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SCIENTIFIC ACHIEVEMENTS IN ENVIROMENTAL AND LIFE SCIENCE

RESEARCH ON PROGRAM AND METHODOLOGY FOR LABORATORY AND FIELD STUDIES OF PEST INSECTS GATHERING MACHINE

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KEYWORDS

pest, surface of sheet, working chamber, suction, festering.

SUMMARY

The paper presents a program and methodology for conducting experiments, including the complex of particular laboratory and field researches on the definition of qualitative and energy indices of the insect pests collecting machine implementation. The experimental studies were focused on the argumentation of the production experiment scheme, performing a multifactorial experiment, reviling the dependence of the insect pests collecting and plant damaging coefficients on the amount of the air rarity, the injection rates, the unit velocity, the disclosure angle of the guides, the height of the air intakes location, and the ascertainment of their rational values. In order to examine the functioning of the experimental pattern, in accordance with existing methods, the field probations were conducted.

PROGRAM OF EXPERIMENTAL STUDIES

The analysis of common approaches and methods of crop cultivation as well as the results of the harmful effects of chemical processing showed the necessity to develop ecologically friendly technologies for crop cultivation. Besides, studies on pneumatic mechanical devices are still lacking [1], [2], [6], [13], [21].

Experimental researches on pneumatic mechanical devices are aimed at determining the influence of different factors (diameter of suction pipe, forms of the working camera, the wind flow speed) on the quality indicators of the device operation.

The aim of the study is to examine the theoretical basis and operating modes and parameters of the tool of the pneumatic mechanical device for pest insects gathering machine.

The testing facility with a set of variable parts, set of measuring instruments and strain gauge equipment are to be produced, with the aim of conducting research and basic experiments.

However, very few publications address the issue of main parameters and working modes of the pneumatic mechanical device and its running efficiency. So, the program of experimental research includes:

- the study of the patterns and character of insect-pest absorption;
- the study of structural and kinematic parameters of the device;
- the observation of the working efficiency of the unit.

The implementation of the research program requests the completing of the following tasks:

- to develop a methodology for carrying out the individual stages of research;
- to select the required standard equipment;
- to develop and produce a construction of laboratory and field service installation;
- to produce the necessary quantity of replacement parts for running the experiments;
- to calibrate the measurement units;
- to take the agro-technical and energy assessment of the pneumatic mechanical device operation in comparison with the traditional tools of crop cultivation;
- to organize the research in accordance with the methodology for experiment planning;
- to analyze the results of the research.

To realize the program of experimental research we developed the methodology for carrying out experiments and elaboration of results.

The implementation of experimental research has been done according to the following scheme (fig. 1).

