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OPTIMIZATION OF TURBULIZATOR SPRAYER PARAMETERS BY MATHEMATICAL PLANNING METHOD OF EXPERIMENTS

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ABSTRACT*--The article highlights the tasks of the stable advancement of diversified and cluster farms in the Republic of Uzbekistan, existing problems in the cultivation of agricultural crops that are planned to be resolved in recent years, in addition to the development of high-quality crops, it has been acknowledged particularly that one of the major potential problems is to improve the technological efficiency and technical-economic performance of chemical defoliation agents, particularly in cotton. In this research, improving the technical efficiency of liquid chemicals (defoliants) used in the process of cotton defoliation, analysis of technologies and technical means developed by the world's leading scientists in this field, although the defoliation process is one of the important factors in improving cotton yield and fiber quality, the working hypothesis by the authors on the formation of highly dispersed droplets has not yet been sufficiently developed in this area, scope, essence, design scheme, technological process of operation of the proposed promising vortex-turbilizator, the theoretical aspects of the formation of high-dispersion droplets, methods, individual dimensions of droplets per 1 cm*^{2} *of the object of study, their distribution, total number of drops, drop density scanner, computer and a multi-factor regression equation representing the detection process in a specially designed software system called "DepositScan" and the process of generating the highly dispersed droplets proposed using a multifactor experiment, optimal values of the main factors of the turbilizator, according to which the working fluid pressure to the reduction of the median-mass diameters of the formed droplets, the annual technical and economic efficiency of the experimental spraying unit equipped with a new sprayer are determined by the fact that the width of the annular holes in the sprayers has a greater impact on the increase in working fluid consumption.*

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***Keywords**--cluster, defoliation, working fluid, spray, sprayer, droplet, high dispersion droplets, factors, parameters, regression equation, optimization, number of droplets, density of droplets, median-mass diameter, DepositScan program, analysis, results, cost-effectiveness.*

I. INTRODUCTION

The President of the Republic of Uzbekistan Sh.M.Mirziyoev in his book pays great importance to the agro-industrial complex and says "The issues of agricultural reform and food security will undoubtedly remain one of the most important tasks. First of all, great attention will be paid to the consistent development of the agro-industrial complex and its locomotive, that is, the diversified farms that are the driving force. [1]

Market connections have been widely developed in the growing of agricultural goods, as well as a significant rise in the purchase price of raw cotton comparison to last year, which has provided an opportunity for timely and full adoption of agro-technical measures in recent years.

In the production of high-quality agricultural crops, mineral fertilizers, stimulants and pesticides play a significant role . Particularly, defoliation steps should be taken to ensure high-quality and short-term processing of cotton. Under the influence of defoliants, the leaves fall off, the air circulation between the rows of cotton is improved, direct sunlight falls on the young branches, the opening of the buds is accelerated. Defoliation works are highly effective, taking into account the composition and norms of defoliants, as well as agrometeorological conditions. Improving the technical efficiency of sprayers used in defoliation to ensure early opening of cotton fields, the application of advanced technologies and modern technical means, which increase the efficiency of spraying working fluid and the level of impact on crops due to the formation of small volumes and high dispersion droplets, is a priority. One of the most urgent and promising tasks is to enhance the quality and profitability of work, and perhaps even the resource-saving of small-volume and high-dispersion droplets, and to justify their fundamental design parameters.

One of the main factors in growing cotton production is to improve the technical efficiency of liquid chemicals (defoliants) used in the defoliation cycle of cotton. The technology and equipment used in this area are not adequately developed.

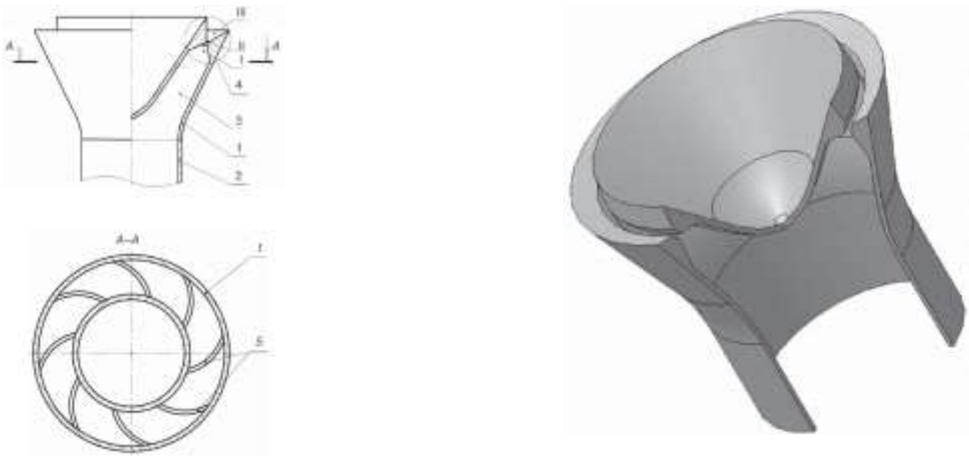
Research by V.N.Stelmax, Markevich A.E. (Ukraine), F.Sh.Khafizov, V.G.Afanasenko, E.V.Boev, A.V.Palapin, R.P.Yatskov, A.N.Ishmatov (Russia), Mireia Altimira, Alejandro Rivas, Gorka S. Larraona, Raul Anton, Juan Carlos Ramos (Spain), Gary J. Dorr, Andrew J. Hewitt, Steve W. Adkins, Jim Hanan, Huichun Zhang, Barry Noller (Australia), Stefan Kooij, Rick Sijs, Daniel Bonn (Netherlands), by Morton M. Denn, Y. Wang, L. Bourouiba (USA), Emmanuel Villermaux (France) and other scientists has been conducted in the world on the development of spraying technologies and improvement of their design, creation of spray nozzles and nozzles used for spraying working fluids, substantiation of their design parameters and operating modes. Also, effective scientific research was carried out by I.A. Ashirbekov, B.U. Utepov, B. Yusupov and other scientists on the improvement of spraying in the agricultural sector of the Republic of Uzbekistan [2; 3; 4; 5; 6; 7; 8; 9;10].

