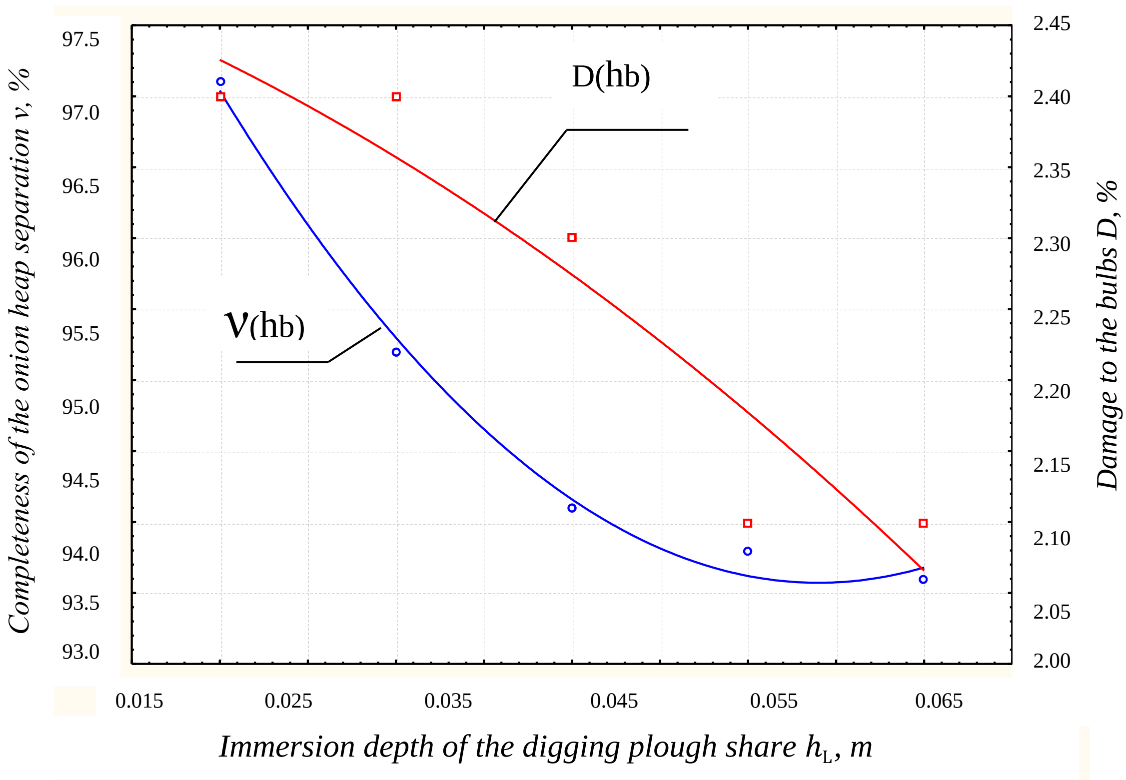


**Fig. 4 – Dependence of separation completeness $v$ and damage to bulbs *D* of a separating rod elevator with an adjustable blade inclination angle vs. depth $h_L$ of the digging plough share immersion into the soil**

The correlation between the quality indicators of the technological process of operation of a root and onion harvester equipped with rod elevator with an adjustable blade inclination angle from the immersion depth $\mathrm{h_L}$ of the digging plough share into the soil is expressed by an equation of parabolic functions:

$$\begin{cases} \nu = 102.32 - 3.24 \cdot h_L + 0.28 \cdot h_L^2, \\ D = 2.52 - 3.28 \cdot h_L - 0.71 \cdot h_L^2. \end{cases} \quad (2)$$

Analysing the graph (Figure 5), we can say that high quality of onion heap separation exceeding 98 % is ensured when the digging depth of the digging plough share is 0.02 m, and when the digging depth is increased, the completeness of onion heap separation is significantly reduced.

This circumstance is explained by an increase relative to the optimal onion heap supply determined under laboratory conditions for the rod elevator studied.

The lowest indicators of damage to onion bulbs, i.e. less than 2.5%, are achieved with the greatest digging depth of the digging plough share into the soil equal to 0.06 m/s, which is explained by the presence of a soil layer between the elevator rods and the separated onion products.