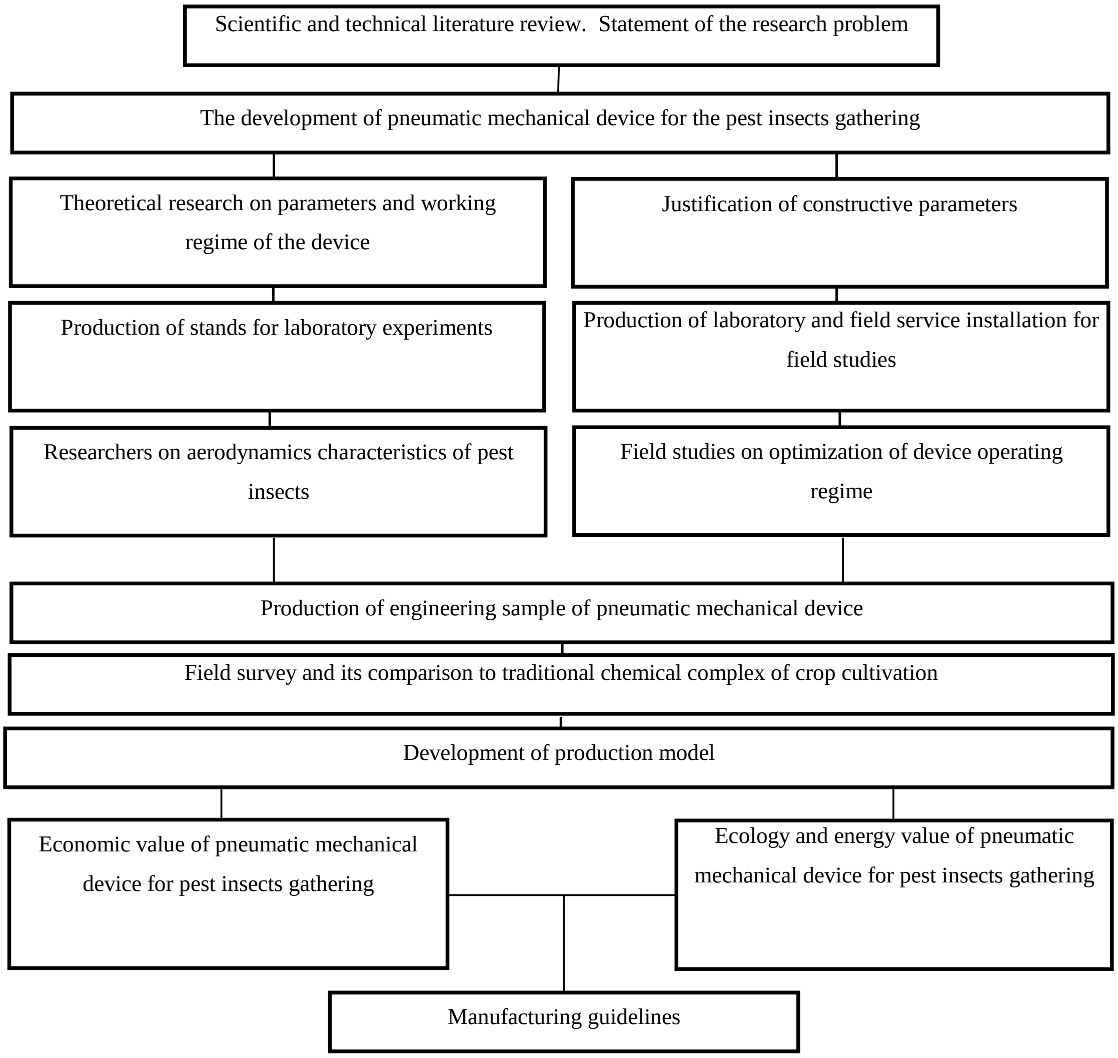

Fig. 1. SCHEME OF EXPERIMENTAL STUDIES REALIZATION

DESCRIPTION OF THE LABORATORY AND EXPERIMENTAL EQUIPMENT NECESSARY FOR RESEARCH

2.1. Unit for the study of aerodynamic properties of pest insects

The experimental unit with a set of changing parts, a set of measuring devices, mini stands and digital equipment was used to carry out search and basic investigations.

The study of aerodynamic characteristics of pest insects, influence of technological indicators (wind resistance capacity, tearing force, etc.) led to the application of the device for studying the aerodynamic characteristics of pest insects.

The device consists of a transparent aerial camera 1, a pressure line 2, a pressure unit (is not shown in fig. 1), an isometric unit 3 (fig. 3.2).

