 https://doi.org/10.1051/e3sconf/202340104029

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 plowshares with the tuber-bearing soil layer. The study aims to substantiate the parameters of 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 potato digger were taken as evaluation criteria. The results of experimental studies to determine the parameters of 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 lattice plowshare should be 55 cm, the angle plowshare installation relative to the horizon is 22°, the length 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.

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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.

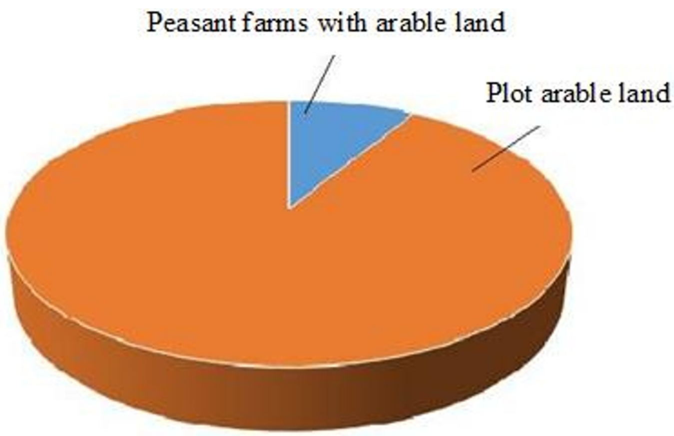

Fig. 1. Total arable land in landholders and farmers ' farms

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]. He has developed swing diggers, sifting diggers, and throwing type diggers. In vibratory-type potato diggers, trough-shaped plowshares 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 plowshares 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 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 plowshares 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).

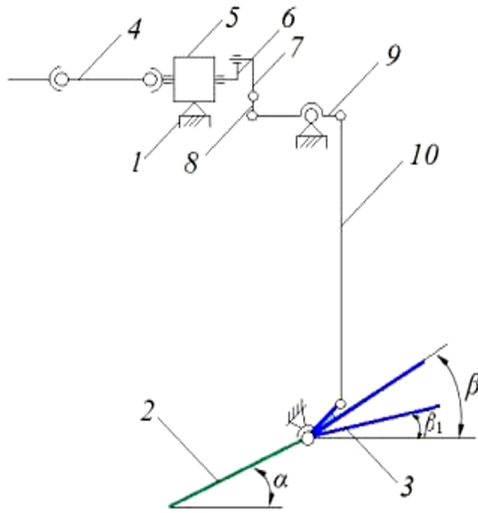

Fig. 2. Scheme potato digger with a lattice plowshare and oscillating rods: 1 is frame; 2 is plowshare; 3 is rod; 4 is driveshaft; 5 is transmission; 6 is crankshaft; 7 is traction; 8 is leash; 9 is double–shoulder link; 10 is rod

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.

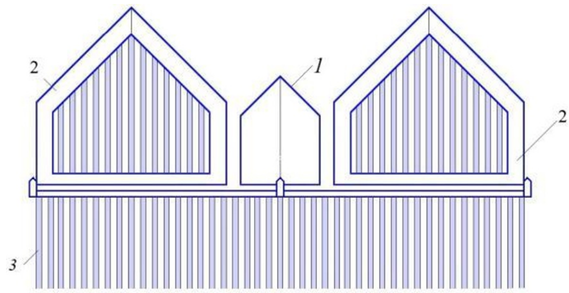

Fig. 3. Grid plow and oscillating harrows: 1 is intermediate plow; 2 is plowshare with a grid; 3 is oscillating wheels

The improved potato digger is equipped with a plow with a flat grid; its main parameters include plow width B_l; angle inclination plowshare to the horizon at the length the plowshare is L_l; the opening angle plowshare g, the width intermediate plowshare 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).

$$B_l = b_m + 2\delta + 2(h - h_x)ctg\varphi_q - t_n, \quad (1)$$

where b_m is the width placement buds in the nest, cm; δ 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 digging depth, cm; h_x is the depth placement marginal nodules according to the width nodule socket, cm; φ_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

$$h_x = h_1 + \frac{h_2 - h_1}{2} = \frac{h_1 + h_2}{2}, \quad (2)$$

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;

Based on our research, if h_1=7,5 cm and h_2=18,5 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).

$$B_l = b_m + 2\delta + 2(h - \frac{h_2 + h_1}{2})ctg\varphi_q - t_n, \quad (3)$$

If b_m=23-30 cm, δ=4 cm, h=20 cm, $h_ч$=13 cm and φ_q=38°, if 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.

