Potato digger with latticed plowshares and oscillating rods

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Abstract. The process of digging potatoes is characterized by high energy costs due to the interaction of the potato digger's plowshare with the tuber-bearing soil layer. The study aims to substantiate the parameters of the potato digger's lattice plowshare. In the proposed potato digger, the plowshare is made latticed and equipped with oscillating rods. This potato digger has a mechanism for transmitting torque to oscillating rods. The experiments were carried out using a special laboratory field installation. Various lattice plowshares were manufactured, and single-factor experiments were carried out. During the experiments, the degree of damage and loss of the tuber and the traction resistance of the potato digger were taken as evaluation criteria. The results of experimental studies to determine the parameters of the plowshare are presented. It is established that the optimal design scheme for a potato digger consists of torque transmission mechanisms, lattice plowshares, and forcibly oscillating rods. As a result, theoretical studies, analytical dependencies, and mathematical models were obtained to determine the parameters of a lattice plowshare. Studies have established that to destroy the tuber formation to the required extent with minimal damage and loss of tuber, as well as energy costs, the width of the lattice plowshare should be 55 cm, the installation angle relative to the horizon is 22°, the length of the plowshare is 38 cm, and the width gap between the bars is 3 cm.

1 Introduction

According to the Food and Agriculture Organization of the United Nations (FAO), potatoes are grown on 22 million hectares in 150 countries worldwide, and it is planned to double its volume in the next 10 years. Based on this, it is required to develop and put into practice tools for digging up the harvested root crops with high-quality work and productivity, as well as with the lowest fuel consumption.

At the end of 2022, potatoes were planted on the main arable land of 67.9 thousand hectares in the Republic of Uzbekistan. As a recurring crop, 28.6 thousand hectares were planted in 3.0 million hectares, tons of potatoes were delivered. Potatoes are grown mainly in Andijan, Namangan, Samarkand, Surkhandarya, Tashkent, and Fergana regions. The total area cultivated in the Kashkadarya region is 65,945 hectares, the area planted by the landlords is 60.214 hectares, and the area cultivated on peasant farms is 5,731 hectares. * Corresponding author: karimovakmalakbarovich@gmail.com
From this, it can be seen that potatoes are mainly planted by the landlords on small arable land (Fig. 1). Since 91.3 percent of arable land is made up of land for landowners, the cultivation of potatoes is handled individually. Growing potatoes in small contours is mainly 0.4-0.5 hectares and even smaller areas.

Fig. 1. Total arable land in landholders and farmers' farms

The development of a small-sized potato digger improved from the above, and the justification of its parameters is considered important for the national economy of our republic. Many scientists, including M Salimzyanov [1], Y Syromyatnikov [2, 6, 7, 17, 18], M Kostenko [3], F Maiviatov [4], M Edrris [5], F Maiviatov [8], S Hrushetsky [9], F Mamatov [10], B Tulaganov [11], Z Wei [12], J Zhou [13], M Kalimullin [14], M Kalimullin [15], A Semenov [16], K Romaneckas [19], E Sarauskis [20], have developed swing diggers, sifting diggers, and throwing type diggers. In vibratory-type potato diggers, trough-shaped plow shares are mainly used. In elevator-type potato diggers, various types of digging organs are used, which are divided according to the principle impact on the tuberous layer: passive, active, and combined. However, these studies do not address the issues of developing potato diggers with lattice plow shares and forcibly oscillating working bodies for digging up the crop root crops and substantiating the technological processes, their work, and their parameters. The study aims to substantiate the parameters of lattice plowshare improved potato digger.

2 Materials and methods

Experiments were carried out by aggregating a potato digger with a New Golland-110 tractor at a 0.8-1.1 M/s aggregate speed. Experimental studies on improved potato pickles were conducted in the summer season on farms of the Kashkadarya region of the Republic of Uzbekistan. The terrain field is flat; the experimental soil field is medium-light, sandy soil. The quality and energy indicators experimental potato digger were evaluated according to the following indicators: the completeness potato digger; potato loss; damage to potatoes; drag resistance cowler. Drag resistance potato digger TST 63.03.2001 "Tests of agricultural machinery. Methods of energy assessment" was determined using tensometric fingers. One-factor experiments were conducted to determine the optimal parameters of the potato digger's lattice plowshare. Lattice plow shares with different gripping widths and slots have been developed and manufactured for experimental studies. During the experiments, the...
degree of damage and loss of the tuber and the traction resistance potato digger were taken as evaluation criteria.

In the taxile transmitted literature [1, 5], an improved potato digger was developed based on early research and agrotechnical requirements poured into potato diggers (Fig. 1).