Produced by Stelmax V.N. [2] that the main median-mass diameter of the working fluid droplets generated by the liquid sprayer was in the range of 100–150 μm. The coating density of the droplets averaged 37 drops per

$1 см^2$ of surface. One of the main disadvantages of this device is the use of rotary disk rotators at high angular velocities reduces the reliability of the spraying unit as a result of rapid wear of the components in the joint.

According to Markevich A.E. [3], in the field of mechanization of chemical control works it is necessary to achieve the production of fine droplets in order to save working fluid for quality processing of agricultural crops. Fine droplets have the ability to form three times more dotted surfaces than large droplets. Due to this, the protective sensitivity of the working fluids is improved.

The structure and principle of operation of the device for the decomposition of working fluids, developed by F.Sh. Khafizov, V.G. Afanasenko, E.V. Boev [4] are shown in Figure 1 below.



a) b)

1- sheath; 2 - input tube; 3- liquid channel; 4- speaker; 5- vortex device.

Figure 1: General view of the vortex sprayer (a), b - three-dimensional model of a vortex sprayer**.**

The working fluid decomposition device works as follows. The liquid is passed through the input tube 2 to the sheath 1 to the liquid channel 3, through which the liquid flows to the speaker 4 in the form of a smooth flow. When the vortex device 5 is installed, the fluid has a rotational motion relative to the axis of the nozzle, and the centrifugal forces increase the angle of the spray torch.

Since this device is designed to break down fuel oil, it is clear that it cannot be used in chemical spraying in the agro-industrial complex. The authors recommend the use of the following formula to determine the diameter of small droplets formed by this device [4]:

$$d_к = \frac{2\sigma_ж}{\xi \cdot \rho_ж \cdot u^2}, \quad (1)$$

where σ_l - is the surface tension of the liquid, N / m; ξ - coefficient of resistance to drop motion; ρ_l - density of sprayed liquid, N / m^3; u - is the difference between the velocity of the liquid drop and the gas transferred to it, m / s.

Cutting surface of the inlet tube:

$$S_к = \pi \cdot R_к^2. \quad (2)$$

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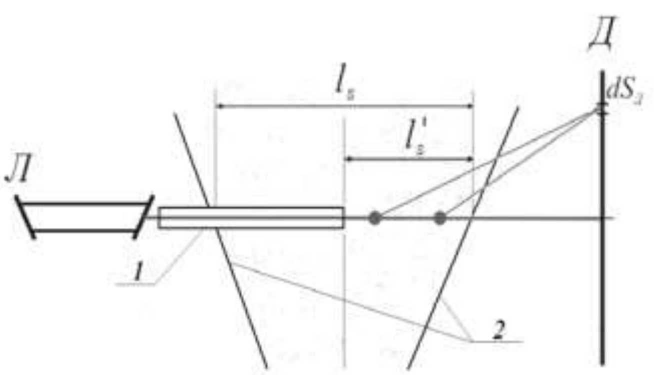
where π - is the const, π = 3.14; R_i - is the radius of the sprayer inlet, m.

The disadvantage of ultra-volumetric spray aggregates generated by the mutual impact forces of liquid and air streams transmitted from both sides in the ultra-small spray proposed by researcher Palapin A.B. [5] is the structural complexity of the sprayers forms highly dispersed droplets.

Ishmatov A.N. [6] studied the device for the formation of finely dispersed droplets by the explosion of liquids. Since this device is mainly designed to create explosive clouds in disinfection, decontamination, mining and other facilities, it can be noted that they can not be used in the process of pest control, disease control and defoliation. The following is a schematic and general view of the experimental device (Figure 2).



a)

b)

L - laser; 1- protection tube; 2- aerosol cloud boundary; D - is the plane where the photodetectors are located; dS_D - dispersed platform radiation angle; l_s - optical path length without protective tube; l_s' - the length of the optical path using as a protective tube.

