DISINFECTING SYSTEM OF DEVICE FOR REMOVING TOP OF PLANT SHOOTS OF POTATO

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Abstract. Potato is an important crop cultivated everywhere in the world. One of the reserves for increasing potato productivity is a technological technique performed during the period of plant care - decapitation. It consists in the removal of the apical kidney, as a result of what the lateral buds are activated, which germinate and form an additional leaf surface, which contributes to an increase in the crop yield. However, a violation of the plant tissue at the cutting site is the site of penetration of pathogenic microorganisms, especially viral ones, which leads to deterioration of varietal qualities. To reduce the negative impact of these microorganisms on the plant, the cut should be sterile. This can be achieved, if the knife is treated with a disinfectant solution before contact with the shoot. The paper considers the possibility of using sprayers for this purpose, which are used on sprayers for chemical plant protection. Based on the obtained calculated and experimental data, recommendations on the choice of sprayer parameters and the mode of the disinfecting system are substantiated. As a result, it was determined that, in order to achieve the goals, it is possible to use TX-VS2 spray tips with a system pressure of 0.40 MPa and a tilt angle to the vertical of 22.5 to 26.7 degrees.

Keywords: decapitation, tips, potatoes, spray angle, pressure.

Introduction

Potatoes (*Solanum tuberosum* L.) are grown almost everywhere in all continents [1]. Russia has large areas occupied under this crop (approximately 2 million hectares) [2] and produces almost 30 million tons. [3], however, the yield in our country remains low – 19.6 $t \cdot ha^{-1}$ [4]. One of the reserves for increasing the yields and improving the quality of potatoes is a technological method – decapitation. It is based on the removal of plant tops to eliminate apical dominance [5-6], in which the presence of a growing apical bud inhibits the growth of lateral buds [7-8]. Removing the apical kidney, or cutting off a growing terminal shoot, stimulates the growth of inhibited lateral buds and the formation of lateral shoots on which leaves develop [9]. As a result, the total leaf surface increases, where photosynthesis takes place and organic substances are formed, which later flow into tubers, which ultimately affects the yield [1; 10-11].

Carrying out decapitation of potatoes over large areas requires the use of mechanized devices; however, their industrial designs are currently missing [12]. We proposed a diagram of a device that can be used to carry out this work [12]. Its design takes into account the characteristics of both the plant and the work performed. So, to increase the degree of coverage of shoots by decapitation, it was proposed to use a pneumatic-type stem-lifting device that provides the ability to move the maximum number of plant shoots to the knife working area without friction on the surface [12]. In addition, it was taken into account that, when the shoot tip is removed, a wound is formed, through which pathogens can penetrate, which will lead to a decrease in the yield and degeneration of the variety [3]. To reduce the likelihood of infection of plants, in the device is provided a system for applying a disinfectant solution to the knife blade.

As a disinfecting solution, any disinfecting drug (potassium permanganate, alcohol-containing solution, hydrogen peroxide) can be used [9; 13]. The most appropriate and easily prepared is hydrogen peroxide, a concentrated solution of which is diluted with water in the required proportion, and when used, it does not harm the environment.

Given the simplicity of the design of the disinfecting system and the durability of its work, it is proposed to apply the working solution to the knife by spraying using tips used for spraying for the purpose of chemical protection of plants.

With the required supply of working fluid it is necessary to ensure its uniform distribution over the surface of the knife (degree of coating and droplet size), which depends on the type and angle of installation of the spray gun to the vertical and pressure in the supply system. The purpose of this study is to substantiate the type of the atomizer, its installation angle and working pressure, ensuring high-quality performance of the operation in question.

Material and methods

The research was carried out at the Departments of Agricultural Machines and Operation of the Machine and Tractor Fleet and High Technologies in Crop Production in 2016-2019. Using the recommendations of the manufacturers, taking into account the required flow rate of the working solution and the shape of the spray pattern, the following brands of Conejet type spray tips were selected: TX-2 (1); TX-1 (2); TX-VS2 (3) and TP 6501E (4). Their characteristics are presented in Table. 1.

Table 1

Characteristics of spray tip type Conejet

Type of the tip	Spray angle, deg.	Tip performance, l·min^{-1}	Size of the drops, µm
TX-2	80	0.190	15-300
TX-1	80	0.095	15-300
TX-VS2	80	0.190	15-300
TP 6501E	65; 80	0.320	15-300

The spray quality was estimated by the size of the droplets y_1, the degree of coverage of the knife surface with the solution y_2, and the spray angle y_3, which depend on the supply pressure of the working solution X_2 of the spray nozzle installation angle β - X_1. The levels of variation of the existing factors are shown in Table 2.