The potato digger consists of a frame 1, equipped with a suspension device, a main 2 and an intermediate colter fixed to the frame, oscillating plows 3 attached to the main plows, and mechanisms that oscillate the plows. Oscillating motion to the tractor 3 is transmitted from the tractor power take-off shaft through a cardan shaft 4, a transmission box 5, a crankshaft 6, a drawbar 7, a bridle 8, a two-shouldered lever 9, and a lever 10.

The technological process of potato diggers is as follows (Fig. 2).

Fig. 2. Scheme potato digger with a lattice plow share and oscillating rods: 1 is frame; 2 is plowshare; 3 is rod; 4 is driveshaft; 5 is transmission; 6 is crankshaft; 7 is traction; 8 is leash; 9 is double–shoulder link; 10 is rod.

The main plowshares 2 separate the soil layer from the bottom soil with the nodes, crush it and partially separate it from the main mass, and then direct it to the oscillating ferules 3.

The harrows intensively separate the tubers from the soil and throw them on the surface field. The process of separating potatoes from the soil and sieving the soil is improved under the influence of oscillating ferules 3. The intermediate blade potato digger scoops up the potatoes that fall between the rows and transfers them to the harvesters.

Fig. 3. Grid plow and oscillating harrows: 1 is intermediate plow; 2 is plow share with a grid; 3 is oscillating wheels.
The improved potato digger is equipped with a plow with a flat grid; its main parameters include plow width \( B_l \); angle inclination \( \varphi \) of the plow share to the horizon at the length of the plow share \( L_l \); the opening angle \( \varphi \) of the intermediate plow share \( B_{ol} \) (Fig. 3 and 4).

In the following years, the row spacing of potatoes in Uzbekistan is 70 and 75 cm. Therefore, we will perform further calculations for a row spacing of 75 cm. We determine the width of the plow with a flat grid by the following known expression, provided that all the nodes located in the field are fully dug with minimum coverage of the soil (Fig. 3).

\[
B_l = b_m + \delta + h - h_x \cdot \cot \varphi_q - t_n
\]

where \( b_m \) is the width placement buds in the nest, cm; \( \delta \) is the displacement row planted with potatoes about the axis of the symmetry plow, due to the row not being straight and the machine not being precisely controlled, cm; \( h \) is the digging depth, cm; \( h_x \) is the depth placement marginal nodules according to the width nodule socket, cm; \( \varphi_q \) is the angle natural slope soil, °; \( t_n \) is the thickness side blade, cm.

Because the depth placement of marginal nodes according to the width terminal socket is variable in a wide range and there is not enough accurate information on it, we determine it according to the following expression

\[
h_x = h + \frac{h - h_c}{2} = h + h_x
\]

where \( h_1 \) is the depth of placement of upper nodules in the bush, cm; \( h_2 \) is the depth of placement of lower node in the bush, cm; \( h_0 \) is the depth of placement of marginal nodules according to the width nodule socket, cm; \( \varphi_q \) is the angle natural slope soil, °; \( t_n \) is the thickness side blade, cm.

Based on our research, if \( h_1 = 7.5 \) cm and \( h_2 = 18.5 \) cm, based on the expression (2), we determine that \( h_x = 13 \) cm.

We put the value of \( h_x \) in (1) according to the expression (2).

If \( b_m = 23 - 30 \) cm, \( \delta = 4 \) cm, \( h = 20 \) cm, \( h_x = 13 \) cm; \( \varphi_q = 38° \); \( t_n = 0.5 \) cm, based on expression (3), we determine that it should be in the range of \( B_l = 48.4 - 55.4 \) cm.

Considering that the potato digger works in fields with a row spacing of 75 cm, we accept \( B_l = 55 \) cm.

Fig. 4. Diagram cross-section field planted with potatoes to determine the parameters tiller.
The potato digger is designed to dig potatoes in two boxes. Taking this into account, based on Fig. 4, we determine the width intermediate plow by the following expression, taking into account the width row interval \( B_k \), the width main plow \( b_1 \), and the width slot between the plowshares \( b_2 \) (Fig. 4).

\[
B_{ol} = B_k - B_I - b_2
\]

If \( B_k = 75 \text{ cm}, B_I = 55 \text{ cm}, \) and \( b_1 = 3 \text{ cm}, \) based on expression (5), \( B_{ol} = 13.5 \text{ cm}. \)

Based on the research conducted by scientists, the opening angle plow share is determined by the condition that its blade cuts grass residues and the roots of potato stalks. According to it, \( \phi_1 = 40 - 45^\circ \), we determine that the angle opening plow share should be in the range of 80 - 90\(^\circ\). In potato diggers, \( \gamma = 90^\circ \) is accepted.

\[ \gamma = \left( \pi - \phi_1 \right) \theta - \phi \]

\[ \phi_1 = 40 - 45^\circ \]

\[ \gamma = 90^\circ \]

\[ \theta 

Fig. 5. Scheme for determining parameters grid plow

Conducted studies on determining the angle deviation of a plow relative to the horizon. According to their research, angle \( \alpha \) should be between 22 - 30\(^\circ\). We take \( \alpha = 22^\circ \).

