International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-2, December 2019

Development Parameters of Pneumatic Slotted Sprayers for Treatment Potato Tubers

Gennady Maslov, Svetlana Borisova, Elena Yudina, Valery Tsybulevsky, Michael Njomon Nda

Abstract*: *This article presents the results of developing the design of the device and optimizing the parameters of the pneumatic slotted spray gun recommended for treating tubers with working fluids. In connection with the task, the flow rates of the working fluid by the sprayer were determined by the experimental design method and the speed characteristics of the airborne droplet for treating tubers in the coulters of a potato planter. It was found that the use of a device for processing tubers during the planting process contributes to the intensification of the cultivation of tubers while reducing financial costs and improving the quality of processing.

Keywords* : *sprayer, working fluid, potato planter, tubers, consumption.

I. INTRODUCTION

In recent years, the term "intensive technology" has firmly entered the agronomic vocabulary.

Under the technology is usually understood as a combination of methods and means of implementing a particular production process. Simply put, technology reflects what, what, how, and when work is done on the cultivation of crops and how much they cost the farm [4].

Intensive technology in relation to the production of potatoes involves taking into account all the factors of intensification - high-quality cultivation of soil, fertilizers, pesticides, growth regulators, new technical means and means of production resources on the best agrotechnical backgrounds, providing the highest return on resources spent with high-quality potatoes at high productivity [3].

Revised Manuscript Received on December 30, 2019.
***** Correspondence Author

Gennady Maslov*, Department of Operation Machine and Tractor Park, Kuban State Agrarian University named after I.T. Trubilin, Krasnodar, Russia. Email: eksp-mtp@kubsau.ru

Svetlana Borisova, Department of Operation Machine and Tractor Park, Kuban State Agrarian University named after I.T. Trubilin, Krasnodar, Russia. Email: eksp-mtp@kubsau.ru

Elena Yudina, Department of Operation Machine and Tractor Park, Kuban State Agrarian University named after I.T. Trubilin, Krasnodar, Russia. Email: eksp-mtp@kubsau.ru

Valery Tsybulevsky, Department of Tractors, Cars and Technical Mechanics, Kuban State Agrarian University named after I.T. Trubilin, Krasnodar, Russia. Email: eksp-mtp@kubsau.ru

Michael Njomon Nda, Department of Tractors, Cars and Technical Mechanics, Kuban State Agrarian University named after I.T. Trubilin, Krasnodar, Russia. Email: eksp-mtp@kubsau.ru

In connection with the stated objective of the research is to carry out theoretical and experimental optimization of the design and operating characteristics of pneumatic slotted sprayers for spraying potato tubers or tuber furrows with protective stimulating liquids simultaneously with planting [1], [2].

II. MATERIALS AND METHODS

The main indicator of the operation of the sprayer, which determines the method of applying working fluids to tubers (pickling), is the performance of the sprayer - consumption. In this regard, studies have been conducted of the dependence of the flow rate of the atomizer on the pressure and diameter of the supply tube.

As a result of planning a two-factor experiment, the optimal parameters of the atomizer were determined. The mathematical dependence of fluid flow on pressure and diameter of the supply tube was obtained by conducting a two-factor experiment [8].

According to the program and research methodology, an experimental setup and a pneumatic slotted atomizer were used for the experiment, the jet former of which has a pear-shaped slotted nozzle formed by a 0.8 mm thick gasket.

For staging a two-factor experiment, a symmetric compositional plan of type Bk was chosen. Factors, intervals and levels of variation are presented in table 1 [9].

Table - I: Factors, intervals, and levels of variation

Variable factors	Coded notation, x_i	Range of variation, Δ_i	Factor levels		
			+1	0	-1
Diameter of feed tube, d_i, mm	x_1	1	2	3	4
Pressure, P_i, bar	x_2	0,5	1,5	2	2,5

The levels of factors were chosen in such a way that their optimal values, taking into account the existing limitations, fall at the center of the interval of variation.

Coding factors performed:

$$x_i = \frac{X_i + X_{iO}}{\Delta_i}, \qquad (1)$$

where x_i – coded value of the i-th factor; X_i – natural value of the i-th factor; X_{i0} – natural value of the i-th factor in the center of the experiment plan; Δ_i – factor variation interval.

