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Application of Drip Tape Stacker with Brake solution for Potato Cultivation

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Abstract. In modern conditions, there is no possibility to obtain a guaranteed harvest while ensuring the required product quality without the use of agro-reclamation activities. These measures are aimed to provide optimal water-air balance for the growth of the plant. In order to organize irrigation, it is rational to use drip irrigation, which makes it possible to deliver irrigation water directly to the root-inhabited area. The large share of hand labor in the process of laying the drip tape prevents the wide development of this promising method of irrigation. Firms that are engaged in the development and production of special equipment for laying drip tape do not have working equipment designed for laying tape in a potato comb. The creation of this special equipment will increase the degree of mechanization of laying work, significantly improve its quality, ensuring uniform laying of the drip tape to ensure its further trouble-free operation.

1 Introduction

The doctrine of food security assumes that potato production should cover the needs of the population and industry by 95%. Until recently, this condition was met, but in recent years there has been a failure to fulfill the plan for collecting potatoes. One of the reasons is the high percentage of potato cultivation in individual subsidiary farms (large farms and agricultural holdings account for a bit more than 30%). Under these conditions, it is difficult to control the quantitative and qualitative indicators of growing agricultural crops, it is difficult to propose measures to increase the profitability of growing agricultural products. There is an increase in production capacities for processing potatoes in the region. Last year, the total capacity of potato processing enterprises reached 170 thousand tons. To ensure the smooth operation of these enterprises, and the supply of raw materials of the required quality, it is necessary to increase the share of large farms and agricultural holdings in the cultivation of potatoes. It was the stake on large farms in the region, which used high-quality seed material and modern equipment that made it possible last year to minimize crop losses from adverse weather conditions, unlike neighboring regions [1-3].

The unevenness of precipitation both during the growing season and throughout the year is another important issue. The difference between low-water and high-water years can

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vary by 2...2.5 times [3,4]. As a result, a decrease in yield under adverse weather conditions, and a discrepancy between product quality and customer requirements.

To ensure a guaranteed harvest, it is necessary to create an optimal water-air balance in the process of plant growth. In interest to provide the optimal water-air balance of plants during the growing season, it is necessary to carry out agro-reclamation measures, including additional irrigation [5-7]. Surface irrigation and sprinkling are the most widespread in the region. In recent years, the farms of the region have been rapidly updating their inventory of sprinkling machines [8]. In case we analyze the composition of new arrivals for so-called hose-drum machines, almost a third of new arrivals over five years are domestic machines (174 versus 400 units of imported equipment), for wide-sprinkler machines, the situation is even more pessimistic - more than 90% of new arrivals are imported equipment (1300 units versus 176 domestic cars) [9]. In this situation, the implementation of the import substitution program is not possible. The way out of this situation would be to expand the areas occupied by drip irrigation. Now such territories make up a near 10% of the structure of irrigated lands. The rate of construction of new drip irrigation systems over the past 10 years has noticeably decreased, meanwhile, the production of drip tape and related equipment shows steady growth
[10,11]. So, last year, the production of drip tape by "Poly plastic Rivulis Irrigation Pipeline Systems" amounted to 270 million linear meters, and the company "New Age of Agrotechnologies" - 200 million linear meters. This made it possible to reduce the share of imports of drip tape from 60% to 35%, but it has not led to the expansion of territories occupied by drip irrigation [11-13].

Drip irrigation has a number of undeniable advantages: the delivery of irrigation water directly to the root zone, which can significantly reduce the consumption of water for irrigation, reducing losses due to evaporation and filtration into deep soil layers almost to zero [14]. With this method of irrigation, the aisles are not moistened, which leads to a slowdown of weeds' growth on them. Drip irrigation systems can be automated, control can be carried out remotely with adjustments according to meteorological observations. However, laying drip tape requires significant labor costs [15]. Increasing the degree of mechanization of the drip tape laying process will make it possible to apply the benefits of using drip irrigation and increase the implementation rate of drip irrigation systems in agriculture.

2 Materials and methods

In Central Federal District, potato cultivation occurs mainly according to ridge technology. Placing drip tape in a potato ridge has certain difficulties. Despite the ubiquity of drip irrigation in world practice, there are only a few companies that produce special equipment for laying drip tape [16].

A wide range of equipment for laying drip tape at different depths for different planting patterns is provided by Andros and Rain Flo companies. However, these firms do not offer special equipment for laying drip tape in a potato ridge [17]. The use of handicraft devices for this purpose leads to uneven tension of the tape, which leads to distortions of the tape in the process of placing it into potato ridge, and sudden changes in the speed of the machine or its stop will lead to twisting of the tape or its breakage. When the tape is twisted, the drip system line fails. Repair work requires significant labor costs. The equipment should ensure uniform laying of the drip tape in the potato ridge at a given depth wh constant tension, regardless of the change in machine speed. For the development of equipment, it is necessary to determine the resistance of laying the drip tape, which will be the sum of the soil resistance for cultivation and the resistance of pulling the tape [18]:

$$F_{ro} = R_{ng} + F_{lv} = R_{ng} + F_{lvr} + F_{ldr} + F_{ltr} = \\ = \mu \cdot G_p + k_p \cdot h \cdot b + \varepsilon \cdot h \cdot b \cdot v^2 + \\ +\left(f_o \cdot G_l \cdot d_o \cdot d_p^{-1} + 2 \cdot G_l \cdot l_e \cdot d_p^{-1}\right) \cdot \left(1 + e^{f_o \cdot \beta}\right) \quad (1)$$

where: Flv–resistance of pulling the tape, kN; Flvr – resistance to tape tension in tape installer, kN; Fldr – a force to overcome the imbalance of the coil, kN; Fltr– resistance to friction of the coil on the axis, kN; Rng– soil resistance for cultivation, kN; f_o - axle friction factor in supports; Gl – the weight of tape coil, kN; do – axle diameter, m; dp – coil diameter, m; le – displacement of gravity center of the coil from the axis of rotation, m; β – tape wrap angle; μ - coefficient of friction of the working body on the ground; Gp – stacker weight, kN; kp – specific cutting resistance, kN/m2; ε – factor that takes into account the effect of cutting speed on digging resistance; h – depth of cultivation, m; b – width of cultivation, m.

To confirm the theoretical dependencies, laboratory studies were carried out with a model of a drip tape stacker on a soil channel. In the course of the study, the numerical values of the resistances were determined, which arise in the process of unwinding the drip tape coil, pulling the tape through the pipe and placing it in the soil (Figure 1).

Fig. 1. Laboratory studies of the drip tape installation process.

Laboratory studies have established that the resistance which occurs during the laying of the drip tape did not exceed 180 N (Figure 2).

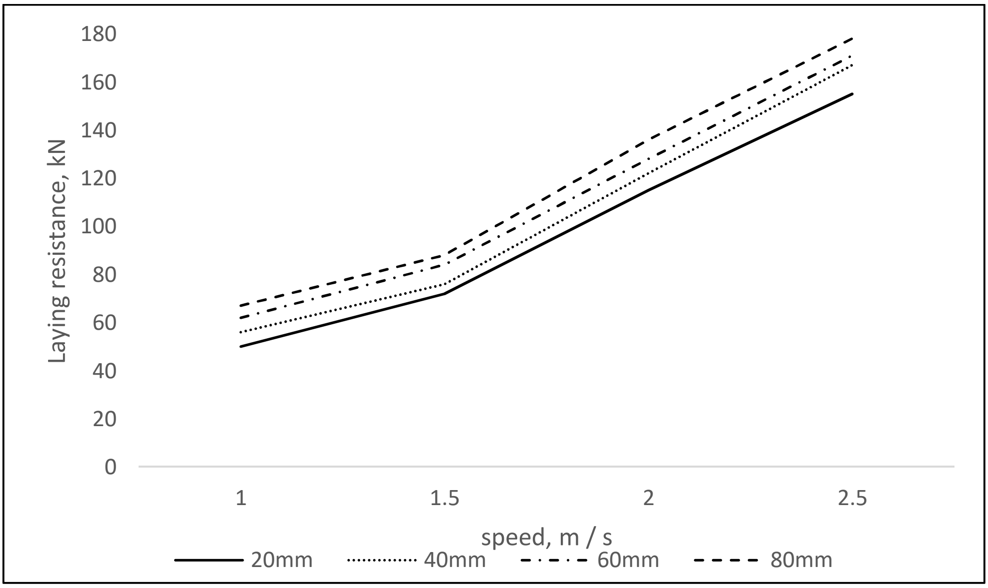

Fig. 2. Traction forces when pulling the drip tape.

Studies have found that an increase in the laying depth will lead to a rise in traction resistance. Therefore, the recommended depth of laying the drip tape was 20 mm.

3 Results and discussion

After analysis of the obtained results in the course of laboratory studies, it was found that the working equipment can be installed on the Grimme GF-75/4 ridge former, which will allow combining technological operations for the formation of ridges and laying the drip tape (Figure 3). The formation of ridges is carried out on the 10-14th day after planting, at this time the plant has enough moisture reserves of the mother tuber, so additional watering is not required.

Fig. 3. Drip Tape Installer Based on Ridge Shaper Grimme GF-75/4.

Field studies were carried out at the Field Experimental Station of the RGAU-MSHA named after K.A. Timiryazev for the purpose of working out technological operations. During tests, it was found that speed fluctuations, as well as sudden stops of the machine, lead to uneven tape tension, changes in its position during laying, twisting and even breakage. To ensure uniform tape tension during the laying process, a permanent brake device was included in the design of the machine.

To determine the inertia force of the vehicle that occurs when it slows down, the following formula to be used [19, 20]:

$$F_{in} = G_m \cdot (k_{sz} + f_m) \tag{2}$$

where: Gm – weight of the vehicle, kN; ksz – friction factor of running equipment with the developed surface; fm – movement resistance factor.

