Research of the operating process of disc displaying machine of potato landing machine

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Abstract. The level of potato production in the developed countries of the world is characterized by the stability of yields reaching up to 45 and more tons per hectare. High potato production in developed foreign countries is achieved through a systematic approach at all stages and technological operations of cultivating and harvesting using advanced technologies and modern technical means.

At the same time, in our country, the gross harvest of potatoes from 78.8 thousand ha is 1.717 million tons, that is, the yield per hectare is 21.8 tons. This significant difference in potato yields between domestic and foreign producers is due to several reasons:

- in our country, about 90% of potatoes are produced mainly on small-contour and scattered plots with an area of 0.2-1.5 hectares of dekhkans and farms. In such areas, the simplest technologies with a low level of mechanization are used;
- low level of provision of potato producers with high-quality seed materials, as well as low-quality planting calibration of tubers in size, which has a significant impact on the quality of work of potato planting machines;
- the lack of domestic potato planting machines differing in the quality of the uniform distribution of tubers during planting, since the quality of the machine depends on this factor;

To successfully solve these and other problems of increasing potato productivity, it is necessary to solve the accuracy of dosing potato tubers and their uniform distribution during planting.

1. Introduction

In our country, large-scale measures are being taken to develop the agricultural and machine-building industries, which ensure the conservation of resources and reduce labor and energy costs. The Strategy for the Further Development of the Republic of Uzbekistan for 2017-2021 outlines tasks, in particular, “... modernization and intensive development of agriculture, ... further improvement of the reclamation state of irrigated lands, development of a network of reclamation and irrigation facilities, widespread implementation of agricultural production of intensive methods, primarily modern water- and resource-saving agricultural technologies, the use of high-performance equipment, the reduction of the area occupied by cotton and ears e and the placement of orchards, vineyards, vegetables and other agricultural crops in the land liberated from them ”in particular potatoes from 80.3 to 116.3 (36%) thousand ha, and to increase the yield to 35 t/ha.

In our republic, the share of farms is 21.4 % of the production of potato, dekhkan - 77.7 %, and the private sector - 0.9 % and they are grown mainly in areas with an area of 0.2-1.5 ha. As a rule, in these categories of farms in the production of potatoes manual labor prevails.
Currently, in some farms, potato cultivation machines are used for planting potatoes of foreign and Russian production of old samples. However, today, there is the possibility of introducing innovations in potato growing, i.e. application of advanced technologies and modern means of mechanization.

Most modern, high-performance potato planting machines are not suitable for working in the conditions of Uzbekistan, with specific mechanical and technological properties of the soil. In addition, these machines are structurally complex and metal-intensive [1, 2, 3].

The use of such machines is hindered by the fact that they do not give the desired effect when used in shallow areas. At the same time, research is underway in our country and abroad to improve the design of both potato planting machines and its planting machines [4, 5, 6, 7, 8, 9, 10, 11, 12].

Therefore, an important task is to develop a planting apparatus for a potato planting machine that provides accurate and high-quality dosing and planting of potato tubers, reduces damage to potato tubers, and allows the possibility of increasing their uniform distribution in a row.

2. The purpose of research
In this regard, the goal was set to create a planting apparatus providing improved planting quality of potato tubers, analysis of the quality of their performance of the technological process with a theoretical justification of its parameters.

3. Materials and methods
At the Department of Agricultural Machines of the Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, a potato planting machine with a disk planting apparatus was developed and manufactured [13, 14, 15] (Fig. 1).

The disk planting apparatus of this machine consists of a separator 1 tubers with rollers having profiled grooves, two metering disks 2 mounted on one shaft, equipped with screws 3, having different directions of turns, tubes 4 installed in the space between the separator and the metering disk, trough-shaped casing 6 with windows for the passage of tubers.

![Diagram of a potato planting machine](image)

Figure 1. Disc Planting Machine: 1 is separator, 2 is landing disc, 3 is auger, 4 is tube, 5 is windows, 6 is casing.

The technological process of the planting apparatus is as follows: potato tubers located in the hopper under their weight and using a trellised flow guard in one layer, continuously move down and fed to the rotating rollers. The potato tuber is carried away by the first roller and feeds them into the working slot between the counter-rotating rollers. The potato tubers are in constant motion and, when they enter the oval-shaped hole, pass through it and are collected in a row in the inner surface of the tube.
During the rotation of the metering disk of the apparatus, its cylindrical surface touching the tubers of the potato located in the tube rotates, when approaching the oval hole, the potato passes through the hole under the influence of its own and the tuber of the potato above it and is exposed to the feathers of the screw located inside the disk. In this case, the lower part of the tuber located in the tube meets the cylindrical part of the disk and remains on its surface until the next holes approach, and then the cycle repeats. At the same time, as the screw rotates, the tuber under its influence moves along the inner surface of the casing and is transmitted through the window to the opener. A similar workflow is carried out in the second half of the apparatus.