Table 2

Factor variation levels

Levels	Factors in kind	
	X_1 (spray angle), deg.	X_2 (pressure), MPa
Lower	15	0.1
Upper	45	0.5
Main	30	0.3
Intervals	15	0.2

It is not recommended to work outside the permissible pressure ranges due to the inability to predict the result on the flow of the working fluid at low pressure (less than 0.1 MPa), and increased wear of the main elements of the disinfecting system and energy consumption at high pressure (more than 0.5 MPa). Changing the spray angle to the vertical was carried out from 15 to 45 degrees, since, when the angle of inclination is less than the lower limit of the specified range, a significant part of the working solution does not fall on the knife and, if the upper limit is exceeded, the peripheral part of the blade is not processed.

To determine the dependences of the droplet size y_1, the degree of coverage of the knife surface with a solution y_2, and the spray angle y_3 on the acting factors, a two-factor experiment was performed using a second-order compromise plan of type B_m, while the response function equation has the form

$$y = a_0 + a_1 \cdot X_1^0 + a_2 \cdot X_2^0 + a_{12} \cdot X_1^0 \cdot X_2^0 + a_{11} \cdot X_1^{0^2} + a_{22} \cdot X_{22}^{0^2} \quad (1)$$

The plan-matrix of experiment B_2 for coded factors is presented in Table. 3.

Table 3

Plan-matrix of experiment B_2

No.	X_0^0	X_1^0	X_2^0	$X_1^0 X_2^0$	X_1^2	X_2^2	Y_J	S_j^2
1	+	+	+	+	+	+		
2	+	-	+	-	+	+		
3	+	+	-	-	+	+		
4	+	-	-	+	+	+		
5	+	+	0	0	+	0		
6	+	-	0	0	+	0		
7	+	0	+	0	0	-		
8	+	0	-	0	0	-		

Research results

The quality of the coating with the cutting disc solution depends on the spray angle of the working solution, the size of the droplets falling on the cutting knife, the flow rate of the working fluid, its concentration, degree of coverage, pressure in the system, etc. For the study, nebulizers were selected, which can form droplets of various sizes depending on the pressure in the system.

The choice of nebulizers is due to the need to maintain the fluid flow at a level of at least 10.0 $l \cdot ha^{-1}$, which is sufficient for high-quality disinfection of cut-off areas. Increasing the performance of the tip leads to an increase in the total flow rate of the working solution and necessitates an increase in the volume of the tank for storage or frequent filling.

According to the literature [14], to increase the density of the coating of the object to be treated with a working solution, it is necessary to use a droplet size of 150-250 μm, while smaller droplets are subject to evaporation and larger droplets cause an overuse of the working solution. Selected atomizer types can provide operation in the specified range of droplet sizes.

According to the study [12], a droplet size of 200 μm is observed during operation of the test tips with a working solution supply pressure of about 0.5 MPa. Thus, the optimal droplet size can be ensured by operation of all the considered spray guns with a supply pressure of up to 0.5 MPa, however, at low pressure (up to 0.2 MPa) the droplet size for the spray guns considered increases by 1.2-1.7 times. The quality of applying the working solution to the surface of the knife depends not only on its quantity, but also on the degree of coverage of the entire necessary surface. As it can be seen from Figure 1, the width of the knife strip processed by the sprayer is influenced by the spray angle α, the angle of inclination of the spray gun to the vertical β, and the distance from the spray nozzle to the workpiece.

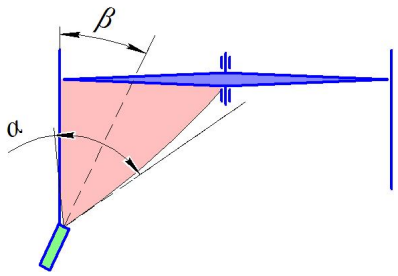

Fig. 1. **Determination of location of the spray gun relative to the knife:**
α – spray angle; β – angle of installation of atomizers

In work [12], it was determined that the spray angle depends on the pressure in the solution supply system and for all the sprayers considered at a pressure of 0.4-0.5 MPa it corresponds to the data specified by the manufacturer. For the TX-VS2 atomizer, the declared value of the spray angle is achieved at a pressure of 0.2 MPa, which makes its use in the device for decapitation considered more preferable, because with less pressure the droplets of the solution will have a larger size, which means less drift from the given spray direction, when working together with a pneumatic stem-lifting device.