The matrix of the design of the experiment and the results of the experiments are presented in table 2

Table - II: Experiment planning matrix and experiment results

№	Natural factors		Coded factor values		Response, (average) ml / min
	d_i, mm	P_i, bar	x_1	x_2	
1	4	2,5	+1	+1	239
2	2	2,5	–1	+1	215
3	4	1,5	+1	–1	248
4	2	1,5	–1	–1	213
5	4	2	+1	0	248
6	2	2	–1	0	219
7	3	2,5	0	+1	309
8	3	1,5	0	–1	312
9	3	2	0	0	315

The experimental setup made it possible to change the fluid pressure from 1.5 to 2.5 bar. To change the diameter of the feed tube of the atomizer, three versions of tubes with an inner diameter of 2, 3, 4 mm were used.

The working fluid from the tank entered the equalization tank, by gravity under constant static pressure into the atomizer, with the possibility of its regulation by changing its position in height relative to the outlet of the feed tube to the outlet nozzle of the jetting device.

For experiments, the position of the atomizer was set at the “0” level (see Figure 1). The diameter of the outlet of the feeding tube 2; 3; 4 mm. Air to the atomizer to create an airborne droplet was supplied from the compressor through a pressure regulator, which set the pressure to 1.5; 2; 2.5 bar. The compressor was turned on, and the valve for supplying liquid from the equalization tank was opened, liquid and air entered the atomizer. At the corresponding pressure and diameter of the feeding tube, 3 experiments were carried out. The amount of liquid consumed in 1 minute was determined using a measuring tank (tank).

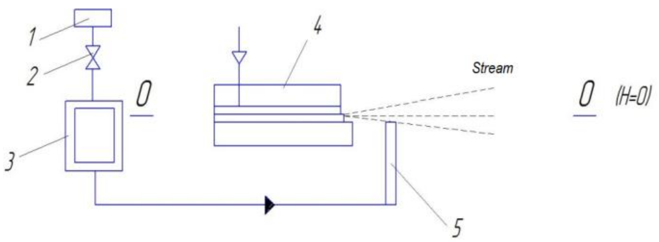


Fig. 1. The scheme of supplying the working fluid to the atomizer: 1 - measured capacity; 2 - crane; 3 - equalizing capacity; 4 - atomizer, 5 - feeding tube

For the experiments used the matrix (table 2), which presents the results of the experiments (average value of the results).

After mathematical processing, we obtained a regression equation for sprayer performance.

$$y = 31,5 + 14,67x_1 + 1,67x_2 + 2,75x_1x_2 + 81,68x_1^2 - 4,68x_2^2, \quad (2)$$

where y – fluid flow rate, ml / min; x_1 - diameter of the supply tube, mm; x2 - air pressure, bar.

We tested the hypothesis of the statistical significance of the obtained regression coefficients by the t-student criterion. All regression coefficients are statistically significant. We tested the hypothesis of the adequacy of the obtained regression equation (2) by Fisher's criterion.

By differentiating the equation with respect to each of the variables and equating the derivatives to zero, we obtained a system of linear equations:

$$\begin{cases} \dfrac{dy}{x_1} = 14,665 - 2,75x_2 - 2\cdot 81,662x_1 \\ \dfrac{dy}{x_2} = -1,668 - 2,75x_1 - 2\cdot 4,667x_2 \end{cases} \quad (3)$$

III. RESULTS AND DISCUSSIONS

To reduce labor costs when planting potatoes, we obtained an invention that is intended for treating tubers or furrows for tubers with protective-stimulating working fluids simultaneously with planting.

The device comprises a tank with a working fluid, an equalizing tank with a tap, a source of compressed air with a pressure regulator, and pneumatic nozzles, which are attached using brackets on the internal cavities of the coulters with a varying angle of inclination relative to the flow of tubers, while in the outlet of the nozzle body, turbodiffuser installed.

Tubers supplied by the planting apparatus enter the opener cavity 8 and pass between two nozzles 4, which create airborne droplets. For their formation, air is supplied to the nebulizers from the compressor installation of the tractor, which atomizes the working fluid entering the nebulizers from the tank 1 through equalization tank 2 and distributor 3. The working fluid is converted into aerosol, which is swirled around the tubers using turbodiffusers 9. The working flow rate the liquid is regulated by changing the diameters of the outlet openings of the nebulizers and the air pressure from the compressor unit (Figures 2 and 3).