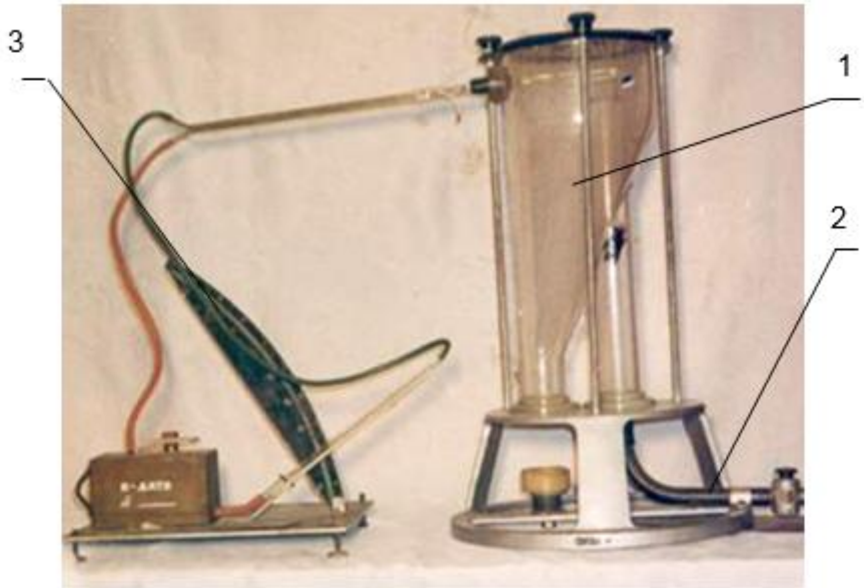

Fig. 2. UNIT FOR LABORATORY STUDY OF AERODYNAMIC PROPERTIES OF PEST INSECTS

2.2. Stand for determination of omission factor of normal and tangential speed component.

As we mentioned in section 2, the particles in terms of jet transport interact with the channel border and to calculate their traffic the dependencies (2.103), (2.104) or (2.119) (2.120) are used [9], [11]. To solve the given equations we need the information about the coefficient magnitude of the reconstruction of normal k_n and tangential speed component K_τ .

We performed the measurements of k_n coefficient for the Colorado beetle. Experiments were presented at the stand.

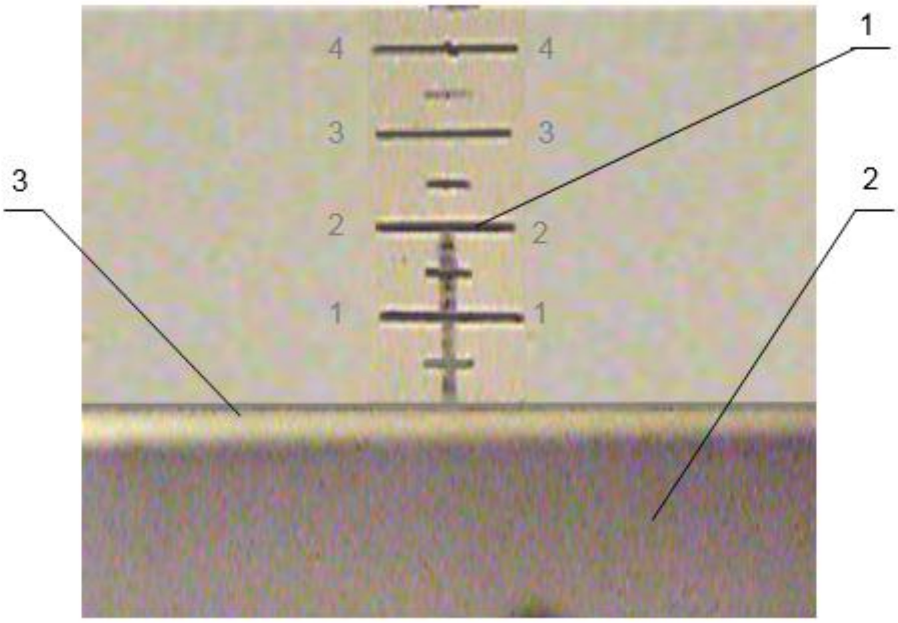

Fig.3. STAND FOR DETERMINING NORMAL K_N AND TANGENTIAL K_τ SPEED COMPONENTS

The stand consists of the measuring scale 1, stand 2, variables of the plates 3 and digital camera (OLYMPUS C -750 Ultra Zoom – in Fig. 3.3 is not shown).

Tab. 1. TECHNICAL CHARACTERISTICS OF DIGITAL CAMERA

Name of the indicator	The meaning
Type	Digital camera
Recording system	Digital record TIFF, JPEG, Exiff 2.2, PRINT Image Matching II
Sound to photos	Wave
Video	Quick Time Motion with JPEG support
Memory	Memory card xD-Picture Card (16 – 256 MB)
Working size	4 million of pixels
Lens	OLYMPUS 6. 3 – 63 mm Lens, F 2.8 – 3.7, 11 items in groups
Photometric system	Digital ESP-System, point-to-point measurements of illumination
Video search service	0.44-inch color liquid crystal display TFT -display, 180000 pixels
Item image	1/2.5-inch CCD matrix, 4220000 pixels (total)
Working distance	0.6 m ~ ∞
Monitor	1.5-inch color liquid crystal TFT display of 114000 pixels
Connection to external devices	AC adapter connector, USB-connector, audio video output
Power supply	4 lithium AA (R6) batteries. AC adapter
Aspect ratio	107.5/66/68
Mass	350 g (without battery and card)

THE DESCRIPTION OF THE TECHNOLOGICAL SCHEME

The technological scheme of the combined unit that joins the sapping cultivation and Colorado beetle gathering without using pesticides. The unit consists of the following elements: air extraction scoop 1, air outlet 2 and inlet duct 3, ventilator 4, tractor 5 (Figure 4).