Deceleration of vehicle to be defined as:

$$j = \frac{g \cdot (k_{sz} + f_m)}{\sigma_{vr}} \tag{3}$$

where: σvr – accounting factor for the rotating masses of the vehicle.

Next, determine the numerical value of the inertial force of the coil stacker:

$$F_{ik} = \frac{G_l \cdot j \cdot \sigma_{vr}}{g} \tag{4}$$

The value of the braking force should be determined by the formula:

$$F_t = \frac{1{,}3 \cdot f \cdot F_{ik} \cdot l \cdot \eta}{l_1} \tag{5}$$

where: f – tension factor; landl1 – length of lever arms, m; η- linkage efficiency.

The force that the brake develops during operation must prevent the coil from unwinding under the action of inertial force:

$$T_r = \frac{1{,}3 \cdot f \cdot F_{ro} \cdot D_d \cdot l \cdot \eta}{l_1} \tag{6}$$

where: Dd- diameter of pressure plate, m.

The brake should work when the tape tension is loosened. When the movement is resumed and the tape tension is increased, the brake should open. Determine the size of the brake spring.

The diameter of the opening spring is calculated by the formula:

$$D = 2{,}1\sqrt{\frac{k \cdot c^3 \cdot F_{po}}{[\tau]}} \tag{7}$$

where: k – coil curvature indexing factor; c – spring index; [τ] – allowable tension for a wire, MPa.

The required length of the spring in free state is calculated as the following:

$$L_z = \frac{10^4 d^2 \cdot h + 1{,}3 \cdot h \cdot c^3 \cdot F_{ro}}{c^3 (F_{ro} - F_v)} + d \tag{8}$$

where: d – wire diameter, mm; h – working stroke of the spring, mm; Fv– spring pre-compression, N.

According to the results of calculations, a braking device was placed in the design of the vehicle (Figure 4).

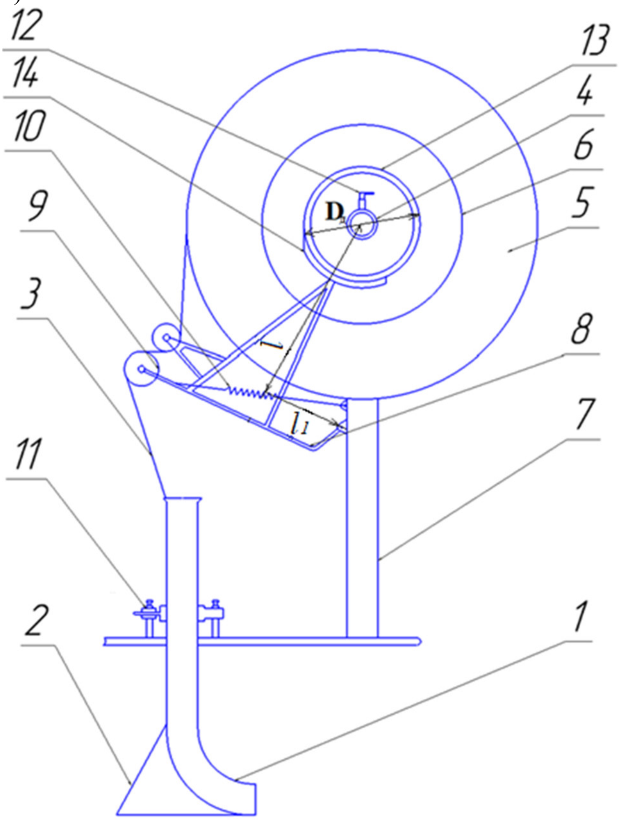

Fig. 4. The design of the drip tape stacker with a brake device: 1 - guide pipe, 2 - coulter, 3 - drip tape, 4 - shaft, 5 - drip tape reel, 6 - pressure disc, 7 - vertical support column, 8 - brake device, 9 - tension roller, 10 - spring, 11 - laying depth adjuster, 12 - disc retainer, 13 - disc rim, 14 - block.

The use of mechanized drip tape laying made it possible to reduce energy cost by 16%, an increase in labor productivity reached 32 ... 36%, and the use of drip irrigation at the Field Experimental Station of the RGAU-MSHA named after K.A. Timiryazev allowed to increase the yield by 22%.

4 Conclusion

In order to obtain a guaranteed harvest and improve the quality of products, agro-reclamation measures are required when growing potatoes, including the organization of additional irrigation. Drip irrigation is the most promising, as it allows you to deliver irrigation water directly to the root area, which allows you to get significant savings in water for irrigation, minimizing its loss through evaporation and filtration into deep soil layers. The installation of special equipment for laying drip tape in a potato comb on the Grime GF-75/4 comb former made it possible to combine technological operations for forming ridges and laying drip tape, which made it possible to reduce energy costs by 16%, increase labor productivity by 32...36%, and use drip irrigation at the Field Experimental Station of the RGAU-MSHA named after K.A. Timiryazev contributed to an increase in yield by 22%.

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