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# Experimental Laboratory Research of Separation Intensity of Onion Set Heaps on Rod Elevator

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**Abstract:** The existing machinery for harvesting root crop and onions do not ensure high quality separation of root crop heaps which causes violation of the agroengineering standards during their harvest. To improve the quality of root crop separation, new solutions must be found, namely, increasing the separation completeness and reduction of damage. This study presents a laboratory equipment design that can determine intensity of separation of onion set trashed heap on a rod elevator. The study describes the research method and the experimental research results for onion set heap separation on a rod elevator. It shows the results of experimental research for a rod elevator in order to determine the intensity of onion set heap separation which can be used as input data for designing secondary separation equipment. It was found that the maximum intensity of onion set heap separation is 600 kg/sec with obtained optimum values of the considered factors: onion set heap feed = 24.8, ..., 28.8 kg/sec and the traveling speed of a rod elevator of 1.58, ..., 1.76 m/sec. The obtained experimental data will ensure designs of secondary separation machinery for onion set harvest both for the first and the second harvest stages and the high quality of the separation technical process.

**Key words:** Onion, technical process, rod, equipment, heap, separation

## INTRODUCTION

The primary limiting factor of a wider industrial production of onion set is lack of mechanized means for onion harvest that would meet the agro engineering requirements, i.e., high quality technical process of harvest regarding the complete separation of the onion set thrashed heap from soil inclusions (Aksenov *et al*., 2016). Besides, due to the increase in crops of onion sets and using heavy-yielding hybrid varieties of seeding material (“Her cules F1”, “Sturon”, “Troy F1”, “Shtur BS 20”, “Centurion F1”, “Forum F1”, “Globus”, “Zolotnichok”) the weight and quantity of onion sets per linear meter has been increasing (Aksenov and Sibirev, 2016). This, in turn, results in increase of onion set thrash heap feed from digger shovels to the separating equipment of modern onion harvest machinery that fail to completely extract the soil inclusions when harvesting onion sets in the modern conditions of onion set production. This reveals the lack of study of the onion set separation process on harvesters for primary and secondary separation.

The design analysis of the existing machinery for harvesting root crop and onions and the analysis of patent and engineering literature shown below has allowed us to detect limitations in the design of separating equipment of root crop and onion harvesters (Farhadi *et al*., 2012) that make them fail to ensure high quality product separation.

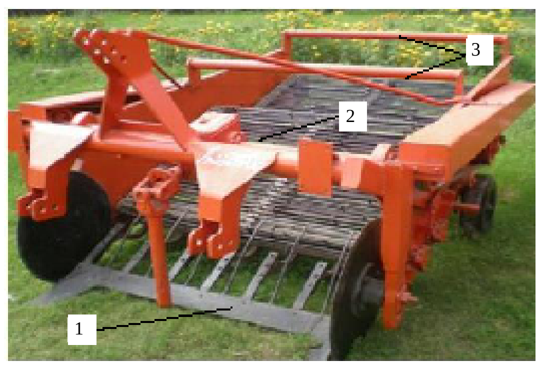

Fig. 1: Overview of a root crop harvester: 1) Digging shovel; 2) Separating rod elevator and 3) Support rod

The known potato harvester (Asghar *et al*., 2014) consists of the following basic parts: digger shovel (1), separating rod elevator (2) and support rods (3) (Fig. 1). The distinctive feature of the harvester shown above is the design of the digging shovel Eq. 1 (Fig. 2) and the separating rod elevator (3) (Fig. 3).

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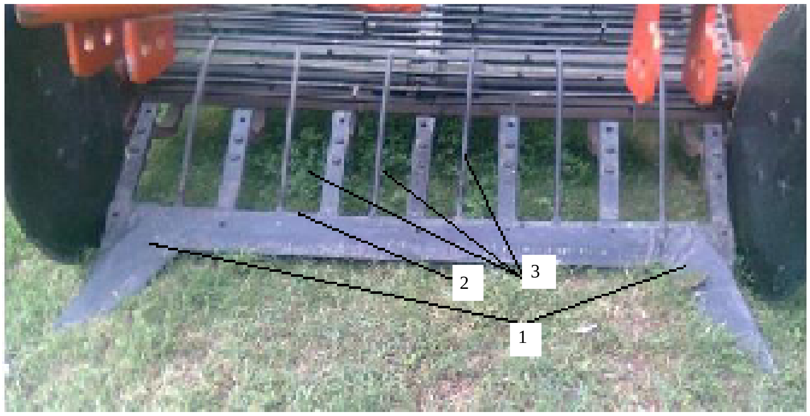