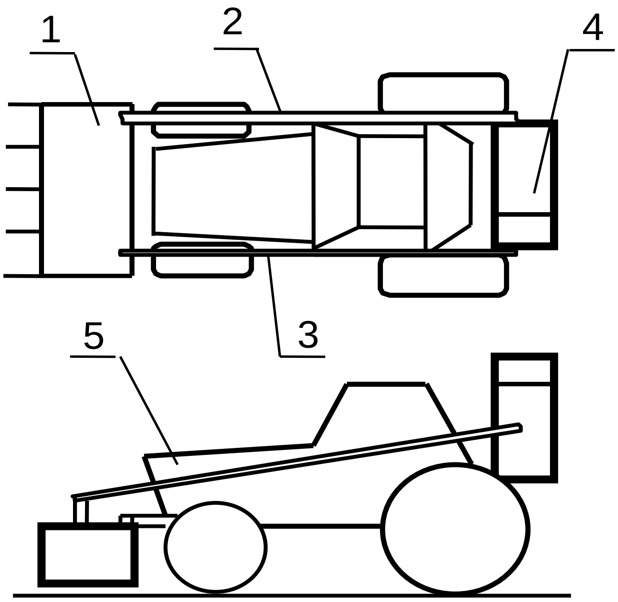

Fig. 4. TECHNOLOGICAL SCHEME OF THE UNIT

Pneumatic mechanical device (fig. 5) includes P-shaped frame 1, the working chambers are mounted at 2. V-shaped tray-pockets are installed along the lower edge of the working cameras, one-sided tray-pockets 3 are installed along the edges of the bearing frame and double-sided ones 4 are inside.

The suction pipes are located in the upper parts of the processing chambers and joined together by the collector 8 and the central pipelines. Each working chamber in front of the camera has blowing tools, made in the form of delivery pipes 5 with attachments 6. A tape final filtering 10 is set in the back of the working chamber and there is the guide device 7 (Fig. 5, 6) in the front part [1], [4].

