The soil preparation machine for seeding potatoes on comb

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Abstract. The aim of the research is to substantiate the main parameters of the machine working elements for preparing the soil for sowing on the ridges and their mutual location. The authors have developed a machine that performs all technological operations to prepare the soil for sowing potatoes on the ridges in one pass in the field. The machine performs surface loosening of the soil, strip deep loosening of the soil, formation of ridges, loosening of the surface layer of the ridge top, compaction, and giving them a trapezoidal shape in one pass. The design of the developed machine for the realization of technology of preparing the soil for potatoes sowing is resulted. The basic principles and methods of classical mechanics, mathematical analysis, and statistics were used in this study. Theoretical studies established the following parameters of the working bodies of the machine: the working width of the bodies 200 mm, length of the blade wing 515-545 mm, angle of slope of the ploughshare left to its base 60, length and height of the guide knife respectively 150 mm and 80 mm, the longitudinal distance between the bodies within 350-400 mm, width and length of the drill bit 80 mm and 115 mm respectively, the working width of the lancet leg 150 mm.

1. Introduction

In the agricultural production of the Republic of Uzbekistan large-scale measures are being taken to reduce labor and energy costs, save resources, cultivate crops based on advanced technologies, and develop high-performance agricultural machinery. Currently, agronomical measures to prepare the soil for potatoes sowing on ridges, consisting of ploughing, cheeseling are carried out by separate units, which in turn leads to moisture loss, delaying sowing time and increasing operating costs. The analysis of studies has shown that to reduce fuel consumption and other costs, as well as the harmful impact of agricultural machinery on the soil in the preparation of fields for potatoes sowing, can be achieved by applying a machine that performs all technological operations to prepare the soil for potatoes sowing on ridges in one pass on the field.

Problems of cultivation and preparation of soils for potatoes sowing are considered in many published scientific works [1, 9-19]. Studies on the creation and application of machines for tillage and preparation of soil for sowing on ridges, the study of their performance and justification of parameters, as well as the study of processes of interaction of working bodies with soil were engaged F.Mamatov, B.Mirzaev [2-7], D.Chuyanov [8, 11], I.Ergashev [5, 6, 7], H.Ravshanov [7], V.Kurdyumov and
E.S.Zykin [20], I.A.Sharonov [21], B.C.Lakhmakov [22] and others. Machines and implements created as a result of these studies are used in agricultural production with certain positive results. However, in these studies, the issues of soil cultivation for potatoes sowing with simultaneous formation of ridges ensuring high quality of work at minimum energy consumption are insufficiently studied. The aim of the study is to justify the main parameters of the machine's working elements for preparing the soil for sowing on the ridges and their mutual location.

2. Materials and methods

The basic and methods of classical mechanics, mathematical analysis, and statistics were used in this study. The developed machine to implement the proposed technology consists of frame 1, lancet tines 5, deep looseners 4, left and right winging bodies 6 and 7, rollers 9 (Fig.1). Lance paws, deep leavers, left and right-tripping bodies of the developed machine are rigidly mounted on the frame, and the rollers - hinged.

![Figure 1: Diagram of the machine.](image)

The machine works like this. During the technological process, the deep loosening machine 4 (Fig.1) performs deep loosening of the soil along the line of the formed ridge. Lancet tines 6 and 7 located at the front of the hulls 5 loosen the top layer of soil to a depth of 8-10 cm, then plough hulls 6 and 7 with guide knives 8 perform undercutting, lifting and laying of soil layers with loosened top parts in the middle of the formed ridge and form ridges. Profile rollers 9 loosen the surface layer of the top of the ridge, compacting and giving it a trapezoidal shape.

3. Results and discussion

A machine based on the potato ridge soil preparation technology should cultivate and prepare a field with a width of 2.8 m in one pass.

The theoretical studies carried out showed that to ensure the required quality of soil loosening, the working width of the lancet leg should be at least 15 cm.

The main parameters influencing quality and energy performance of the straight-post chisel drill are as follows: height of the straight-post chisel, angle of crushing, width and length of the chisel, angle of sharpening of the bit blade, angle of sharpening of the stand, thickness and width of the stand. Based on previous studies: we accept angle of chisel shredding α₁=30°, bit blade sharpening angle i₁=15°, rack grinding angle i₂=60°, thickness and width of the rack respectively t₁=5 and b₁=18 cm.