Figure 2: Schematic of the experimental device (a) and general view (b)

Foreign scientists have studied the formation of droplets of hydraulic-vortex sprayers. Spanish scientists Mireia Altimira, Alejandro Rivas, Gorka S. Larraona, Raul Anton, Juan Carlos Ramos theoretically discussed the formation of a thin spray torch in vortex sprayers [7], Australian scientists Gary J. Dorr, Andrew J. Hewitt, Steve W. Adkins, Jim. Hanan, Huichun Zhang, and Barry Noller conducted research on the main factors influencing droplet dispersion [8]. They noted that droplet dispersion depends on the flow rate of the working fluid, the rate of disintegration of the droplets ejected outside from the sprayers, the spray angle, and the density of the working fluid.

Along with foreign scientists, leading scientists of the Uzbekistan have conducted research on the creation of used spray nozzles and sprayers, substantiation and improvement of their design parameters and operating modes [23].

Researcher Utepov B.B. [9] and Yusupov B.Yu. [10] conducted research to substantiate the main parameters and modes of the disc rotor and torso rotor breaker, which splits the working fluid into cotton wool in which the process of disintegration of a capillary under the influence of a perpendicularly directed aerodynamic flow was studied. In this case, it is proposed to determine the force acting on the primary droplet using the following expression:

$$A = C_{\mathrm{A}} \frac{\pi d_T^2}{4} \cdot \frac{\rho_{в} U^2}{2}, \tag{3}$$

where C_A - is the aerodynamic force coefficient; d_T - is the theoretical diameter of the drop, µm; ρ_a - air density, kg / m^3; U- aerodynamic air flow rate, m / s.

However, as a result of the operation of these types of sprayers at high angular velocities, the details of the sprayer compounds are rapidly worn. Both of the above methods are designed to obtain polydisperse droplets, which have a high energy capacity when operating under high speed conditions, as well as they are not widely introduced into the production process of the Republic of Uzbekistan.

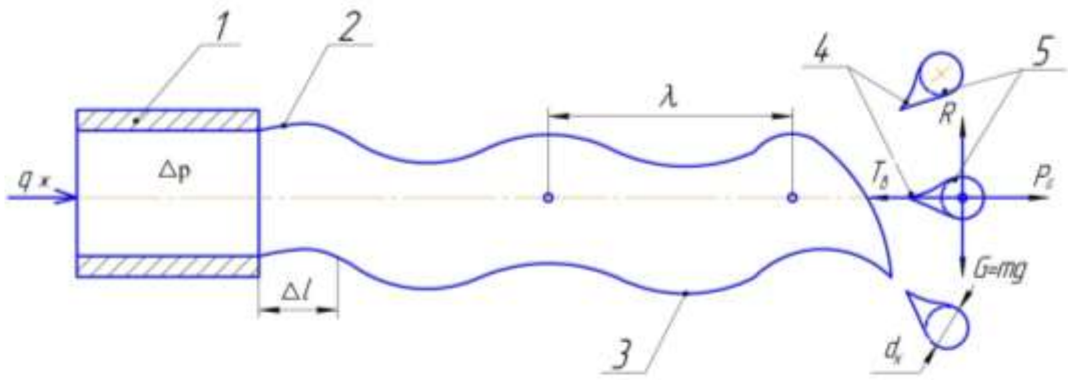
Therefore, in the process of chemical treatment and defoliation of cotton fields in the Republic of Uzbekistan, centrifugal-vortex sprayers are widely used in OVX-600 spray units, which mainly produce polydispersed droplets.

We have created a new promising a vortex-turbulization sprayer as a result of many years of scientific research and patent research in order to develop low-volume, high-dispersion sprayers considering that the above-mentioned sprayers do not provide the formation of highly dispersed droplets and low-volume spraying during defoliation process in pre-cotton harvesting.

Based on the afore-mentioned, the purpose of the study in this case is to justify the parameters that improve the quality of defoliation of cotton by chemical treatment of crops due to the formation of highly dispersed droplets, providing increasing the technical efficiency of the working fluid.

Existing problems. A new sprayer design has been designed to produce highly dispersed droplets and to regulate working fluid consumption [17]. The optimal values of the proposed parameters of the proposed turbilizator sprayer for fan spray units were calculated by using the method of mathematical planning of multi-factor experiments under the conditions of the study object and it should be noted that it was initially tested in single-factor experiments.

Materials and methods. The formation of highly dispersed droplets during the spraying process is one of the most important scientific and technical problems today. In particular, the flow of liquid out of the cylindrical narrow crack mounted on conventional spraying units is high energic, as shown in Figure 3, and is characterized by low technical efficiency, high working fluid consumption as a result of the formation of primary large polydisperse droplets over long distances [11; 12].



1 - a sprayer speaker; 2 - cylindrical hydraulic flow; 3-wavy flow; 4- upcoming drop-satellites; 5 - primary large droplets; Δl - is the unbroken cylindrical part of the flow; λ - is the wavelength of the flow; G-gravity force, T_a-air resistance force; R_l - is the compressive strength of the working fluid, R - is the breaking strength of the drop; d_d - is the diameter of the primary drop; q_l and Δp - working fluid consumption and pressure.

