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Proximate Design of Onion Harvester Separating Surface

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Abstract: High variability of soil and climatic conditions in Russia requires to develop and use appropriate technologies and technical means to harvest root crops. The authors have determined input parameters that depend on physical and mathematical characteristics of harvested crops, soil type and condition and have a critical impact on developing crop harvesters and harvesting technologies. (*Research purpose*) The research aims at determining the separation intensity of onion-soil heap on the rod elevator, as well as onion heap supply from the surface of the rod elevator trails to the secondary separation mechanisms – all relating to onion harvesting machines. (*Materials and methods*) The size and mass parameters of the studied material are limitative for designing basic parameters of the working elements of technical equipment. The issue of increasing quality indicators of onion picker separators is considered on condition that basic input parameters should be precisely defined as they determine technological process of onion cleaning from soil and plant impurities. The authors have determined the amount of onion heap supply to the onion harvester lifting share in accordance with onion dimensional and mass characteristics. (*Results and discussion*) The onion fraction in the total lifted heap has been determined as well as the weight of onion heap and impurities on the rod elevator trails and onion heap supply from the surface of the rod elevator trails to the secondary separation mechanisms. The authors have also specified separation intensity as well as interdependencies describing a possibility of loss prevention in onion heap fractional composition passing through the rod elevator slots. The influence of design and technical parameters of the rod elevator as well as the influence of fine soil fraction mass on the onion heap separation intensity of the rod elevator have been revealed as well. (*Conclusions*) The formula has been obtained to determine onion heap supply from the rod elevator surface to the secondary separation mechanisms depending on design and technical parameters of the rod elevator as well as the onion heap weight.
Keywords: onion; onion harvesting; clumped soil; heap supply; heap fractions; separation intensity.

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The development of industrial production of seed onion is restrained by the lack of means for mechanically harvesting bulbs that meet one of the agrotechnical requirements - the complete separation of the heap of bulbs from soil impurities [1, 2]. In addition, due to the increase in the yield of seed onion using high-yielding hybrids as a seed material (Hercules F1, Sturon, Troy F1, Shtur BS 20, Centurion F1, Forum F1, Globus, Zolotnichok), the mass and the number of seed onion bulbs are increased for one running meter [3].

Consequently, the supply of a heap of bulbs from the surface of digging devices to the separating working elements of primary and secondary separation of modern harvest harvesting machines is increased, which do not ensure the complete removal of soil impurities in the harvesting of onion.

The quality of the technological process performance of a machine for onion harvesting is primarily determined by the work of the digging working element. Depending on its type and technological parameters, the design and technological parameters of the separating devices may change [4-7].

The peculiarities of the change in the intensity of separation of the tuberous heap in a potato harvester have been revealed [8]. But potato tubers and seed onion bulbs have different size-mass and physical-and-mechanical properties. Therefore, when calculating the separating devices for onion bulbs, it is necessary to clarify the corresponding empirical coefficients and analytical dependencies.

Research purpose – determination of the intensity of separation of the onion-soil heap on the rod elevator, and the amount of heap passed from the surface of the rod elevator to the secondary separation devices as exemplified by machines for onion harvesting.

Materials and methods. To determine the amount of onion bulb heaps passing from undercutting working elements to the separating elements of a harvesting machine, it is necessary to provide laboratory conditions identical to the real ones when cultivating onions.

Results and discussion. The proportion of bulbs $W_л$ in relation to the total volume of the onion-soil heap is determined from the expression [9]:

$$W_{Л} = \frac{V_{Л}}{V_{В}}, \quad (1)$$

where $V_л$ – volume of bulbs, dug by a share, m^3;

$V_В$ – the volume of the onion-soil heap dug by the share, m^3.

The supply of an onion heap $Q_{Вп}$ onto a digging share is found from the expression [10]:

$$Q_{Вп} = \frac{V_В v_л (\rho_П + \rho_л)}{l_П}, \quad (2)$$

where $v_л$ is the translational velocity of the digging share, *m/s*;

$\rho_п$ – soil density, *kg/m*^{3};

$\rho_л$ – the density of bulbs, *kg/m*^{3};

$l_п$ – the length of digging share, *m*.

Thus, with a known scheme of onion cultivation, the amount of heap inflow on the digging share can be determined by formula (2), taking into account the physical-and-mechanical properties of soil and bulbs.

The composition of the onion heap $m_{вп}$, coming from the surface of the digging working element to the separating elements is formed by five main fractions (by weight, *kg*):

- fine soil impurities m_1;
- soil clumps that are equal to bulbs in size m_2;
- large soil clumps m_3;
- bulbs m_4;
- plant impurities m_5.

The working surface of the rod elevator is formed by a set of bars with a diameter $d_П$ with a slot distance between them $S_П$, due to the implementation of the separation process in accordance with the conditions [4]:

- maximum sifting of soil and other impurities;
- reduction to a minimum of losses and damage of root crops.

The implementation of the first condition requires increasing the clearance in the elevator and the intensity of the impact on the heap components. The second condition assumes narrowing of the gaps and a partial load mode of operation. According to the technological scheme of the machine for harvesting root crops and onion, the primary separation devices are designed to separate small soil impurities m1, therefore slotted holes to prevent losses of marketable products are selected from the condition:

$$S_П < d_К, \quad (3)$$

where $d_К$ is the minimum diameter of the root crop, *m*.