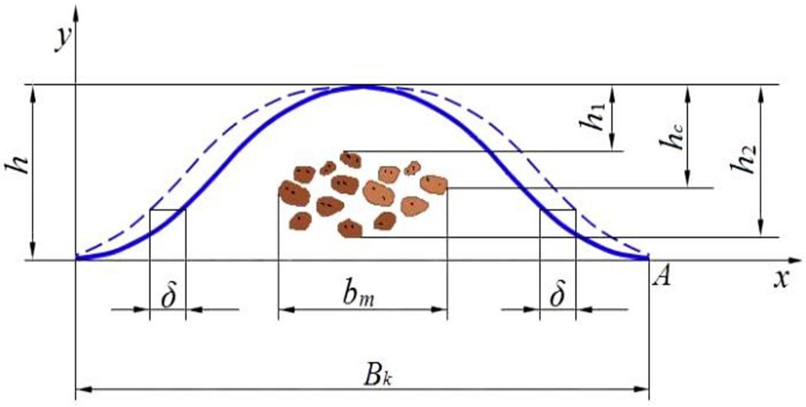

Fig. 4. Diagram cross-section field planted with potatoes to determine the parameters tiller

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, and the width slot between the plows b_1 (Fig.4)

$$B_{ol} = B_k - B_l - 2b_1, \tag{4}$$

where B_k is the row spacing width, cm; b_1 is the width slot between the plowshares, cm.

$$B_{ol} = B_k - \left[b_m + 2\delta + 2\left(h - \frac{h_2 + h_1}{2} \right) ctg\varphi_q \right] - 2t_n - 2b_1, \tag{5}$$

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

Based on the research conducted by scientists, the opening angle plowshare is determined by the condition that its blade cuts grass residues and the roots of potato stalks. According to it $\gamma = 0{,}5(0{,}5\pi - \varphi_1)$, φ_1 – is the maximum value of the angle friction soil and potato roots on the blade plow, º. By putting φ_1=40-45º in the expression, we determine that the angle opening plowshare should be in the range of 80-90º. In potato diggers γ=90º is accepted.

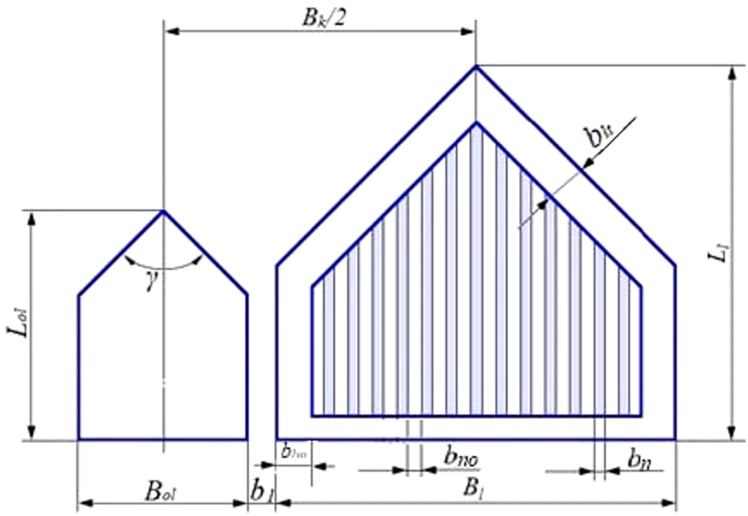

Fig. 5. Scheme for determining parameters grid plow

Conducted studies on determining the angle deviation of a plow relative to the horizon. According to their research, angle a should be between 22-30º. We take α=22º.

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

$$L_l \le ctg(\alpha+\varphi)\left\{\frac{\sigma_b}{\rho_x g}-\frac{2V_M^2}{g}\sin\tau[\cos\tau tg(\alpha+\varphi)-\sin\tau]\right\}, \tag{6}$$

where σ_b is the temporary resistance to compression soil, Pa; ρ_x is volume density of soil, kg/m^3; τ is the soil refraction angle, ^{o}; g is acceleration free fall, m/s^2; V_M *is* movement speed, m/s.

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

$$\tau = arctg\frac{K-\cos\alpha}{\sin\alpha}; \tag{7}$$

$$K=\frac{a_1}{h}, \tag{8}$$

where K is the coefficient of soil subsidence; h is digging depth, cm; a_1 is the thickness plow blade, cm.

If α=22^o, φ=25^o, σ_b= 6·10^3 Pa, τ=25^o, K=1.1, ρ_x=1350 Kg/m^3 and V_M=0.8-1.1 m/s (6) should not be larger than L_l=36-39 cm according to the expression. We accept L_l=38 cm.

We determine the width of lattice slots b_{no} because the nodes do not pass between them. Previous studies show that this distance should not exceed 3 cm. We accept b_{no}=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

$$n_{nx}=\frac{B_l-2b_{lyo}}{b_{no}+b_n}. \tag{9}$$

Since B_l=*55* cm*,* b_{po}=*3* cm*,* b_{ly} =*10.5* cm, and b_p=*1* cm, the number of lattice hives per expression (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.