Figure 3: The process of forming primary droplets from a cylindrical stream in conventional spraying units.

More aerodynamic spraying methods are commonly used in practice in the decomposition of working fluids, based on the reference reviews [11; 12; 13; 14; 15]. The main factor in this is the aerodynamic force and the resistance to disintegration of the first large droplets produced by the cylindrical hydraulic flow has the following ratios:

$$\frac{\gamma_x w_{нис}^2}{2g} u \frac{4\sigma}{d_T}, \tag{4}$$

where γ_a -is the density of the flowing air, kg / m^3; w_{rel} - relative motion of a drop in air, m / s; g-free fall acceleration, m/sec^2; σ - is the surface tension of the working fluid, kg/m; d_{in} - is the initial diameter of the drop, mThe initial condition of equilibrium of the primary large drop can be described as follows[11]:

$$\frac{\gamma_x w_{нис}^2}{2g} \approx \frac{4\sigma}{d_T}, \tag{5}$$

According to Volynsky M.S. [12], in condition (5) the decomposition criterion for the initial large droplet is as follows:

$$D = \frac{\gamma_x w_{нис}^2 d_T}{g\sigma}. \tag{6}$$

According to the results of the study of the working fluid, the decomposition criterion D is a constant value. If D≥0.7, the droplets begin to split in two, and if D≥14, the droplets begin to disintegrate rapidly.

The limiting velocity, which determines the state of motion of droplets in the air without disintegration, can be determined as follows:

$$w_{нис} = \sqrt{\frac{g\sigma D}{\gamma_x d_T}} = \sqrt{\frac{g\sigma D}{2\gamma_x r_T}}, \tag{7}$$

where - r_T the initial drop radius, m .

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We considered as a *working hypothesis* that high-dispersion droplets could be formed under the influence of the kinetic energies of local and main turbulent air currents created by the spray fan on the conical thin liquid film that flows out of the annular hole on the basis of the above initial theoretical researches

In order to form highly dispersed droplets, a new sprayer design was created [16,17], therefore, hydraulic sprayers were selected as the object of study.

Application scope of turbilizator sprayer. In agriculture and chemical engineering, particularly in chemical protction of plants from pests and diseases, weeds; defoliation of cotton; machines, devices and apparatus for dispersing growth-promoting working fluids; liquid mineral fertilizers and other processes involving the addition of liquids in the chemical technology industry, as well as for spraying liquids with high density is used.

Meaning. It is a functioning fluid dispersing system consisting of a central tube positioned around the middle of the housing with a bottom outlet channel and a guided conical flow expander. The device is additionally equipped with a conical interchangeable turbilizator with a large number of holes, the channels of which are fxed at an angle to the axis of symmetry of the turbilizator.The outlet channel is made in the form of a annular hole, with the presence of a disc holder, which is made in the form of a single block with a central tube and a conical flow expander connected to the body by a threaded connection.

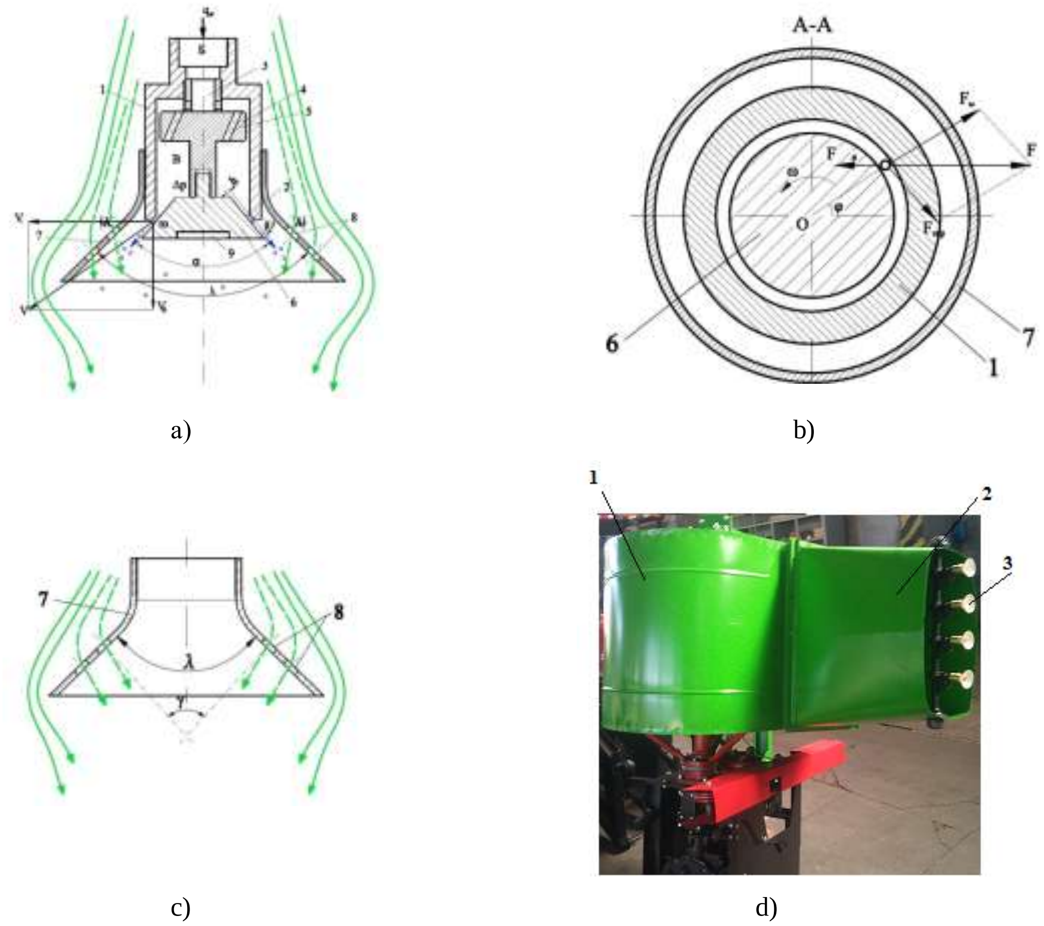
One of the key drawbacks of current correction devices [4; 16] is the complexity of their construction, high energetic of ongoing technical operations, the impossibility of acquiring highly dispersed droplets, and such shortcomings restrict the technological capability of the sprayers.