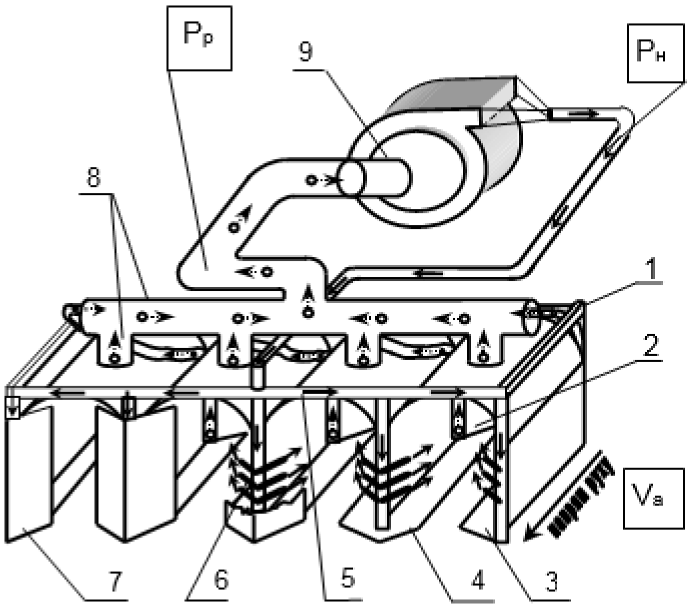

Fig.5. EXPERIMENTAL FIELD DEVICE

Вид А

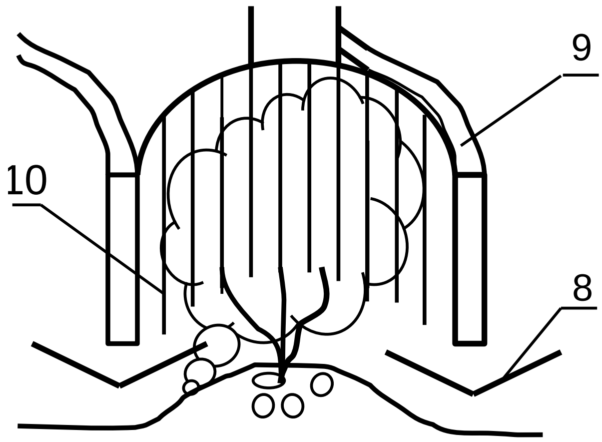

Fig. 6. BACKGROUND IMAGE OF WORKING CAMERA IN TERMS OF INSECT-PEST GATHERING

The unit operates in the following way. The plants are transported by the guides to a working chamber to collect the insects. When the plants are passing the front part of the device, they are effected by air flow that is directed by spray nozzle. Partly blown off insects, fall into the pockets and get into the central inlet pipeline. When the central part of the working camera is going over potato bush an insect is taken by the scoop and is sent to the inlet pipeline. When the bush is on its way from the working camera the process of plant additional cleaning from pests is completed by rubber straps. The process of discharge and suction goes by means of ventilator.

The fan drive of the experimental field installation can be carried out both with the help of tractor GDP and tractor hydraulic system. Besides, a hydraulic motor is installed for the drive.

To conduct further measurements of energy indicators the measuring equipment will be installed at the field unit. Technical characteristics of the experimental are given in Table 2.

Tab. 2. TECHNICAL CHARACTERISTICS OF EXPERIMENTAL FIELD INSTALLATION

NAME OF THE INDICATOR	The meaning
TYPE	ADD-ON
Quantity of cultivated rows	4
The number of cameras, PCs.	4
PLANTING WIDTH	0.7
USEFUL SWATH WIDTH, M	2.8
PRODUCTIVITY, HECTARE/H	1.51
VENTILATOR DRIVE	HYDRAULIC MOTOR OR GDP
WORKING SPEED, KM/H	6-9
TRANSPORT SPEED, KM/H	UP TO 26
AGGREGATED WITH MULE TRACTOR	1.4
THE NUMBER OF STAFF PEOPLE	1
MASS, KG	550

THE METHODOLOGY OF EXPERIMENTAL RESEARCH AND DETERMINATION OF THE MEASURED VALUES

To develop the methodology of experimental research RD 10.8.5-89 "Agricultural Machinery Testing" was used. Technological process monitoring was done by the method of measurement. The experimental researchers were divided into 2 stages: the searching and basic experiments.

The searching experiments were conducted according to the following scheme:

- the definition of factors that affect the process of collecting insects, i.e. the selection of major factors (screening experiment);
- the determination of the influence of the most important factors on the implementation of the collection technological process;
- the examination of devices according to the conditions of the experiments;
- the determination of the facts necessary for the number of experiments.

The searching experiments cannot identify the patterns of the technological process. They may be developed before the methodology of research, in the process of its development or after it.

To establish the basic laws of indices and objective analysis of the experimental data it is necessary to determine the conditions of the research.

The conditions of the laboratory of experimental plants were identified in accordance with the existing requirements [7], [8], [9].

4.1. The determination of the insects size characteristics.

The size of insects is the basis of experimental data presented in the table or graphically in the form of histogram or polygon scattering. In the construction of the histogram the size of the beetle (length, width, thickness and weight) is given on the horizontal axis and the relative frequency is put on the vertical axis

$$\omega = \frac{n_{xi}}{\mathrm{N}} \tag{1}$$

The sum of rectangles, the width of which is an accepted interval size and the height, is considered to be a relative frequency ω of the histogram.

If the middles of the upper part of the box are connected by straight lines we will get a polyline that is supposed to be an empirical curve of dispersion of insect size or ground scattering. The histogram and the polygon are visual representation of the character of the random value dispersion (in our case-size of insects).

The area within the interval is equal to the relative frequency on the histogram or polygon of dispersion and the area within the interval is equal to the probability of size occurrence in this interval on the theoretical curve.

According to the law of large numbers (the probability that is close to accurate), we can argue that the frequency of experimental activity (size) in terms of a large number of experiments can differ as little as possible from its probability. Therefore, the theoretical scattering curves obtained by approximation of histogram or dispersion empirical curves are used for practical calculations.

There is a set theoretical dispersion laws for approximation. We will use a common law of normal scattering (Gauss's law), which is expressed by the equation:

$$y = \frac{1}{\sigma\sqrt{2\pi}} e^{\frac{-\left(x-\bar{x}\right)}{2\sigma^2}} \qquad (2)$$

The final conclusion on the choice of the dispersion law is made after determining the conformity of experiments and theoretical dispersion curves to one of the approval criteria (Kolmogorov's criteria, Pearson, etc). Knowledge of dispersion law of beetle random sizes allows us to consider the practical issues of aerodynamic characteristics of insects and the parameters of the artificially generated air flow. The approximate calculation of the dispersion law gives its number characteristics. All of them are of medium size, if they are calculated from the central point, the moments are called starting, and if they are calculated from the center of dispersion law, the moments are called central.