The experiments were carried out in 3 replicates. The dispersion analysis of the results of the experimental studies was carried out in accordance with the standard methodology for planning the experiment [15]. Spray quality indicators were determined according to GOST R 53053-2008. The presence of gross errors was checked by the G criterion (Cochren). The coefficients of the regression equation (1) were determined by the least squares method in matrix form (Table 4). The adequacy of the equations was checked by Fisher's criterion.

Table 4

Values of the coefficients of the regression equation for the degree of coverage of the knife

Tip view	Equation coefficients						S_{ad}^2
	a_0	a_1	a_2	a_{12}	a_{11}	a_{22}	
TX-1	75.25	-0.5	7.835	0.75	-10.25	-1.25	4.833
TX-2	80.75	-2.667	10.002	-1.25	-16.25	-1.25	0.833
TX-VS2	89.0	-5.001	6.501	0	11.00	-4.50	$1\ 614 \cdot 10^{-5}$
TP-6501E	80.25	-3.834	7.835	-1.75	-17.25	-1.25	6.167

The studied function has a pronounced extremum (Fig. 2).

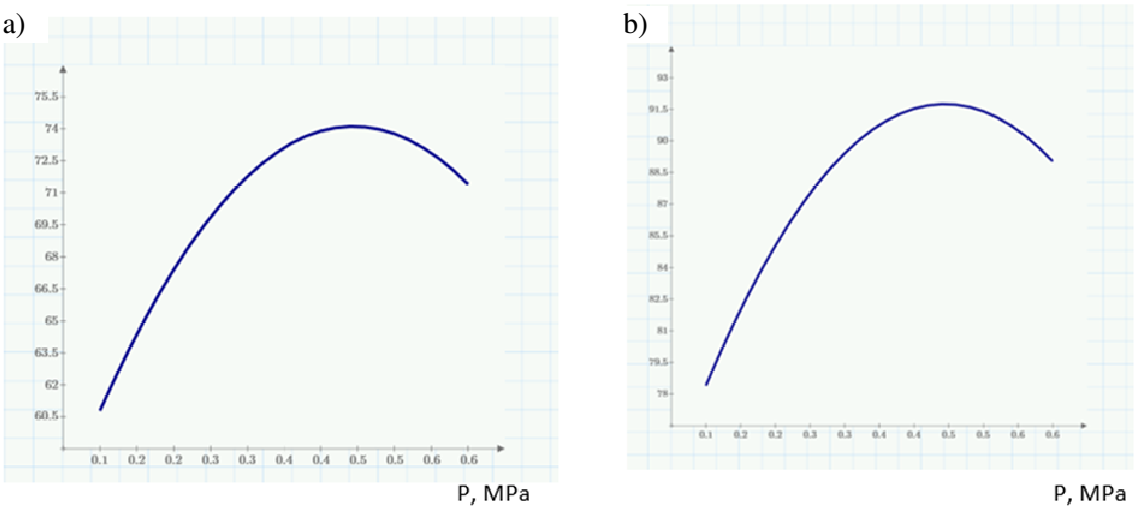

Fig. 2. **Dependence of the degree of coating of the knife with a disinfectant solution on the pressure in the system P at the installation angle of 15º (a) and 30º (b)**

The optimal pressure and angle of the studied spray guns to ensure the maximum degree of coverage of the knife with a disinfectant solution are presented in Table. 5.

Table 5

Optimum pressure indicators and angle location of spray

Atomizer type	Degree of coverage	
	Pressure, MPa	Angle location, deg.
TX-1	0.92	29.70
TX-2	3.70	31.23
TX-VS2	0.40	26.70
TP6501E	1.12	28.34

From the analysis of the data obtained, it follows that the maximum degree of coverage of the knife will be when using tips: TX-1 at a pressure of 0.92 MPa and a spray angle of 29.7 degrees, TX-2 – 3.7 MPa and 31.23 degrees. TX-VS2 – 0.404 MPa and 26.7 degrees, TR-6501E – 0.926 MPa and 28.34 degrees. The optimum values of only one tip TX-VS2 meet the requirements of the permissible range of variation of the acting factors.

Conclusions

1. For a high-quality coating of a knife with a working solution, the recommended tip installation angle is 30 degrees, which allows using any tested tip regardless of the pressure in the system.
2. The best considered, according to our data, is the TX-VS2 spray tip, which will provide a high degree of coverage of at least 93 % at a system pressure of 0.4 MPa and a tilt angle of about 27 degrees.

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