Fig. 2: Overview of the digging shovel equipment: 1) Chiseling tool; 2) Digging tool and 3) Openings for preliminary separation

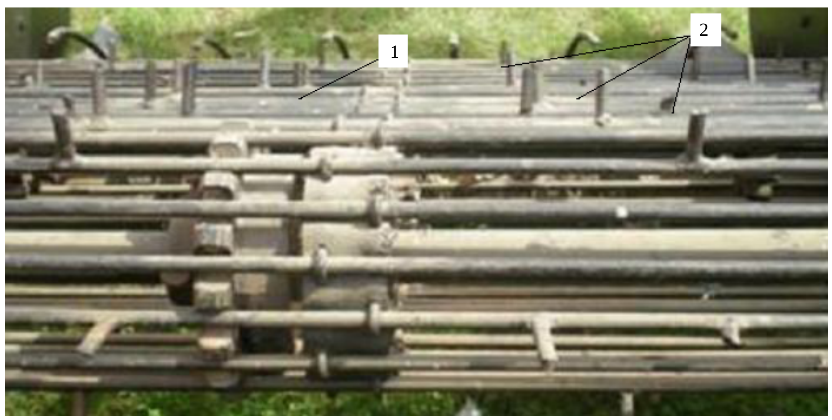


Fig. 3: Overview of a separating rod elevator: 1) Bar and 2) Rod

The digging shovel equipment is a combination of the chiseling and digging tools with openings for preliminary separation designed as a part of the operating surface of the digging tool.

The chiseling tool (1) of the operating digging tool performs preliminary chiseling of the dug soil layer to reduce the number of soil clods to the separating equipment, thus, intensifying the root crop cleaning process from the soil clods of relevant sizes and reducing the amount of damage to the product resulted from its collision with soil clods on the separating rod elevator of the harvester.

The digging tool (2) extracts root crop from soil and performs preliminary separation through the openings for preliminary separation (3).

The limitation of this digging shovel equipment include an increased loss of root crop through the openings (3) of the digging tool (2); besides, this type of design of the digging shovel equipment fails to decrease damage to the separated products due to lack of chiseling of the soil layer where root crop is located. The design of the separating surface of the rod elevator includes rods (2) located on bars (1) (Fig. 3).

The main purpose of the rods (2) located on the bars (1) is destruction of soil clods fed by the digging shovel equipment of the harvester. However, besides destructing the soil clods it self, the rods (2) also have a force impact on the root crop which increases the amount of damage to the separated products.

There is also a rod elevator design (Fig. 4) that uses a passive double-arm shaker (4) as the separation intensifier, located under the upper side of the rod elevator blade (3) (Natenadze, 2016).

Besides that, the front part of the rod elevator blade from the side of the digging shovel (9) moves along the vertical plane affected by the mounting bracket (6) of the digging shovel (9) on the supporting roller (5) resulting in additional force impact on the soil surface and therefore, intensifying the separation process of soil and plant inclusions.

The limitation of such rod elevator design include an increased root crop damage when transferred from one chain to another as well as inability to spread the root crop thrashed heap along the full width of the conveyor. Analysis of the technical means of the mechanized root crop harvesting leads to the assumption that the functioning parts of a harvester with different types of separation intensity fail to ensure high quality harvest of root crop along such parameters as separation completeness and root crop damage.

**Research objective:** Experimental research has been conducted in order to determine the intensity of onion-soil heap separation on the most common primary separation tools, rod elevators as this value determines the design of secondary separation tools with optimum parameters of quality thrashed heap cleaning.

## MATERIALS AND METHODS

The intensity ($q_B$) of onion-soil heap separation was determined with laboratory equipment (see the overview and the layout of such equipment in Fig. 5 and 6.