Based on theoretical studies are justified: the height of the ripper stand H=74 cm, bit length l₁=11.5 cm.
The width of the drill bit is determined by the following expression taking into account critical cutting depth [23].

\[ b_d \geq \frac{a_{\text{max}} (m + \text{ctg} \alpha_d)}{0.1 \left[ \frac{\sigma_e}{\tau_k} \right] (1 + 3 \text{tg} \varepsilon) - n} \]  

(1)

Where: \( a_{\text{max}} \) is the maximum depth of cultivation of a deep cultivator, \( m \); \( [\sigma_e] \) is specific resistance of soil to buckling, \( \text{Pa} \); \( \tau_k \) is critical (limit) resistance of soil to buckling, \( \text{Pa} \); \( \varepsilon \) is inclination angle to the horizon of the resulting forces acting on the deep cultivator bit from the soil side, degree; \( m \) and \( n \) are dimensionless coefficients, depending on physical and mechanical properties of soil.

At \( a_{\text{max}}=35 \text{ cm}, \ a_d=300, \ m=4.2; \ [\sigma_e]/[\tau_k]=100, \ n=2.5 \) adopted on the basis of agrotechnical requirements for the formation of a ridge for sowing potatoes and earlier studies, the calculations carried out on the expression (1) showed that the width of the bit should be less than 79 mm. We accept \( b_d=80 \text{ mm}. \)

Basic parameters of the body (Fig. 2) are determined on the basis of the crest formation of the required shape and height. Based on previously conducted studies, the form of the cross-section of the pre-formed ridge is taken by a sinusoid. To form a crest of such shape it is necessary to cut, lift and turn towards each other soil layers of the right and left outermost part of the formed ridge with a width of \( B_m. \) We determine the working width of the body.

\[ b_k = \frac{B_m}{4} + \Delta \]  

(2)

Where: \( \Delta \) is the value of the teachable relief roughness, \( \Delta=2.5 \text{ cm}. \)

In expression (2) \( b_k=20 \text{ cm}. \)

Maximum depth of soil cultivation by the body is determined based on the condition of stability of the laid layer

\[ a = a_{\text{max}} - \frac{1}{2} b_k \text{tg} \tau \]  

(3)

By expression (3) at \( a_{\text{max}}=15.75 \text{ cm}, \ b_k=20 \text{ cm}, \) and \( \tau=6^\circ \) the hull processing depth is \( a=14.7 \text{ cm}. \) We accept \( a=15 \text{ cm}. \)

Hull height was determined on the basis of conditions of the free turn of formation under the frame and exclusion of clogging by vegetative remains of the machine by the following dependence

\[ H_k = 2.25a + 1.25\sqrt{a^2 + (b_k - \Delta_p)^2} \]  

(4)

Calculations made by expression (4) at \( a=15 \text{ cm} \) and \( b_k=20 \text{ cm} \) showed that the minimum height of the body should be \( H_k=56.25 \text{ cm}. \)

The guide knife 4 is fixed to the heel of the ploughshare (Fig.3). Its main parameters are the following: distance from the blade to the blade \( l_p \), length and height of the guide knife \( l_p \) and \( h_n \), angle of setting the guide knife blade to the horizon \( \alpha_n. \)

The setting angle of the blade of the guide knife to the horizon is determined by the sliding cutting conditions of the soil. According to calculations \( \alpha_n=30-33^\circ. \) We take \( \alpha_n=30^\circ. \)

The height of the guide knife is determined from the condition of minimizing the collection of the layer and the furrow wall from the side of the formed ridge by the following formula

\[ h_n \geq a - b_k \text{tg} \tau - \Delta_p. \]  

(5)

At values, \( b_k=0.2 \text{ m}, \ \Delta_p=0.05 \text{ m}, \) and \( \tau=6^\circ \) in expression (5) the minimum height of the guide knife should be at least 79 mm. We accept \( h_n=80 \text{ mm}. \)

Taking into account the constructive difficulties in installing the knife, the longitudinal distance from the knife to the toe of the ploughshare was determined by the following dependence

\[ l_{\text{ip}} = 0.6b_k \text{ctg} \gamma_1. \]  

(6)
Performed calculations on expression (6) at \( b_k = 0.2 \) m and \( \gamma_l = 42^\circ \) the longitudinal distance from a ploughshare to the nose of a knife should be not less than \( l_p = 130 \) mm.

The length of the guide knife shall be determined by the following formula

\[
l_n = b_k \cot \gamma_l - l_p + b_{le} \cos \varepsilon + (a - b_k \tan \tau - \Delta_n) \cos \alpha_n.
\]

(7)

Calculations performed on expression (7) showed that at \( b_k = 0.2, \gamma_l = 42^\circ, a = 15 \) cm, \( l_p = 0.22 \) m, \( \Delta_n = 0.05 \) m, \( \varepsilon = 25^\circ, \tau = 6^\circ, \) and \( \alpha_n = 30^\circ \) the length of the guide knife should be at least 140 mm. We accept 150 mm.