An important starting moment is the first one:

$$\bar{x} = \int_{-\infty}^{+\infty} xp(x)\partial x \qquad (3)$$

It is known, that the larger the number of experimental data is, the more the average number approaches the average expectations. In terms of a limited number of experiments χ Wed we have:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \qquad (4)$$

where N is the number of experiments (the size of insects).

A scatter-band limit of the results is the second central moment (dispersion):

$$\sigma_x^2 = \left(x-\bar{x}\right)^2 = \int_{-\infty}^{+\infty}\left(x-\bar{x}\right)^2 p(x)dx \qquad (5)$$

or the average quadratic deviation:

$$\sigma_x = +\sqrt{\sigma_x^2} \qquad (6)$$

If a number of experiments is more than 25, we can determine the average quadratic deviation by the formula:

$$\sigma_x = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left(x_i - \bar{x}\right)^2} \qquad (7)$$

The third central moment is a limit of asymmetric dispersion or asymmetry:

$$\mu = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\frac{\left(x_i - \bar{x}\right)^3}{\sigma_x^3}} \qquad (8)$$

The fourth central moment characterizes the kurtosis:

$$V = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\frac{\left(x_i - \bar{x}\right)^4}{\sigma_x^4}} \qquad (9)$$

The function of scattering the probability and all moments has an important characteristic: being a characteristic of random numbers that are not coincidental.

The variation curves of beetle size indicators that are presented in the form of the variation curves were done on the basis of experiment samples. All received variation curves are used to calculate the technological parameters of air flow that separates the beetle from the leaf surface.

4.2. The definition aerodynamic characteristics of insects

Colorado beetle behavior in the air stream is determined by insect aerodynamic characteristics. Indicators that characterize the aerodynamic properties of the insects are the critical speed v KR (stuck), wind resistance coefficient and coefficient of aerodynamic resistance cf .

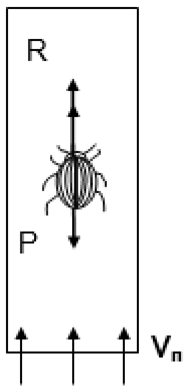

Fig. 7. THE SCHEME OF INTERACTION BETWEEN INSECTS AND VERTICAL AIR FLOW

Let us consider the behavior of the object in the vertical air flow. The insect (fig. 7) is influenced by the gravitation force P and the pressure force R of the air flow (separation force of the object) that is determined by the formula:

$$R = k\rho_{\Pi} S\left(v_{кр} - v\right)^2 \quad (10)$$

where pp is the density of air, kg/m3;

S is the area of body projection on the plane, perpendicular to the direction of air flow (the middle section of insect body);

vKR is a critical speed m/s;

v is the speed of body movement m/s.

P and R forces in vertical air flow are directed to the opposite sides. According to the ratio of these forces the movement of particles down P > R, movement upwards R > P and its stable condition P = R in terms of u = 0 are possible. According to the air flow speed vCD the body is located in the balanced position and it is called the critical velocity.

Taking into account the condition of P = R, we have:

$$v_{kp} = \sqrt{P / k\rho_{\Pi} S} \quad (11)$$

The coefficient k of aerodynamic resistance depends on the shape of the body, the state of its surface, the state and the kind of the object environment, as well as the speed movement of the air. Increasing the speed of air flow leads to k reducing.

$$k = \frac{k_{\Pi} m}{\rho_{\Pi} S} \quad (12)$$

where m is the mass of the Colorado beetle, kg;

S is the area middle cross section of beetle body, m2.

The coefficient of wind resistance (k) is found according to the connection:

$$k_{пар} = \frac{9.8\rho_{\Pi} S}{P} \quad (13)$$

Calculating the expression s (11) and (13) we receive:

$$k_{nap} = \frac{9.8}{v_{kp}^{\ 2}} \quad (14)$$

The installation consists of a special laboratory device (wind resistance sizer). In the area of air flow influence on the object the Pilot tube that is connected with the flexible rubber tube by liquid filled pressure gauge is installed. The liquid filled pressure gauge allows us to measure the dynamic pressure of the air where the material is counterweighted in pneumonic unit chamber.