The laboratory equipment consists of a container for preliminary storage of heap (1), a separating rod elevator (2) (operational length-2.3 m, width-0.6 m), designed as intersecting rods fixed on flexible traction elements with a set step and a metal tray (3) located under the belt of the separating rod elevator (Fig. 5).

The electric motor (5) powers the rod elevator belt (2); the equipment also has an option of smooth adjusting of the belt speed within the range of 1.4, ..., 1.8 km/h with a variable speed drive (7). Under the rod elevator belt (2), a metal tray (3)-2.3 m long and 0.6 m wide was placed.

The onion set heap is continuously fed onto the rod elevator (3) from the container for preliminary storage of thrashed heap (2) with the intensity of 20-48 kg/sec, adjusting the container (2) incidence angle to the horizon which corresponds to the changes in the thrashed heap feed ($Q_{Bn}$) from the digging tools to the separating tools when harvesting onion set on the optimal digging depth of $h_r$ = 0.02, ..., 0.05 m.

For high quality performance of the harvesting process, it is required that the chain belt speed that defines the separation intensity by defining the period of the separated substance location on the operating tools should follow the Eq. 1:

$$v_{ch} = \frac{v_t}{coB a_{ch}} \quad (1)$$

where is the traveling speed of the harvester in m/sec is the incidence angle of the operating chain of the rod elevator belt, 20, ..., 25°. The separation intensity was defined according to the following Eq. 2:

$$q_B = \frac{m.v_{ch}}{B_{ch}.L_{ch}} \quad (2)$$

Where:

m = The mass of the soil on the canvas for collection of inclusions in kg
$B_{ch}$ = The width of the rod elevator conveyor in meters
$L_{ch}$ = The length of the rod elevator conveyor in meters

Three levels were chosen for each factor the lower level, the upper level and the basic, zero level. Then the factor variability interval was set (Table 1) and a multi-factor experiment was conducted according to the plan $3^2$ (Table 2).

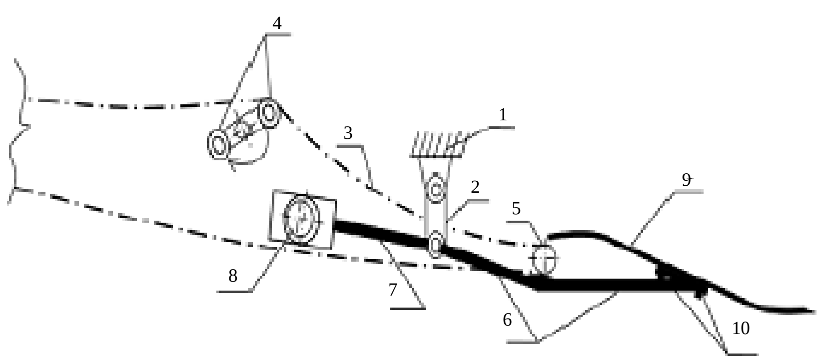


Fig. 4: Layout of a separating rod elevator: 1) Frame; 2) Motor; 3) Rod elevator; 4) Double-arm shaker; 5) Supporting roller; 6) Mounting bracket; 7) Intermediate bracket; 8) Supplementary shaft; 9) Digging shove and 10) Digging shovel mounting