The working width of the arrowhead mounted in front of the bodies is determined from the conditions of the soil loosening of the formed row spacing under the action of its and deep loosening by the following formula

\[
b_n = (B_k - b_d) - 2(a_{max} - a_n) \cot \psi_1.
\]

(8)

Performed calculations by expression (8) at values \( B_k = 0.7 \) m, \( b_d = 0.08 \) m, \( a_n = 0.1 \) m, \( a_{max} = 0.35 \) m and \( \psi_1 = 48^\circ \). The minimum working width of the boom arm must be at least 140 mm. We accept \( b_n = 150 \) mm.

The longitudinal distance from the hull forearm to the nose of the lancet leg was determined from the condition that the zone of soil deformation by the hulls did not reach the structural elements of the lancet leg (Fig. 3).

![Fig.2. Basic parameters of the housing with a guide knife: 1 is rack; 2 is blade; 3 is ploughshare; 4 is guide knife.](image)

![Fig.3. Scheme for determining the longitudinal distance between the drill bit toe and the tines.](image)

\[
l_x \geq \frac{1}{2} b_n \cot \frac{\gamma_n}{2} + (a - a_n) \tan \frac{1}{2} (\varepsilon + \phi_1 + \phi_2)
\]

(9)

Where: \( b_n \) is working width of a lancet leg, m; \( \gamma_n \) is the angle of a solution of a lancet leg, degree; \( \varepsilon \) is the angle of a ploughshare occurrence in soil, degree; \( \phi_1, \phi_2 \) are angles of external and internal friction of soil, degree.

Calculations made on expression (9), at \( b_n = 0.15 \) m, \( \gamma_n = 60^\circ, a = 0.15 \) m, \( a_n = 0.1 \) m, \( \phi_1 = 30^\circ, \phi_2 = 40^\circ \) and \( \varepsilon = 25^\circ \) have shown, that the longitudinal distance between a toe of a ploughshare of the case and a toe of a lancet leg should be not less than 185 mm.

The longitudinal distance from the toe of the drill chisel to the toe of the arrowhead leg was determined from the condition of exclusion of overlaying the soil deformation zone with the ripper and arrowhead leg (Fig. 3).
By setting \( a_{\text{max}} = 0.35 \text{ m}, \ a_n = 0.1 \text{ m}, \ \phi_1 = 30^\circ, \ \phi_2 = 40^\circ, \ \alpha_d = 30^\circ \) and \( \alpha_n = 20^\circ \) on expression (10) we will receive, that the longitudinal distance from the drill bit to the toe of the arrowhead leg should be not less than 200 mm.

The longitudinal distance from the nose of the bit to the nose of the ploughshare of the body is determined by the following formula (Fig.4):

\[
l_{kch} \geq l_4 - l_1 - l_2.
\]

Calculations made on the expression (11) at \( l_4 = 41.7 \text{ cm}, \ l_1 = 17 \text{ cm} \) and \( l_2 = 13 \text{ cm} \) showed that the longitudinal distance from the bit to the ploughshare to the sock should be at least 117 mm.

To determine the longitudinal distance between the support wheel and the deep rake, the following expression was obtained from the condition that the deformed soil is shifted freely with the deep rake bit (Fig. 4):

\[
l_3 \geq l_d \cos \alpha_d + a_{\text{max}} \cot \phi_2 + \sqrt{R_k^2 - (R_k - h_k)^2}
\]

At values \( a_{\text{max}} = 0.35 \text{ m}, \ R_k = 0.45 \text{ m}, \ \psi_2 = 40^\circ, \ \alpha_d = 30^\circ, \ l_d = 0.115 \text{ m} \) and \( h_k = 0.02 \text{ m} \) the minimum distance \( l_3 \) should be 65 cm by expression.

By results of theoretical researches, it is established that at width and length of a bit of the deep looser accordingly 80 mm and 115 mm, the height of a rack 740 mm, the width of working of a lancet foot 150 mm, the small and big diameter of a roller accordingly 160 and 400 mm qualitative loosening of soil with the minimum expenses of energy is reached.

The analysis of design features of existing machines, implements and working bodies, used for preparing the soil for potatoes sowing, made it possible to develop the design of the tool, which allows preparing the soil for potatoes sowing on the ridges.

4. Conclusions

1. According to the results of theoretical and experimental studies, it was established that with the width of the left and right turning semis crew bodies with guide knives 200 mm, length of the blade...
wing 515-545 mm and the angle of slope of the blade left to its base 60, the formation of ridges of the required degree with minimal energy costs is achieved.
2. At the longitudinal distance between the hulls, set by the working surfaces towards each other within 350-400 mm, and the transverse distance of 700 mm the required height of the crest with minimum energy consumption is achieved.
3. By results of theoretical researches, it is established that at width and length of the deep loosener chisels accordingly 80 mm and 115 mm, the height of a rack 740 mm, the width of working of a lancet tine 150 mm qualitative loosening of soil with the minimum expenditure of energy is reached.

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