The procedure of aerodynamic research on pests has the following stages:

1. A portion of the material is put in the aerodynamic tube of wind resistance sizer. The dynamic resistance of the air is determined with the help of fan that corresponds to the counterweighted state of the other objects.

Dynamic air pressure is determined by the formula:

$$h_d = l \sin \alpha g \gamma \qquad (15)$$

where hd is a dynamic air pressure, PA;

l is dynamic pressure of air that is determined by changing the level of the liquid in the tube gauge, mm; α = 300 ;

γ is the density of a liquid gauge, t/m3; for γ = 1 t/m3 .

2. The critical air speed for insects is determined with the help of the formula:

$$v_{kp} = 1.28\sqrt{h_d} \qquad (16)$$

3. According to the formulae (12) and (14) we define aerodynamic resistance coefficient and wind resistance coefficient.

The effort of separating the pest from the leaf under the air critical speed v KR condition is used to determine the speed coefficient, indicating the number of times the actual speed of the air flow is bigger (vd > vKR) to provide reliable insect removal from the leaf surface of plant:

$$K_v = \frac{P_{y.j.}}{P_{v.j.}} \qquad (17)$$

where $P_{y.j.}$ is a withholding force of the beetle;

$P_{v.\,j.}$ is a detachment force of insects.

For known v_{KR} and k_v we find the working value of the air flow velocity:

$$v_p = v_{kp} K_v \qquad (18)$$

According to the results of the measurements variation tables of insect size indices were built.

4.3. Field investigations of experimental unit

Field researches were focused on examining the serviceability of the experimental unit and its efficiency, determination of the insect gathering coefficient Kz, plant damage coefficient Cp, and studying the optimal ingredients for pest development.

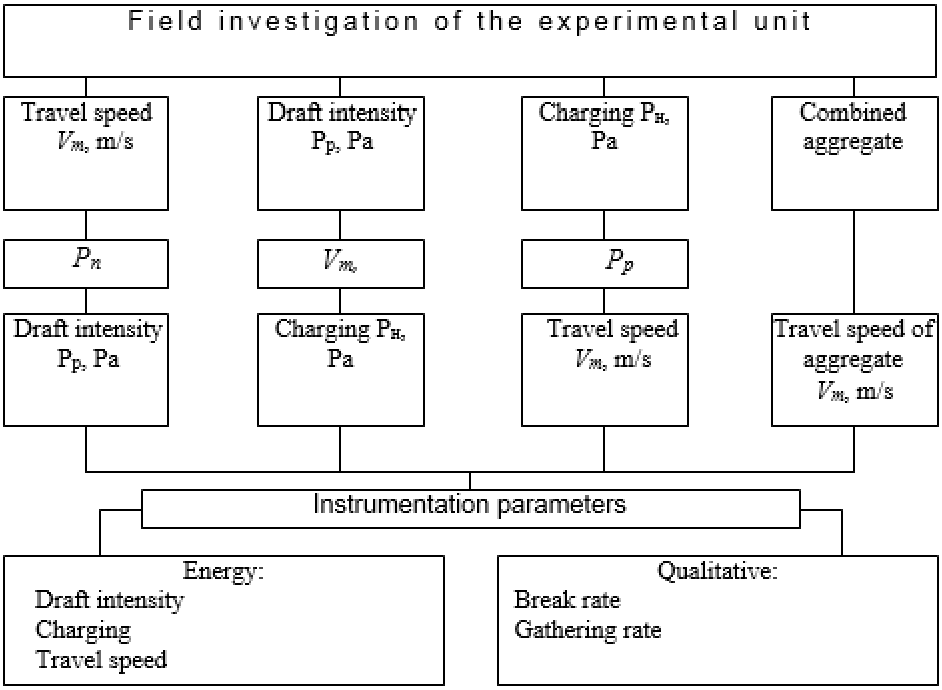

Fig.8. THE SCHEME OF FIELD EXPERIMENTAL RESEARCH

The research area of the field planted with potatoes was divided into 3 parts: 15 meters long and 2.8 meters wide.

Watching the beetles on potato bushes (the number of pest at different stages of its development) and using literary sources, we have found the optimum ingredients for insect development. This research allows us to predict the speed of generation development and output of beetles after wintering.