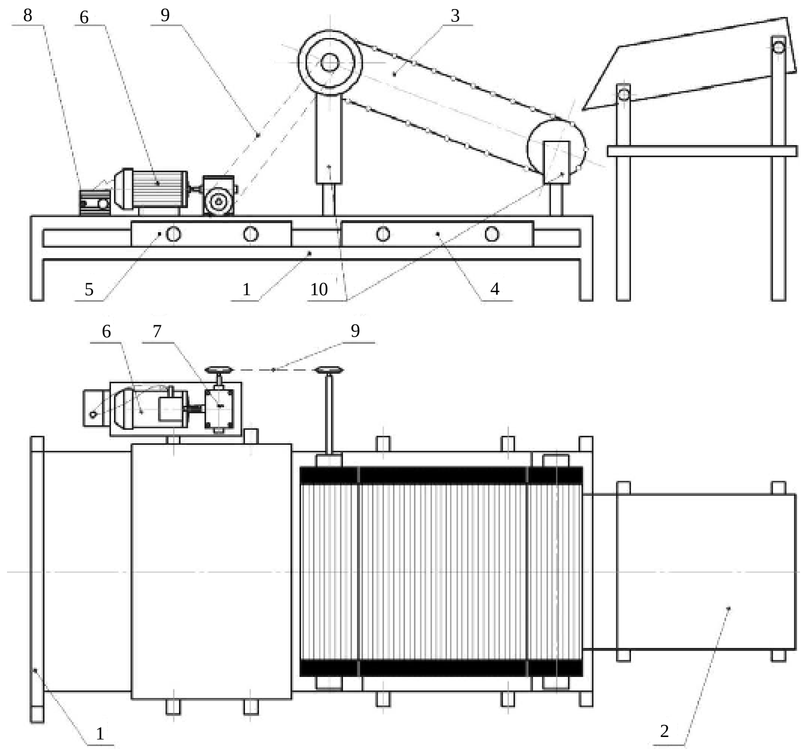


Fig. 5: Layout of the laboratory equipment for studying the intensity of onion set heap separation: 1) Frame; 2) Ontainer for preliminary storage of thrashed heap; 3) Separating rod elevator; 4) Canvas for collection of inclusions; 5) Canvas for separated products; 6) Electric motor; 7) Single-stage reducer; 8) Variable speed drive; 9) Chain gear and 10) Supporting rack

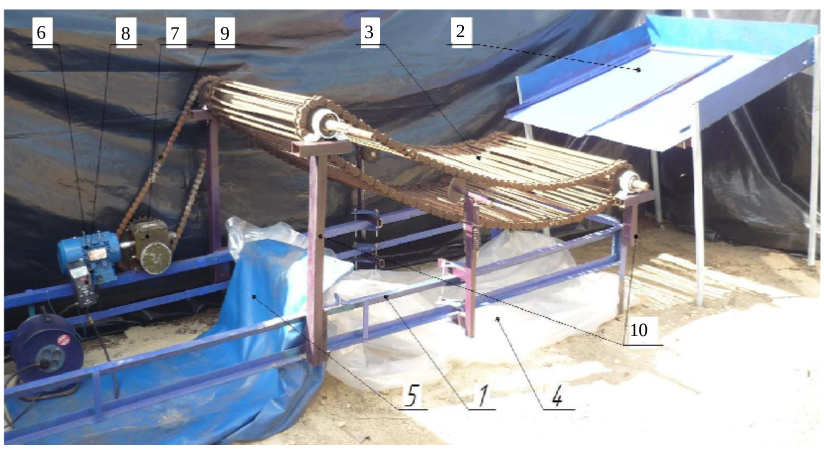


Fig. 6: General view of the laboratory equipment for studying the intensity of onion set thrashed heap[ separation: 1) Frame; 2) Container for preliminary storage of thrashed heap; 3) Separating rod elevator; 4) Canvas for collection of inclusions; 5) Canvas for separated products; 6) Electric motor; 7) Single-stage reducer; 8) Variable speed drive; 9) Chain gear and 10) Supporting rack

The research was conducted in order to determine the effect of the technological parameters ($Q_{bn}$ and $v_{ch}$) of the separating rod elevator of an onion harvester on the separation intensity $q_B$ of onion set thrashed heap in a lab environment.

Table 1: Factor variability interval in determining the separation intensity for onion set heap

| Variability levels | Feed of onion set thrashed heap ($Q_{Bn}$, kg/sec) | Traveling speed of the rod elevator ($v_{ch}$, M/c) (Variable factors) | Optimization criteria: Separation intensity for onion set thrashed heap ($q_B$, kg/m$^2$c) |
|---|---|---|---|
| | Variability interval | | |
| | 10.0 | 0.2 | |
| upper (+1) | 40.0 | 1.8 | |
| lower (-1) | 20.0 | 1.4 | |
| basic (0) | 30.0 | 1.6 | |
| codes | $X_1$ | $X_2$ | Y |