It is known that the length of the plow share potato digger affects whether the nodular mass accumulates in the front plow share. As the length plow share increases, the speed of movement of nodular mass along the surface plow share decreases, which, in turn, causes the soil to accumulate in front plow share and disrupt the technological process. Under the influence plow, the nodular mass should move freely and disintegrate sufficiently on its surface. The length plow share was determined. We determine by the following expression.

\[
B_{ol} = B_k - b + \left[ h - \frac{h_1 + h_2}{2} \right] \cot \phi - t_n - b_2
\]
where \( \sigma_b \) is the temporary resistance to compression soil, Pa; \( \rho_x \) is volume density of soil, kg/m\(^3\); \( \tau \) is the soil refraction angle, \(^\circ\); \( g \) is acceleration free fall, m/s\(^2\); \( V_M \) is movement speed, m/s.

The angle of refraction soil in the expression (6).

\[
\tau = \arctg \frac{K - \frac{a}{\alpha}}{h}
\]

\[
K = \frac{a}{h}
\]

\[\alpha = 22^\circ, \phi = 25^\circ, \sigma_b = 6 \times 10^3 \text{Pa}, \tau = 25^\circ, K = 1.1, \rho_x = 1350 \text{Kg/m}^3, V_M = 0.8 - 1.1 \text{m/s} \] (6)

should not be larger than \( L_l \geq 36 - 39 \) cm according to the expression. We accept \( L_l = 38 \) cm.

We determine the width of lattice slots \( b_{po} \) because the nodes do not pass between them. Previous studies show that this distance should not exceed 3 cm. We accept \( b_{po} = 3 \) cm. We take the width bars of the grid to be 1 cm, the width side of the plowshare to be 10.5 cm, and the width blade gridded plowshare to be 110 mm. In that case, the number of furled fence (9) will be 8 pieces.

3 Results and discussion

The results of experimental studies are shown in Figures 5 and 6. According to the results (Fig. 5), with an increase in the angle inclination lattice plowshare, losses and damage to potatoes first decrease and then increase according to the law of concave parabola. This can be explained by the fact that the time movement tuber-bearing mass soil on the surface of the plowshare first decreases and then increases with an increase in the angle inclination plowshare. The traction resistance potato digger increased with an increase in the angle inclination at both speeds. The main reason for this is that with increasing speed, the impact of plowshare on the tuberous soil and the inertia forces acting on the plowshare from the soil increases.
Based on the above, the angle inclination of the plowshare to the horizon is assumed to be 22º. The influence of the width of the lattice plowshare on the quality and energy indicators of the potato digger was studied. To justify the width of the lattice plowshare, lattice plowshares with widths of 35, 45, 55, and 65 cm were experimentally developed and manufactured. According to the results of experiments (Fig. 6), with an increase in the width of the lattice plowshare, potato losses first decrease and then increase according to the law of concave parabola. Damage to potatoes decreases with an increase in the width of the plowshare. This is because with smaller values of the width of the plowshare, they do not completely cover the tuberous mass, and the tubers are damaged by the blades of the plowshare. When the width of the plowshare is more than 60 cm, the volume of soil covered by it increases, which leads to a decrease in the degree of separation of the tubers from the soil and, accordingly, an increase in their loss. At the same time, the damage does not change significantly. According to the results of experiments, the width of the plowshare should be 55 cm.
Fig. 7. Graphs of changes in potato losses ($P_y$), damage ($Sh$), and traction resistance ($R$) depending on width plowshare ($B_l$).

4 Conclusions

The most optimal design scheme for an improved potato digger consists of transmission mechanisms, lattice plowshares, and forcibly oscillating rods. As a result, theoretical studies were carried out, and analytical dependencies and mathematical models were obtained to determine the parameters and operating mode of an improved potato digger with lattice plowshares and oscillating rods. To destroy the tuberous formation to the required extent with minimal energy consumption, the width lattice plowshare should be 55 cm, the angle plowshare installation relative to the horizon should be 22°, the length plowshare should be 38 cm, and the width gap between the bars should be 3 cm.

References

7. Syromyatnikov Yu N 2018 Achievements of equip. and tech. in the agro-ind. complex 222-230


22. CONMECHYDRO - 2023 https://doi.org/10.1051/e3sconf/202340104029