Consequently, the fractional composition of seed onion heap- at the $m_{СХэл}$ descent from the rod elevator consists of:

- clumps of soil equal in size with bulbs, m_2;
- large soil clumps, m_3;
- bulbs, m_4.

It is possible that the bulb intersects the surface of the rod elevator parallel to its bars (Fig.).

The probability of this event [4]:

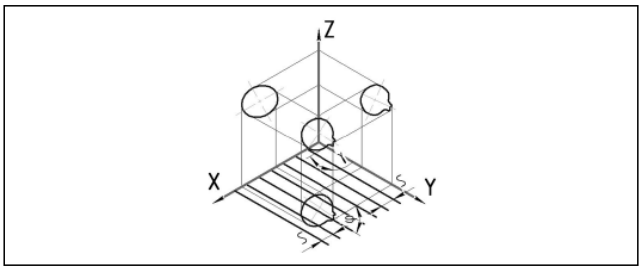

Fig. Diagram to possibility determination of onion penetration through rod elevator blanks

$$P = \frac{8}{\pi^2 S} \int_{\varphi_1}^{\varphi_2} \int_{\gamma_1}^{\gamma_2} \frac{d_К \sin\varphi \sin\gamma - S_П}{2} d\varphi d\gamma, \quad (4)$$

where φ is the angle between the horizontal projection of the bulb and the bars of the elevator, *deg.*;

γ – the angle between the vertical projection of the bulb and the elevator rods, *deg.*

Wherein:

$$\varphi_1 = \arcsin \frac{S_П}{d_К \sin\gamma}; \quad (5)$$

$$\varphi_2 = \arcsin \frac{2S_П}{d_К \sin\gamma}; \quad (6)$$

$$\gamma_1 = \arcsin \frac{S_П}{d_К \sin\varphi}; \quad (7)$$

$$\gamma_2 = \arcsin \frac{2S_П}{d_К \sin\varphi}, \quad (8)$$

where γ_1, φ_1 are minimal, and γ_2 and φ_2 are the maximum values of the parameters.

The probability *P'* of excluding losses of the fractional composition of onion heap (m_2, m_3, m_4) through the slots of the rod elevators is determined by the expression [4]:

$$P' = \frac{\pi - 2\eta_2}{\pi} + \frac{2d_К}{\pi^2 S_П}(\eta_2 - \eta_1) -$$

$$- \frac{d_К}{\pi^2 S_П}(\sin 2\eta_2 - \sin 2\eta_1) - \frac{4}{\pi^2}(\eta_2 - \eta_1), \quad (9)$$

where:

$$\eta_1 = \arcsin \sqrt{\frac{S_П}{d_К}}; \quad (10)$$

$$\eta_2 = \arcsin \sqrt{\frac{2S_П}{d_К}}., \quad (11)$$

where η_1, η_2 are the limits of the variation of the angles φ and γ, which are favorable for this event.

Fractions of bulbs, large soil clumps and clumps equal in size with bulbs come off from the separating surface of the rod elevator. Therefore, the mass of onion heap coming out of the rod elevator is:

$$m_{СХэл} = (m_2 + m_3 + m_4)\, P'. \quad (12)$$

Let us calculate the probability of passing of $P'_П$ mass $m_{СХэл}$ through slots $S_П$ of the rod elevator:

$$P'_П = 1 - P'. \quad (13)$$

According to formula (12), we obtain the mass of onion heap at the $m_{СХэл}$ descent from the surface of the rod elevator:

$$m_{СХэл} = 2P'(m_2 + m_3 + m_4) - (m_2 + m_3 + m_4). \quad (14)$$

The mass of the separated fine soil fraction m_1 can be found from the expression:

$$m_1 = m_{Вп} - m_{СХэл}, \quad (15)$$

where $m_{Вп}$ is the mass of an onion heap coming from digging to separating working elements, *kg*:

$$m_{Вп} = \frac{Q_{Вп} l_П}{v_л}. \quad (16)$$

With the known supply of an onion heap on a digging share $Q_{Вп}$, we determine the intensity of the separation of the onion bulb heap on the surface of the rod elevator of the harvesting machine $q_В$. In accordance with [11, 12], we refine the well-known formula according to the expression (12):

$$q_В = \frac{m_1 v_{ЭЛ}}{B l^2_{ЭЛ}}, \quad (17)$$

where $v_{эл}$ is the translational speed of the rod elevator, *m/s*;

B – the width of the rod elevator, *m*;

$l_{эл}$ – the length of rod elevator, *m*. The amount of feeding a bulb heap from the surface of the rod elevator to the secondary separation devices is determined by the formula:

$$Q_{Вэл} = \frac{m_{СХэл} v_{ЭЛ}}{l_{ЭЛ}}. \quad (18)$$

Conclusions. The results of the conducted studies allow to determine the intensity of the separation of bulbs, the amount of feeding of bulbs from the surface of the rod elevator to the secondary separation devices with respect to machines for onion harvesting. These indicators are the determining factor in the design of the secondary separation devices.

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