The calculations of the technological process of the disk dosing apparatus were carried out using the basic provisions of the laws and methods of classical mechanics and mathematics.

4. Results and Discussion

The working process of the disk planting apparatus of the potato planting machine consists of three successively alternating phases, performed for one revolution of the metering disk: a selection from the feed layer of potatoes and the creation of a uniform flow of tubers in the inner cavity of the tube, which is carried out by a roller separator and tubes, single selection of tubers by a metering disk, and also feeding them to the opener with the help of a screw and further into the groove.

The initial data for the technological calculation of the working process is the total number of tubers that is, the planting rate of tubers that must be planted per 1 ha and the layout of the tubers - the planting step and the row spacing.

The main parts of the planting apparatus are driven from the supporting wheel of the machine. The number of potato tubers sown per 1 ha is determined from the expression

\[ Q = \frac{10^4 Z_m}{bl} \]  

(1)

where \( Z_m \) is the number of tubers per nest, pieces;
\( b \) is the row spacing, m;
\( l \) is the distance between nests, m.

An analysis of formula (1) shows that the number of potatoes sown per 1 ha of the area depends on the row spacing and a given distance between the nests (Fig. 2 and 3).

![Figure 2. Dependence of the rate of planting of tubers sown per hectare \( Q \) on the width between the nests in a row \( l \).](image-url)
Figure 3. The dependence of the number of tubers taken by the metering disk per revolution of the drive wheel (Mk) on the rate of tuber planting (Q).

It can be seen that with a row spacing of $b = 70$ cm and with a distance between nests of $l = 20$ cm, $Q = 71428$ pieces are placed on 1 ha of area, and at $l = 25$, 30, 35 and 40 cm, respectively, $Q = 57142$ pcs.; $Q = 40816$ pcs. and $Q = 35714$ pcs.

The number of tubers separated by the metering device per revolution of the wheel of the potato planting machine is determined by the formula:

$$M_{k} = \frac{\pi d_{k} Q b z}{10^{4}}$$

where $d_{k}$ is the diameter of the wheel, m; $Q$ the rate of the planting of potato tubers, pcs/ha; $z$ is the number of planting apparatus.

The number of tubers separated by the metering device per revolution of the wheel of the potato planter, taking into account the sliding of the wheels, is determined by the formula:

$$M_{k} = \frac{\pi d_{k} Q b}{10^{4}(1-\eta)}$$

where $\eta$ is the slip coefficient.

When carrying out the drive of the planting apparatus from the running wheels of the machine, the number of tubers separated by the metering apparatus depends on the diameter of the wheel. The graph of changes in the number of tubers separated by the metering disk depending on the rate of tuber planting is shown in Figure 3.

It can be seen that at a rate of planting from $Q = 35714$-$71428$ pcs/ha for one revolution of the running wheel, the metering disk of the device should separate from 5 to 12 pieces of pods.

To sow 1 ha of the area with a translational speed of the aggregate $V_{m}$, the planting apparatus per unit time must plant a certain number of potato tubers, which is determined from the equality:

$$Q_{iv} = \pi d_{m} V_{m} M_{k}$$

from here:

$$Q_{iv} = \frac{V_{m} Q b}{10^{4}(1-\eta)}.$$

Given that the metering disk of the planting apparatus has several $Z_{m}$ openings for the passage of tubers, with the condition that only one tuber passes through each hole, we determine the number of tubers separated per unit time:
\[ Q_{1c} = \frac{Z_m n_d}{60}, \]  

(6)

where \( n_d \) is the rotational speed of the metering disk.  
\( Z_m \) is the frequency of nest formation per unit time.  
The frequency of formation of nests is determined from the equality:

\[ Z_m = \frac{V_m}{l} \]  

(7)

Based on the equality condition \( Q_{1c} = Q_{1c}' \), we can determine the rotation frequency of the metering disk:

\[ n_d = \frac{60 V_m Q_b}{Z_m 10^4 (1 - \eta)} \]  

(8)

From the formula (7) it can be seen that the frequency of the metering disk of the planting apparatus depends on the speed of the unit, the given planting rate of tubers, the row spacing and the distance between the nests. Figures 4 and 5 show graphs of the dependence of the rotational speed of the metering disc on the speed of the sowing unit.