We have established the design of a promising sprayer based on its optimum parameters [17; 18; 19; 20] in order to simplify the design of conventional sprayers and improve their technological capacities.

The turbilizator consists of a annular and an expandable outlet channel 2 sheath 1 (Fig. 4a), a central tube 3, oblique angular 5 disc vortex 4, and a flow expander 6 and as well as is equipped with a sheath 1 rotating cone-shaped galvanized turbulizator 7 with sloping channels 8 and is mounted at an angle γ to the axis of symmetry of the turbilizator (Fig. 4c). The conical flow expander 6 has a lower side adjusting channel 9. Rotation F_{rot} (4; b) acting on the surface of a thin working fluid in the range of annular cleavage 2, since the resulting force F, which is the sum of the centrifugal forces F_c, is many times higher than the friction force, the primary droplets pass rapidly through the thin liquid film in a wave state and begin to disintegrate into highly dispersed droplets under the influence of the local aerodynamic air flow generated by the turbilizator.

The thin film, which passes into the wave current at short intervals, provides forming short-distance highly dispersed droplets under the influence of axis V_o, tangential V_τ and the resulting velocities V (kinetic energy of the liquid $m\upsilon_0^2/2$) at the point m (Fig. 4a, 4b) to the annular thin liquid membrane.

Technological process of operation of the sprayer. We have established a new and promising turbilizator sprayer design as a result of several years of research and patent-search work, (Figure 4).



Designation:

- vortexed fluid flow; -local air flow with droplets;

- main aerodynamic flow.

1- sheath; 2-annular expansion speaker channel; 3- central tube; 4 - thickener; 5-sloping ditch; 6- conical flow expander; 7- cone-shaped galvanized turbulizator 8 - air gate; 9- adjustment channel; q_l - flow rate of the transmitted working liquid, l / min; F_c - centrifugal force, N; F_{rot} - rotational force, N; F - resultant force, N; F_v - the viscosity of the working fluid, N; ω - is the rotational speed of the thin liquid layer coming out of the annular hole; α - is the angle of expansion of the flow expander; β - is the angle of expansion of the spray torch; λ - is the angle of expansion of the turbilizator speaker; φ - is the angle of rotation of the thin liquid layer coming out of the annular hole; m - is a particle of a thin liquid layer; h- annular slit width; Δp - working fluid pressure; V_o, V_τ and V - axis, tangential and the resulting velocities at the point m of fluid, **a-** is a scheme of operation of the sprayer; **b** - is a diagram of the forces acting on a thin annular membrane; **c** - the state of local and main air flow around the turbilizator; **d** - general view of the spray unit with an experimental fan (1- blower fan; 2- speaker; 3- turbilizator sprayer).