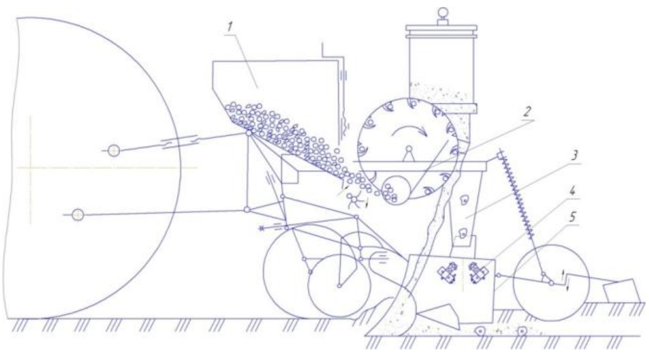


Fig. 2. Technological scheme of a potato planter: 1 - hopper; 2 - landing gear; 3 - tuber pipe, 4 - sprayer; 5 - opener

Having solved the system of linear equations, we found the coordinates of the extremum point of the response surface: x_1 = 0.09326; x_2 = –0.20618.

Substituting the values of x_1 and x_2 into the original regression equation (2), we found the values of the optimization parameter at the extremum point of the response surface with the free term of the canonical equation Y_s = 323.7 ml / min.

The angle = 1.02° of rotation of the initial coordinate axes of the response surface was determined before aligning with the main axes of the figure.

International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-2, December 2019

Substituting the available data, we got the response surface equation in canonical form:

$$Y - 32,37 = -81,69X_1^2 - 4,64X_2^2 \qquad (4)$$

Since the coefficients of the canonical equation have different signs, the response surface has the form of a hyperbolic paraboloid, and the smallest value of the response function is at the point with coordinates: x_1 = 0.09326; x_2 = –0.20618.

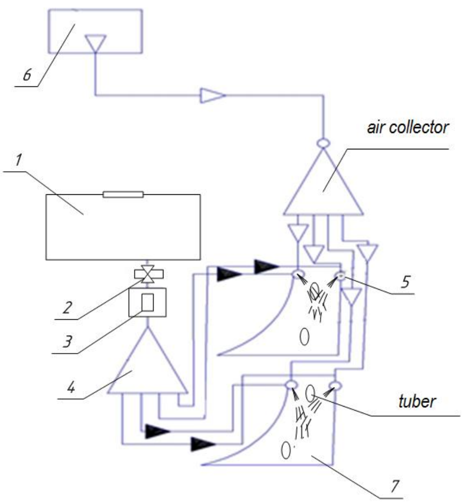
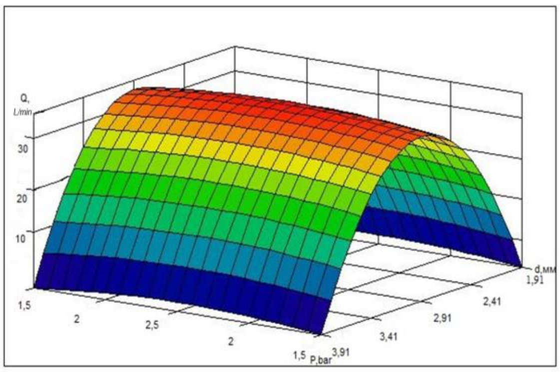


Fig. 3. Pneumohydraulic scheme for planting potatoes with a potato planter with the treatment of tubers with protective and stimulating agents: 1 - tank; 2 - crane; 3 - equalizing capacity; 4 - the distributor; 5 - a spray; 6 - compressor installation; 7 - opener

We studied the response surface (Figure 4) near the optimal factor values using two-dimensional cross sections (Figure 5). Substituting various values of the response Y into the canonical equation (4), we obtained a family of conjugate isolines in the form of hyperbolas (Figure 6).



K

Fig. 4. The response surface of the dependence of fluid flow on the diameter of the supply tube d_i and air pressure P_i

The isolines obtained as a result of the cross section of the response surface are elongated along the coordinate axis corresponding to the second factor — air pressure (P_i). This indicates that the diameter of the supply tube to a lesser extent affects the flow rate of the atomizer than the second factor - air pressure. This is also indicated by a smaller absolute value of the coefficient of the second factor in the canonical equation (4).

The maximum fluid flow rate will be at the circumferential speed of the rotor edge in encoded form x_1 = 0.09326; and air pressure x_2 = –0.20618. Substituting these values into equation (2), we obtained the actual values of the studied factors: X_1 = 2.904 mm, X_2 = 2.5 bar.