**Figure 4.** The dependence of the speed of the metering disk \((n_d)\)
from the operating speed of the landing unit (Vm): a) when the distance between the nests \( l = 25 \) cm and the norm of planting tubers \( Q = 57142 \) pcs/ha; b) when the distance between the nests \( l = 30 \) cm and the norm of planting tubers \( Q = 47619 \) pcs/ha; 1, 2 and 3, respectively, with the number of holes 1, 2, and 3 pcs in the metering disk.

Figure 5. The dependence of the speed of the metering disk (\( n_d \)) from the operating speed of the landing unit (Vm): a) when the distance between the nests \( l = 35 \) cm and the rate of the planting of tubers \( Q = 40816 \) pcs/ha; b) when the distance between the nests \( l = 40 \) cm and the rate of the planting of tubers \( Q = 35714 \) pcs/ha; 1, 2 and 3, respectively, with the number of holes 1, 2, and 3 pcs in the metering disk.
It can be seen that the rotation frequency of the metering disk of the planting apparatus increases with an increase in the speed of movement of the planting unit and with a decrease in the frequency of nest formation per unit time, i.e. the pattern of change has an upward rectilinear character.

To ensure the sowing of potatoes with a norm of tuber planting, \( Q = 57142 \text{ pcs. per hectare} \) with a width between nests \( l = 25 \text{ cm} \), at a speed of the sowing unit of 4, 5, 6 and 7 km/h, the metering disk of the scooper having one hole for the passage of tuber should rotate with a frequency of 293.9, respectively; 367.7; 442.6 and 517.3 rpm.

At the same speeds of the sowing unit, with a decrease in the rate of the planting of potatoes from \( Q = 57142 \text{ pcs/ha} \) to \( Q = 47619 \text{ pcs/ha} \) and with an increase in the width between the nests from \( l = 25 \text{ cm} \) to \( l = 30 \text{ cm} \), the rotation speed of the metering disc of the planting disk decreases apparatus by 20%, respectively. At the same speeds of the sowing unit with a decrease in the rate of the planting of tubers \( Q = 40816 \text{ pcs/ha} \) and with an increase in the width between the nests to \( l = 35 \text{ cm} \), the rotational speed of the metering disk decreases accordingly to 40%. The same tendency is observed when the tuber planting rate decreases to \( Q = 35714 \text{ pcs/ha} \) and the width between the nests increases to \( l = 40 \text{ cm} \), while the rotation speed of the metering disk decreases to 60% (Fig. 5 and 6).

An increase in the number of holes for the passage of tubers in the metering disk of the planting apparatus leads to a decrease in its rotation frequency. For all indicators of the speed of the sowing unit, the rate of tuber planting and the width between the nests with an increase in the number of holes in the metering disk of the planting apparatus from 1 to 2, its rotation speed decreases by half, and with an increase in the holes for the passage of tubers from 2 to 3 of the metering apparatus leads to a decrease of 1.5 times.

The productivity of a potato planter equipped with a disk planting apparatus depends on the working speed of the unit and the technological capabilities of the working bodies and is determined from the expression:

\[
W = 0.1bn_kV_M,
\]

where \( n_k \) is the number of rows sown.

At sowing unit speeds from 4 to 7 km/h, the productivity of a potato planter with a disk planting apparatus is 0.55-0.99 ha/hour.

5. Conclusions
The obtained analytical dependencies make it possible to analyze the technological process of the planting apparatus of a potato planting machine with a metering disk and determine its kinematic parameters depending on the speed of the sowing unit and establish the operation modes of the potato planting machine as a whole.

The results of these studies are confirmed by experimental studies and used in the construction of a prototype potato planter equipped with a disk planting apparatus. At a working speed of the sowing unit of 4-7 km/h, a hole width of the disc metering unit of at least \( b = 70 \text{ mm} \), a length of 83-105 mm, a rotational speed of the metering disc of 150-180 rpm, it will ensure machine performance of 0.55-0.99 ha/hour.

It should be noted that the potato planting machine equipped with a disk planting apparatus differs from the known prototypes in its simplicity in design, laboriousness in manufacturing and metal consumption, as well as the most convenient for use in local soil and climatic conditions, ensuring a high-quality planting of potatoes in small contour areas.

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