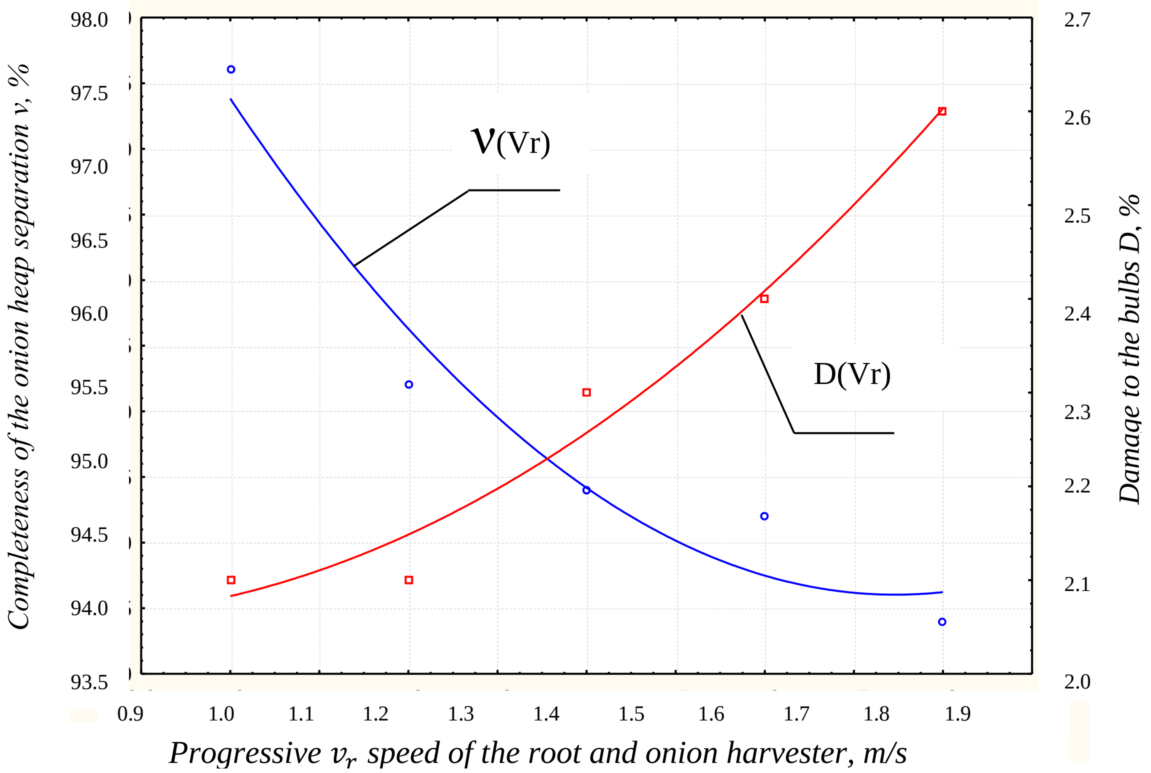


**Fig. 5 – Dependence of the completeness of separation $\nu$ and damage to bulbs *D* of separating rod elevator with adjustable blade inclination angle vs. the progressive $v_r$ speed of the root and onion harvester**

When determining the quality indicators of the technological process of operation of a rod elevator with adjustable blade inclination angle, we obtained a correlation dependence of the separation completeness of the onion heap ν in % and damage to the bulbs *D* in % on the progressive speed of the seed onion harvester:

$$\begin{cases} \nu = 114.29 - 2.37 \cdot v_K + 0.67 \cdot v_K^2, \\ D = 2.39 + 0.85 \cdot v_K + 0.53 \cdot v_K^2. \end{cases} \quad (3)$$

An analysis of quality indicators of operation of the root and onion harvester equipped with rod elevator with adjustable blade inclination angle depending on changes in the progressive $v_K$ speed of the root and onion harvester shows that the completeness of separation and damage to the bulbs drop with an increase in the technological indicator under study.

According to the graph shown in figure 6, it follows that the optimal ratio of onion harvesting quality indicators is ensured when crossing curves approximating the separation completeness of 95.7 % and bulb damage of 2.6 % at a progressive speed of the root and onion harvester equal to 1.38 m/s.

The results of studies of progressive speed $v_{EL}$ of the rod elevator with adjustable blade inclination angle with regard to quality harvesting indicators in the field indicate that the optimal value of the studied factor corresponds to 1.6 m/s with separation completeness of 98.5 % and production damage of 2.3 %.