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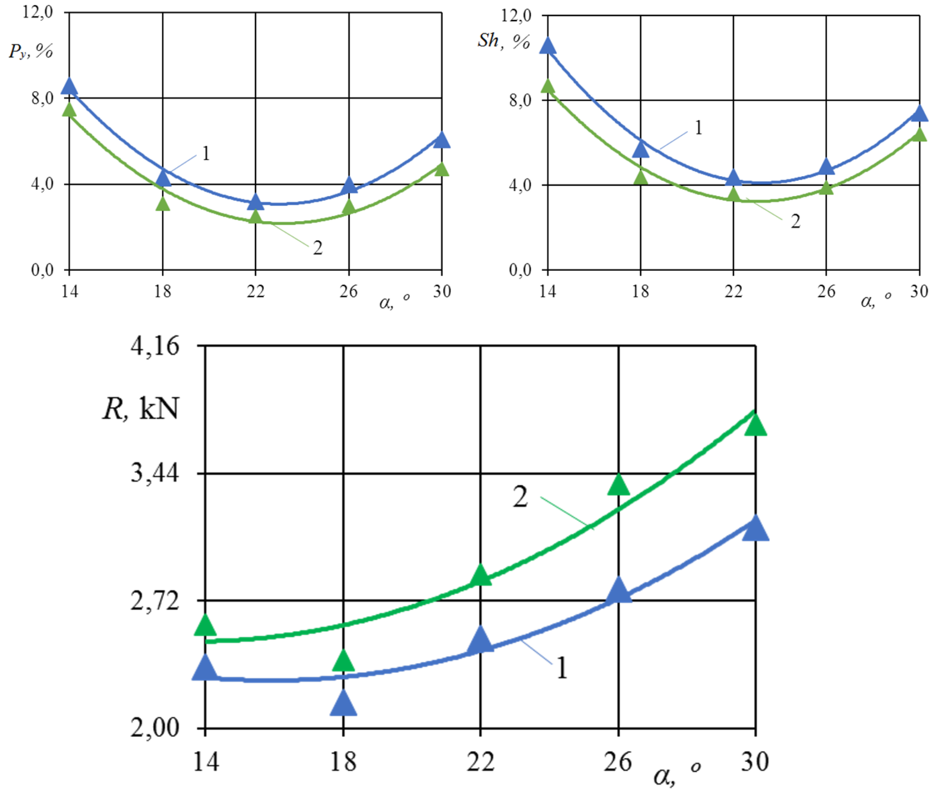
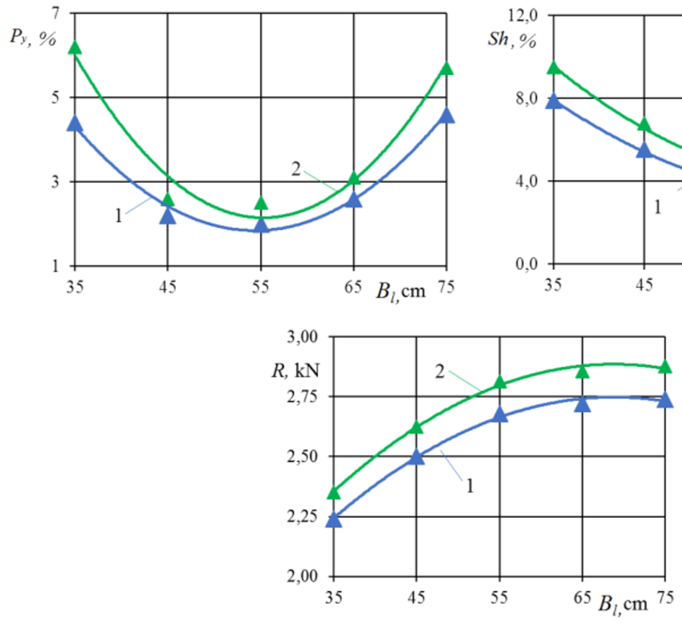


1 – V=0.8 m/s; 2 – V=1.1 m/s

Fig. 6. Graphs of changes in potato losses (R_u), damage (Sh), and traction resistance (R) potato digger depending on angle of inclination (α) lattice plowshare to the horizon

Based on the above, the angle inclination plowshare to the horizon is assumed to be 22º.

The influence of width lattice plowshare on the quality and energy indicators potato digger. To justify the width of 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 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 plowshare. This is because with smaller values widths of the plowshare, they do not completely cover the tuberous mass, and the tubers are damaged by the blades of the plowshares. When the width plowshare is more than 60 cm, the volume of soil covered by it increases, which leads to a decrease in the degree of separation 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 plowshare should be 55 sm.



1 – V=0.8 m/s; 2 – V=1.1 m/s

Fig. 7. Graphs of changes in potato losses (P_y), damage (Sh), and traction resistance(R) potato digger 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.

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