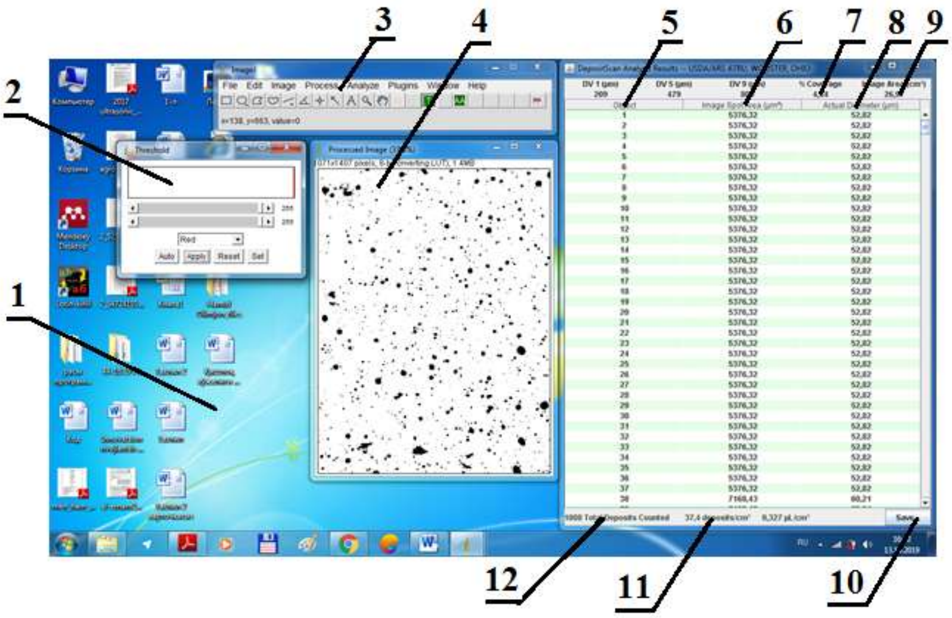
Figure 4: Schematic of the process of formation of highly dispersed droplets in a turbilizator sprayer.

This sprayer distinguishes from the conventional models in that it is mounted with a conical turbilizator 7 and a conical flow expander 6 in order to create highly dispersed droplets. The working fluid q_f passes from the cavity 1 B of the sheath to the cavity of the disk vortexer 4 and from there oblique angular channels 5 to the folding chamber B, then the working fluid pressure under the influence of Δp passes into the annular and expanding outlet channel 2, where it begins to break down into highly dispersed droplets under the influence of the kinetic energy of the vortex current. The relatively large droplets begin to disintegrate rapidly inside the cone-shaped galvanized turbulizator 7 under the influence of a relatively large primary droplet-conical local air flow. A strong aerodynamic air flow then generated by the spray fan surrounding the outside of the turbilizator disintegrates a third time, forming highly dispersed droplets over short distances. This droplet is sprayed in the direction of the crop area, which is further disintegrated under the influence of the main strong air flow that surrounds the outside of the turbilizator. Under the influence of the cone-shaped galvanized turbulizator 7, a thin liquid membrane is transformed into high-dispersion droplets at a short distance, which allowed to increase the technical efficiency of the working fluid used.

In a turbilizator sprayer [17], the transition process under the influence of local turbulization and the main aerodynamic currents was studied (Fig. 4a, 4b, 4c). In this case, it was found that the process of disintegration of droplets formed in the sprayer is a multi-stage process. Analytical expressions were obtained to determine the working fluid flow rate from the annular hole of the proposed turbilizator sprayer. Based on experimental studies, the formation of highly dispersed droplets was achieved by optimizing the flow rate of the working fluid flowing out of the annular hole and the values of the angles of expansion α, β, λ (Fig. 4a, 4b, 4c).

Experimental investigations to select the optimal parameters of the turbilizator sprayer were also carried out on several types of vortex-turbulizator sprayers on a special test machine developed by JSC "Agregat".

The individual dimensions of the droplets per 1 cm^2 of the surface of the special liquid-sensing droplet number 9950-0028 (Water Sensitive Paper), their distribution, total number of droplets, droplet density were determined using the DepositScan program (Fig.5) [21; 22; 24].



1-ASUS A43S laptop; 2- Threshold box to determine image quality; 3- ImageJ control window; 4- sample of the drop card under analysis; 5- individual order number of drops; 6- individual drop volumes, mm^2; 7- drop coverage level,%; 8 - median-mass diameter of the drop, μm; 9- surface of the analyzed droplet card, cm^2; 10

storage button; 11 - the number of drops per 1 cm^2 of the surface of the drop card; 12- The total number of drops on the analyzed drop card.

Figure 5: The process of analyzing scanned drops using the DepositScan software on an ASUS A43S laptop.

Systematic special DepositScan program developed by USDA-ARS Applied Technology Research Division (Wooster, Ohio, USA) is designed to estimate quickly the individual size of small particles or droplets on water-sensitive paper or Kromekote® card, their distribution, total number of droplets, droplet density. The system is integrated with a mobile phone scanner, computer, and a specially designed software package called DepositScan [21; 22; 24]. The software consists of a specially integrated software module used by an image processing program (ImageJ) to produce a series of measurements that are suitable for describing the distribution of splashes.

After scanning the special liquid-sensing droplet number 9950-0028, the individual dimensions of the droplets, their distribution, the total number of droplets, the density of the droplets are displayed on a computer screen and stored in a special spreadsheet (Figure 5).

The research is based on the State Standard of the Republic of Uzbekistan UzDSt 3202: 2017, developed by the Uzbek State Center for Testing and Certification of Agricultural Machinery and Technologies and registered by the Uzbek Agency for Standardization on 25.08.2017 №6257, was conducted on the basis of the methodology of conducting research on technical recommendations [25; 26; 27; 28].