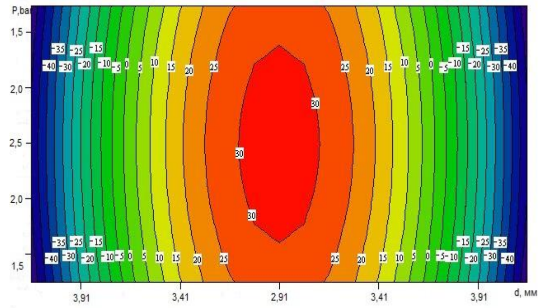


Fig. 5. Two-dimensional surface section of the dependence of fluid flow on the diameter of the supply tube (d_i) and air pressure (P_i)

Table - III: Flow rate at a nozzle height of 0.5 mm

H	c	ml / min	p	c	ml / min	H	c	ml / min	p	c	ml / min
0	58	103	1,5	26	231	0	29	207	1,5	15	400
5	34	176	2,0	27	222	5	11	545	2,0	17	353
10	25	240	2,5	28	214	10	8	750	2,5	18	333
P = 0,2			H = 10 (5)			P = 0,2			H = 10 (5)		
d = 2 mm			d = 2 mm			d = 4 mm			d = 4 mm		

Along with productivity, an equally important indicator of the operation of sprayers is the propagation velocity of an airborne droplet, which determines not only the length of the jet, but also the degree of dispersion of the droplets of the working fluid and the effect of the jet on the processing object [5].

Our design of a pneumatic slotted nozzle creating a high-speed jet has advantages in comparison with hydraulic nozzles [6].

Ultra-low-volume spraying is carried out according to the scheme (Figure 6).

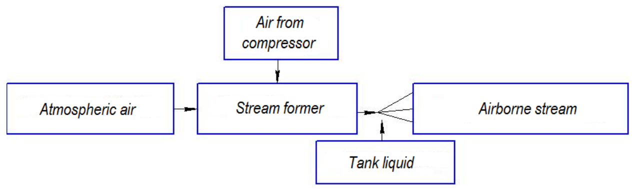


Fig. 6. The scheme of operation of the pneumatic slotted spray

Since the speed of the air jet of the atomizer, and its mass flow rate provides a certain productivity of the atomizer, it is necessary to know the specified parameters of the jet.

To study the axial velocity of the air stream created by the sprayer, a stationary pilot plant with a sprayer was used, the characteristics of which are shown in Table 4.

Table - IV: Sprayer performance and modes

Nozzle width b, mm	Nozzle thickness a, mm	Air pressure p, bar	Distance from sprayer L, m
6	0,5	1,5; 2,0; 2,5	0; 0,3; 0,6; 0,9; 1,2; 1,5

Measurements of the axial velocity of the air stream were carried out at distances L (table 4) using a manual anemometer (M-95).The results of the speed of the air stream at various modes of operation of the atomizer are shown in table 5.

Table - V: Results of the study of the dependence of the speed of the air stream on the distance to the object and air pressure

P atm.	Without turbo diffuser						With turbo diffuser				
	Distance to measuring point (h, m)										
	0	0,3	0,6	0,9	1,2	1,5	0	0,3	0,6	0,9	1,2
	Air stream speed (U, m / s)										
0,5 (4)	17	9	4	0,5			9	5	3	1	
1,0 (3)	18	10	4	1			16	9	4	1	0,5
1,5 (2)	20	17	5	3	1	0,5	17	13	4,5	1	
2,0 (1)	22	19	6	1,5	1	0,5	21	15	6	2	0,5

Based on the results of experimental studies, we plotted the dependence of the axial velocity of the air stream from the slot nozzle on the air pressure in the pneumatic line $v_{ox} = f$ (figure 7).

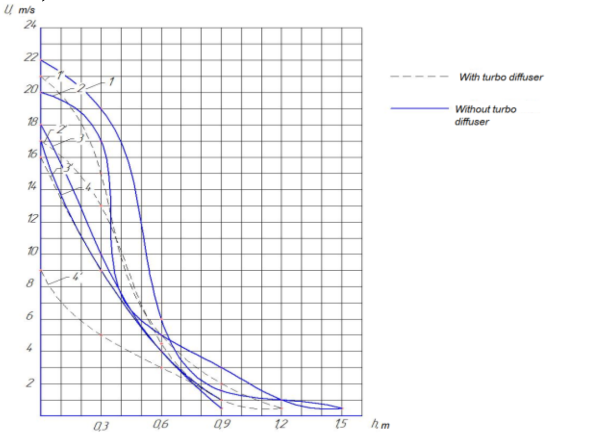


Fig. 7. The graph of the dependence of the speed of the air stream on the distance to the object and air pressure

The graph shows the experimental curves for the atomizer, in which a slotted jet element is located inside the tubular body, with a turbodiffuser and without a turbodiffuser.