Table 2: Two-factor experiment planning matrix

| Designation | Factors: Feed of onion set heap ($Q_{Bn}$, kg/sec)$x_1$ | Traveling speed of the rod elevator ($v_{ch}$, m/sec)$x_2$ |
|---|---|---|
| 1 | -1 | -1 |
| 2 | 1 | -1 |
| 3 | -1 | 1 |
| 4 | 1 | 1 |
| 5 | 1 | 0 |
| 6 | -1 | 0 |
| 7 | 0 | 1 |
| 8 | 0 | -1 |
| 9 | 0 | 0 |
| 10 | 0 | 0 |
| 11 | 0 | 0 |
| 12 | 0 | 0 |
| 13 | 0 | 0 |

## RESULTS AND DISCUSSION

After processing the results of the multi-factor experiment with the "STATISTICA-6.0" Software,the response function values were obtained the intensity of onion set thrashed heap separation with variable factors and an adequate mathematical model was obtained that describes the interrelation of the intensity of onion and soil thrashed heap separation $q_B = f(Q_{Bn}, v_{ch})$ in a coded form depending on the selected factors:

$$Y = 621.34+31.33x_1+27.39x_2+0.11x_1^2-0.47x_2^2-0.005x_1x_2 \quad (3)$$

The hypothesis on adequacy of the presented model was verified with a regression equation statistical analysis. The response surface center coordinates are defined by differentiating the Eq. 3 and solving the simultaneous equations:

$$\begin{cases} \dfrac{dy}{dx_1} = 13.33+0.22x_1-0.005x_2 = 0 \\ \dfrac{dy}{dx_2} = 27.39-0.94x_2-0.005x_1 = 0 \end{cases} \quad (4)$$

After solving the simultaneous Eq. 4, we find the response surface center coordinates as a code $Q_{Bn}$ = 30.8 kg/sec, $v_{ch}$ = 1.67 m/sec). By substituting the values of $x_1$ and $x_2$ and into the Eq. 3, we obtain the value of the response function in the surface center:

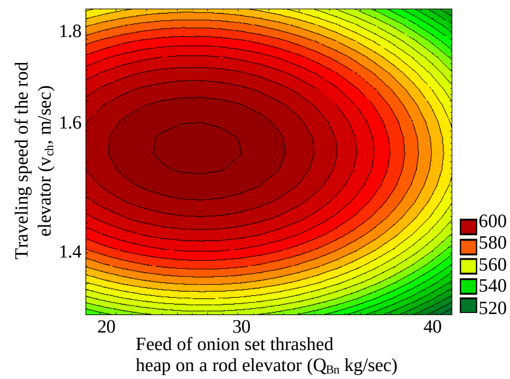


Fig.7: 2D section of the response surface that shows the dependence of onion set thrashed heap separation from the onion set heap feed to the separating rod elevator (kg/sec) and the traveling speed of the rod elevator (m/sec)

$$Y_s = 621.38 \quad (5)$$

After canonical transformation of the Eq. 3, we obtain a classical view of the equation: The shaft rotation angle is:

$$Y\text{-}621.38 = 0.0015x_1^2-0.47x_2^2 \quad (6)$$

By substituting different values of the response function into the Eq. 3, we obtained counter plot equations ellipses. The calculation results are shown on Fig. 7:

$$tg2a_2 = \frac{0.005}{0.11-0.005} = 0.047 \quad (7)$$

By analyzing Fig. 3, we can see that the maximum intensity of onion set heap separation is 600 kg/sec, provided that the optimum values of the considered factors are found: feed of the onion set heap $Q_{Bn}$ = 24.8, ..., 28.8 kg/sec and the traveling speed of the rod elevator $v_{ch}$ 1.58, ..., 1.76 m/sec.

## CONCLUSION

The data obtained from the experimental research will allow for designing secondary separation tools of onion set harvesting machinery both for the first and the second harvesting stages to ensure high quality separation process according to STO AIST 8.7-2013 “Machinery for harvesting vegeta ble and cucurbits crops. Methods for functional evaluatio” (Anonymous, 2013).

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