The optimal values of the parameters of the proposed turbilizator sprayer theoretical basis and initially studied in single-factor experiments for conventional fan spraying units, widely used in cotton growing in the conditions of the Republic of Uzbekistan, were determined by using the method of mathematical planning of multifactor experiments [29; 30].

In theoretical studies and single-factor experiments, the width of the annular gap between the nozzle sheath and the conical flow expander, the pressure of the working fluid transmitted from the rotor-roller pump in the hydraulic system, the number of sprayers mounted on the fan speaker was selected as the initial factors which is the most influencing the quality performance of the spraying process.

Based on the experimental analysis and one-factor experiments referred to above, the values of the defined factor rates and variance intervals are shown in Table 1.

Table 1: Unit of measurement of factors, conditional designation and intervals of variation

№	Naming of factors	The unit of measurement of factors	Conditional determination of factors	Range of variation of factors	Level of factors		
					- 1	0	+1

1	The width of the annular hole gap between the sprayer sheath and the conical flow expander, h	mm	X_1	0,4	0,2	0,6	1,0
2	Working fluid pressure, Δp	kgf/cm^2	X_2	3	2	5	8
3	Number of nozzles, n	pieces	X_3	2	2	4	6

The experiments were conducted in compliance with the Hartley-3 plan [29; 30] assuming that the influence of the factors on the measurement criterion will completely cover the secondary polynomial.

The criteria was adopted for measurement in multifactorial studies was the level of operational fluid intake (Y1, l / min), ie 100-150 l / ha for defoliation of cotton, the amount of drops per unit region of cotton leaf (Y2, pieces / cm^2) and the median-mass diameters of droplets (Y3, μm). The plan for conducting multifactorial experiments and their results are shown in fig.6.

The experimental data were processed using the PLANEX program. The Cochrane criterion was used to evaluate the homogeneity of the variables, the Student criterion was used to evaluate the value of the regression coefficients, and the Fisher criterion was used to evaluate the adequacy of the regression models.

II. RESULTS AND DISCUSSION

The results of the experiment were analyzed in the prescribed order and the following regression equations were obtained, correspondingly representing the measurement criteria:

- the level of operational fluid intake (l/min)

$$Y1=+17.528+14.617X1+5.900X2+9.350X3+ +4.491X1X1+4.533X1X2+8.983X1X3+ +0.441X2X2+1.600X2X3+1.391X3X3; \quad (8)$$

- the amount of drops per unit region of cotton leaf ($pieces/cm^2$)

$$Y2=+208.374+51.417X1+140.550X2+35.217X3-138.801X1X1+0.000X1X2-86.542X1X3+ +25.816X2X2+0.000X2X3-18.734X3X3; \quad (9)$$

- the median-mass diameters of droplets (μm)

$$Y3=+155.716+49.383X1-64.467X2+22.717X3+17.505X1X1-40.800X1X2+2.533X1X3+ +29.322X2X2+5.150X2X3+6.105X3X3. \quad (10)$$

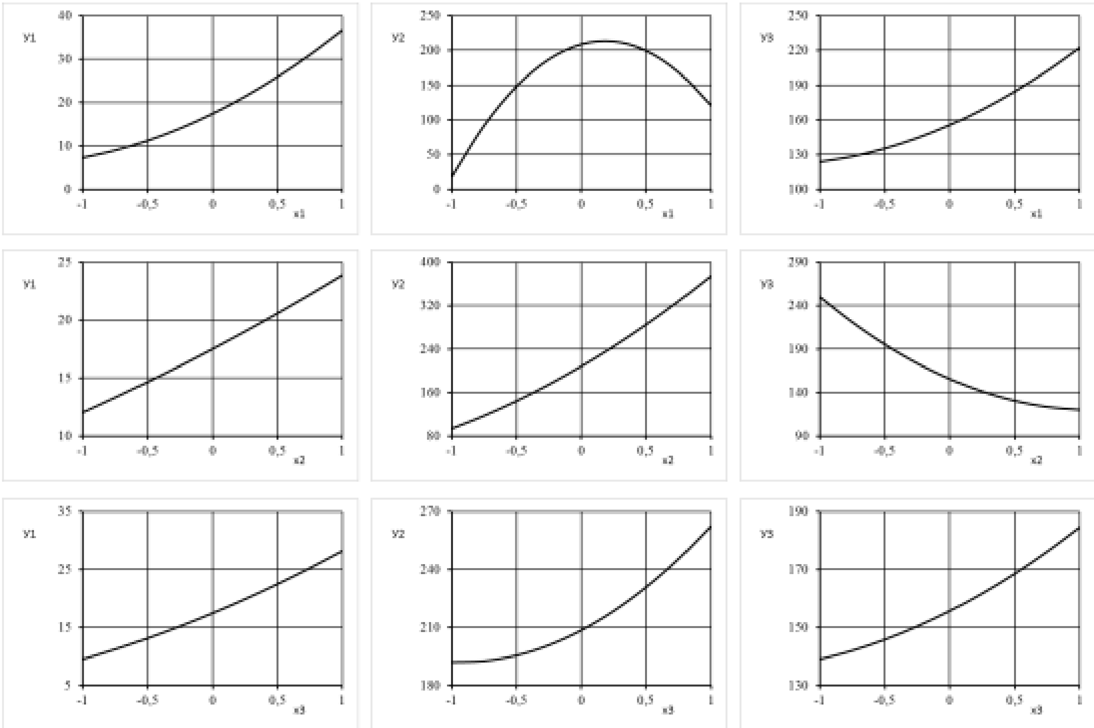


Figure 7: Graphical representations of a multifactorial experiment.