The axial velocity of the jet at the outlet when the pressure in the pneumatic line changes from 0.5–2.0 MPa, when the point changes, measurements are from 0–1.2 m, for an atomizer without a turbo diffuser the speed varies from 1–22 m / s, and with a turbo diffuser 0 , 5–21 m / s, since when using a turbodiffuser additional air resistance is created, thereby reducing the speed of an airborne droplet, but increasing the dispersion of the spray and the density of tuber coating with drops of the working fluid, and improving the quality of processing.

IV. CONCLUSIONS

1. Use of a device for processing tubers in the planting process contributes to the intensification of the cultivation of tubers while reducing the consumption of WGM and improving the quality of processing.

2. Experimental studies of a pneumatic slot nozzle by means of a two-factor experiment made it possible to determine their optimal design and operating parameters. So, the flow rate of the working fluid can, if necessary, vary from 100 to 350 ml / min with the following parameters: air pressure in the system from 1.5 to 2.5 bar, diameter of the feeding tube 2, 3, 4 mm.

3. The speed of the airborne droplet can vary from 1 to 22 m / s, and it is recommended for the treatment of tubers in the openers to reduce it by installing a turbo diffuser in the sprayer, which improves dispersion of the working fluid.

REFERENCES

1. Gennady Maslov, Valery Lavrentiev, Valery Tsybulevsky, Elena Yudina, Vasily Tkachenko. Optimization of Parameters of a Multifunctional Unit Based on a Spring Harrow. International Journal of Engineering and Advanced Technology, 2019; 9 (1): 1915-1918.
2. G.G. Maslov, E.I. Trubilin, E.V. Truflyak. Parameters optimization for multifunctional aggregates in plant growing mechanization. Research Journal of Pharmaceutical, Biological and Chemical Sciences, 2016; 7 (3): 1919-1926.
3. G.G. Maslov, V.T. Tkachenko, E.M. Yudina, M.R. Kadyrov, S.A. Kalitko. The improvement of the technology of winter wheat grain production for the purpose of energy saving. Biosciences Biotechnology Research Asia, 2015; 12 (3): 2071–2080.
4. G.G. Maslov, E.I. Trubilin Rational process machines system for producing sunflower seeds its efficiency, 2014; World Applied Sciences Journal, 2014; 29 (12): 1615-1620.
5. CM. Borisova, N.A. Rinas. Ejection helium spray for seed dressing. Country machine operator, 2014; 9 (67): 16.
6. CM. Borisova, K.V. Ermakov, D.M. Underheating. The advantages of ultra-low-volume sprayers. Ejection slot nozzle for seed dressing. Country machine operator, 2015; 3: 10–11.
7. G.G. Maslov, S.M. Borisova, V.A. Nebavsky. Patent 2132611, Russian Federation. Ultra-low-volume sprayer; applicant and patent holder Kuban GAU.
8. Kiefer J. Optimum experimental designs. J. Royal Stat, 1959, B 21: 272-319.
9. Kiefer J. Optimum designs in regression problems II. Ann. Math. Stat., 1961; 32: 299–325.
10. Matthews G. A. CDA controlied dropiet application. PANS, 1977; 23: 387–394.

AUTHORS PROFILE

Gennady Maslov, doctor of technical sciences, professor, department of operation machine and tractor park, Kuban State Agrarian University named after I.T. Trubilin.

Svetlana Borisova candidate of technical sciences, associate professor, department of processes and machines in agribusiness, Kuban State Agrarian University named after I.T. Trubilin.

Elena Yudina, candidate of technical sciences, associate professor, department of operation machine and tractor park, Kuban State Agrarian University named after I.T. Trubilin.

Valery Tsybulevsky, candidate of technical sciences, associate professor of the department of tractors, cars and technical mechanics, Kuban State Agrarian University named after I.T. Trubilin.

Michael Njomon Nda PhD student, department of processes and machines in agribusiness, Kuban State Agrarian University named after I.T. Trubilin.