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Sprouted Potato Tuber Dynamics and Kinematics during Mechanized Planting

V.N. Ozherelyev, F.N. Kotikov*

Bryansk State Technical University, 7, Bulvar 50 let Oktyabrya, Bryansk 241035, Russia

Abstract

The article reviews the interaction process of a sprouted potato tuber withpotato-planter's operating units. The purpose of the research is to ensure its stable orientation on the bottom of a furrow with the sprouts upwards. As a result of mathematical process simulation, the reasons of tubers' space orientation instability during utilization of known machine prototypes. With regard to this, an optimal algorithm of sprouted tubers' planting process was defined resulting in design of a new planting machine and implementation of the algorithm for interaction with planted tubers that is close to optimal. Besides, the axis of the vehicle's supporting wheels is the axis of planting machine at the same time which eliminates the need in both mechanical transmission and rolling bearings. In other words, the operating procedure optimality is successfully combined with simplicity of the construction and low price of the machine. The potato-planter has been successfully utilized at the farms in the Bryansk region for many years.

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Keywords: potato tuber; potato-planter; planting machine; curve; mechanized planting; rotation of tuber.

1. Introduction

In view of sustainable growth of potato production within the last years, the segment of potato of autumn harvest on Russia's market is almost full with domestically produced product. Hence, the increase of competitiveness of the early-harvested potato producers, in particular, small farms, is becoming challenging.

One of the ways of solving this specific problem is decreasing price of the utilized machines while saving and improving their operation quality. First of all, it concerns planting mechanization, which, if performed with a

* Corresponding author. Tel.: +7-906-502-6870.
E-mail address: vicoz@bk.ru

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sufficient level of quality, reasonably affects not only the harvest volume, but also its rate of maturation and whether the maturation is even. It is a well-known fact, that the reduction of period and ensuring the even maturation of early potato is promoted by stability of the operating procedure of depositing the preliminarily sprouted potato tubers on the bottom of a furrow with sprouts orientation upwards. This may be achieved subject to ensuring optimal kinematics for a planted tuber, being in a complex interactivity with the rotating and static parts of a mechanism and the furrow's bottom against which the machine is moving.

2. Identification of problem

Sprouted potato planting machines are known both abroad and within Russia. In the 1970s, the mentioned problem on huge monocultural farms of the USSR was partially solved by means of utilization of a special planting machine model SAYa-4 [1], which was equipped with bunker containing conveyor belt transporting tubers to the feed hopper. The conveyor belt turned on automatically if there were tubers in the feed hopper. The planting machine constituted an infinite bush roller chain with open scoops, driven by the tractor's power take-off PTO.

The disadvantage of this potato-planter is that it may not operate reliably with a huge length of the sprouts, they are broken off both while tubers' transportation to the feed hopper and while they are grabbed by the scoops of the planting machine. Besides, the construction does not ensure tuber's sprouts orientation upwards in furrow, which causes seedling unevenness and significantly fades the effect of a continuous pre-planting sprouting.

Development of planting machine within the last decades is carried out on account of optimization of its parts' features, mainly feed hopper's and shakers' bottom [2,3]. Besides, an attempt was made to reduce the degree of fixity of contact both between tubers and tubers with scoops by means of pouring collecting hopper of the planter with mordant (for their anti-parasite and anti-disease treatment) [4,5]. As a result, the safety rate of sprouts slightly increased, but in this event it was also impossible to completely eliminate the damage, mainly because the method of tubers' transportation to the hopper remained by means of conveyor belt.

The planter Structural 4000 was designed in the Netherlands, wherein the metering of sprouted tubers is carried out by means of concurrently moving hawsers with different speed. Despite the fact that the construction is innovative, it is also unavailable to carry out gentle planting of tubers with long sprouts. Moreover, the construction does not ensure an optimal space orientation of the planted tubers.

Manual delivery of the sprouted tubers to the revolver planting machines (with vertical rotation axes of barrels) or to the vertical elevators' hoppers ensure the safety of sprouts. Two- and four-row potato planters of such type are designed and successfully utilized in Italy, Poland, Finland, Belorussia and other post-soviet countries. Their construction is relatively simple, which is important for the economy of small monocultural farms, however the depositing of all the tubers in the furrow with the sprouts upwards is not guaranteed.

3. Research hypothesis

The main reason for chaotic orientation of planted tubers on the bottom of furrow is their rotation during the process of falling from the hopper of vertical elevator in the lower phase of its path of motion (fig. 1). While skirting of vertical elevator of the lower sheave or chain wheel 7 by the tractive element 6 the hopper's bottom 1 is inclined, resulting in the tuber's sliding 3 while exceeding the friction angle φ_{exc} of the potato on the hopper's surface [6] by inclination angle α (fig. 1a). When gravitational vector mg crosses the lower edge of the hopper's bottom 1 (position 4) the overturning moment $M_{op}=mgx_i$ occurs (fig. 1a), as a result of which the tuber starts clockwise rotation about mounting point, performing plane-parallel movement in space.

Until the moment of losing the tuber's contact with a lower edge of the hopper's bottom 1 it rotates for angle φ_0 (fig. 1 b). Besides, according to d'Alembert principle, the condition of its balance (without taking into account the linear movement with regard to a low speed) may be described by the following equation:

$$mgx - J_к \frac{d^2\phi}{dt^2} = 0 \quad (1)$$

where J_k – momentum of tuber's inertia about A point (fig. 1 b), kgm^2;