According to the regression equation obtained, the working fluid pressure has a greater impact on the decrease in the median mass of the formed droplets, and the improvement in the functioning fluid intake has a greater effect on the width of the annulus hole in the sprayer. According to the study of the regression equations collected, both variables have a major effect on the assessment criteria:

- the change in the diameter of the annular hole between the sprayer sheath and the conical flow expander lead to an improvement in the rate of consumption of the working fluid from the sprayer, initially increasing and then reducing the amount of drops per unit area of the processed cotton leaf, raising the median-mass diameters of droplets;

-with an increase in the working fluid pressure of the rotor-roller pump in the hydraulic system, an improvement in the rate of working fluid intake, an rise in the amount of drops per unit area of the cotton leaf and a reduction in the median-mass diameters of droplets;

- with an increase in the number of sprayers mounted on the liquid tube in the fan speaker, the working fluid consumption rate increased, the number of drops per unit area of the cotton leaf increased, and the average median-mass diameter of the droplets increased.

The regression equations (8), (9), (10) were solved together on the PC "Pentium IV" by the Excel program "search solution" in order to determine the values of the studied parameters, which provide the necessary quality of quality of work while maintaining resource performance.

Following conditions were adopted as a criterion Y1 in the joint solution of the regression equations, i.e. the rate of consumption of working fluid for the defoliation phase of cotton in the range of 100-150 l / ha; as a criterion Y2, ie the increase in the number of drops per unit area of the cotton leaf to a maximum value of not

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less than 20 pieces/cm^2; and as a criterion Y3, i.e., the average median-mass diameter of the droplets per leaf surface unit in the range of 50–200 μm.

Table 2: Optimal values of the main factors of the turbulizator sprayer

№	Factors	Unit of measurement	Conditional designation	Coded value	Real value
1	The width of the annular hole gap between the sprayer sheath and the conical flow expander, h	mm	X_1	0,10149	0,6406
2	Working fluid pressure, Δp	kgf/cm^2	X_2	-0,1026	4,6922
3	Number of nozzles, n	pieces	X_3	0,01	4,02

The following appropriate turbulator sprayer parameters have therefore been determined which ensure the conformity with the aforementioned requirements:

- the width of the annular hole between the sprayer sheath and the conical flow expander h = 0.6 mm;

- pressure of the transmitted working fluid from the rotor-roller pump in the hydraulic system Δp=5,0 kgf/cm^2;

- the number of nozzles installed on the liquid tube in the fan speaker n = 4.0 pcs ;

Based on these factors, the rate of flow of working fluid is 18.5 l/min, the number of drops per unit area of cotton leaf is 198.3 pieces/cm^2, and the average median-mass diameter of the droplets is 168.5 μm.

By utilizing the experimental spraying unit, the average annual mechanical and economic output per car per season become 11553067.8 sum (at costs in February 2020).

III. CONCLUSION

1. The proposed vortex-turbulator sprayer enabled the forming of rapidly dispersed droplets from a thin layer of liquid streaming out of the hole. The following feature measurements have been found to be acceptable: the decomposition process of the droplets is accelerated when annular width of the sprayer h = 0.6 mm; the angle of expansion of the flow expander $\alpha=60^0$; number of holes in the turbilizator n = 16; working fluid pressure in

the system $\Delta p = 0.5$ MPa; the flow rate of the working fluid sprayed from the sprayer is $q_s = 18.5$ l / min. The total amount of drops on the liquid-sensitive number drop cards 9950-0028 (Water Sensitive Paper) is 2111, the number of drops per 1 cm^2 of surface is 198.3, the median mass of the droplets produced by the sprayer is 168.5 μm.

2. High-dispersion droplets produced from experimental vortex – turbilizator sprayer have been shown to be beneficial in these regimes in controlling developed pests growing on cotton fields, especially on the underside of leaves of other chemically treated agricultural crops.

3. The proposed vortex – turbilizator sprayers were mounted on the experimental OVX-600T spraying unit and used in field research based on the laboratory design parameters and the optimum operating modes.

4. Regression equations have been obtained using the optimization approachdescribing the process of formation of widely dispersed droplets produced by experimental sprayer according to which the decrease in the median-mass diameters of the formed droplets was found to be more influenced by the working fluid friction, and the rise in the working fluid flow was more influenced by the width of the annular hole in the sprayers.

5. Once the experimental spraying unit has been used, the average annual mechanical and economic output per machine per season reached 11553067.8 sum.

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