The correlation between quality indicators ($\nu$ and $D$) of onion harvesting and progressive speed $v_{EL}$ is determined by a correlation dependence, which is expressed by an equation of parabolic functions:

$$\begin{cases} \nu = 82.79 + 12.2 \cdot v_{EL} - 2.14 \cdot v_{EL}^2, \\ D = 0.45 + 0.05 \cdot v_{EL} + 0.53 \cdot v_{EL}^2. \end{cases} \quad (4)$$

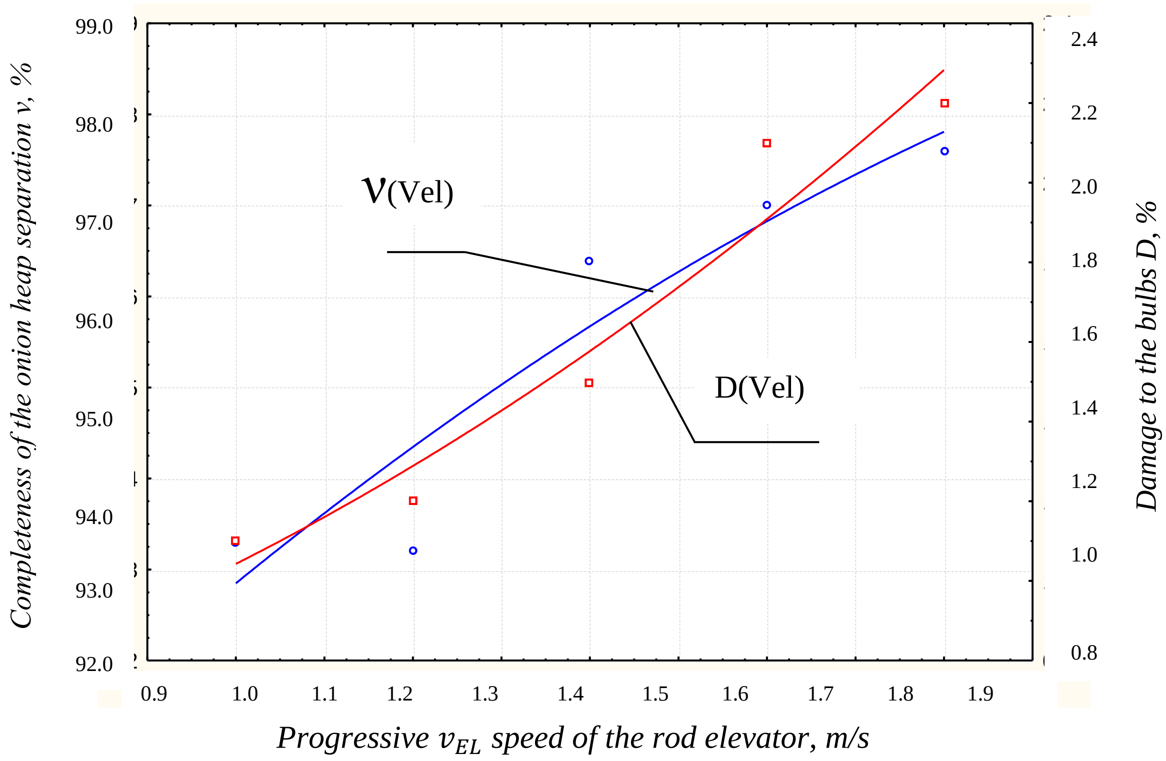


**Fig. 6 – Dependence of the completeness of separation $\nu$ and damage to bulbs $D$ of separating rod elevator with adjustable blade inclination angle vs. the progressive speed $v_{EL}$ of the rod elevator blade**

## CONCLUSIONS

The results of production studies performed on a root and onion harvester equipped with rod elevator with adjustable blade inclination angle demonstrated high-quality performance of the technological process of separation of an onion heap with optimal values of parameters:

– progressive speed $v_{EL}$ of the rod elevator with adjustable blade inclination angle of 1.6 m/s, with separation completeness of 98.5 % and product damage of 1.3 %;

– movement speed $v_K$ of the root and onion harvester 1.38 m/s, with separation completeness of 95.7 % and damage to the bulbs of 1.6 %;

– digging depth $h_L$ of the digging plough share equal to 0.02 m with onion heap separation completeness exceeding 98 % and damage to the products less than 1.5 %.

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