To check the efficiency of the experimental field unit and to study its effectiveness we considered the achievements of laboratory research and the critical speed of beetle VKr, in particular.

Density of planting was defined by counting the bushes at four rows of each plot. Numbers correspond to the quantity of bushes in thousands of pieces per one hectare.

Measurements and calculations are followed by cutting and weighing the potato bushes. The biological crop is identified by the formula:

$$U_B = \frac{q_B\ n}{100} \tag{19}$$

where U B is a biological crop potato, kg/ha;

q B is a potato mass of one bush, kg;

n is a number of bushes per one hectare, PCs.

The time of experimental installation operation is fixed by a stopwatch and the speed of movement is calculated by the formula:

$$V_a = \frac{3{,}6\ \Delta l}{t_{пр}} \tag{20}$$

where Δl is a covered distance (length of the plot), m;

t is a duration, s.

The next step is to determine the damaged leaf surface and stems after pneumatic unit passing. To do this the damaged bushes are counted after pneumatic desinsection and coefficient of damage is calculated by the formula:

$$K_p = \frac{K_1}{K_n} \tag{21}$$

where k1 is a number of damaged bushes, pcs

Kn is the total number of bushes, pcs.

Fig. 9. TESTING OF PNEUMATIC MECHANICAL DEVICE

The next stage of our research is to determine the coefficient of crop retrieval kwith. So, before each passage of the unit the number of insects on the selected area is determined, the pests in various stages of their development are counted separately (example/bush). Such definitions should be done after pneumatic desinsection.

The data make it possible to determine the coefficient of crop retrieval kfrom by the formula:

$$K_{3} = \frac{K_{2}}{K_{\Sigma}} \qquad (22)$$

where K2 is the number of collected insects;

K∑ is the total number of insects on the bush research areas before aggregate passing, pcs.

After selecting the main factors, during the second stage of research, the experiments on planning a full factorial experiment (FFE) 2 n were conducted.

MULTIFACTOR EXPERIMENT PLANNING AND RESULT PROCESSING OF RESEARCH STUDY

The primary element of the study is the planning of the experiment. In addition, we should take into account the content of experiments to get the experimental data of different factor influence on the selected parameter of optimization.

To get full information and to learn the phenomenon, it is necessary to examine the influence of several factors on the process and find the links between them, simultaneously. So, this is the aim of full factorial experiment where the value of one factor is combined with values of all other factors. Such experiment planning is much more efficient in comparison with the traditional experiment of the same content. Full factorial experiment provides the possible interaction between factors. Moreover, the number and time of researches are reduced [7], [8], [11].

During the parameterization and the study of pneumatic mechanical process of insect collection, the most efficient factors (coefficient of air depression pp, forced air supply pn and the speed of the unit Vas) are highlighted.

A set of multifactorial experiments was carried out to assess the influence of different factors and to select the most significant one. The plan of the experiment consists of the following stages:

- creating the matrix of experiment planning;
- calculating the coefficients of regression;
- testing the value of regression coefficients;
- building a regression model;
- checking the adequacy of the model;

Coefficient of air depression pp, forced air supply pn and the speed of the unit Vas were chosen to be the controlled factors. These factors exist in terms of two levels in selected for each of them range of variation.

Working chamber is an object, which status is determined by many factors. At the same time the factors that influence the effectiveness of the process can be divided into 2 groups: the regulated and unregulated. To make the mathematical model, the regulated factors are included in the equation in the form of running arguments, and unregulated factors will cause random fluctuations of the source function and their levels are impossible to fix.

As the initial function of Y, we take the value of the air velocity v KR, at which the insect is thrown into the main pipe. All the quantitative methods for the removal of controlled factors seem to be non-effective while studying the influence of external factors on the initial function, their overall assessment, ranking and selecting the most significant characteristics, since these methods involve a change in the levels of the investigated factors. These methods provide changes in levels of investigated factors. We consider the method of analysis of variance to be the most suitable for designing the model. According to this methodology the assessment of the total dispersion of the initial value is reduced to the components that are dependent on random influences of each of the factors and their interactions. In addition, the statistical significance of interaction dispersion according to the error of renewing the experiment is defined. This analysis is based on the following statements:

- the observation of the response function of Y is normally distributed random variable with the center of distribution of M (Y) = f(X1, X2, X3). Thus, the factors, determining the magnitude only on average, let the random errors of observations that are subordinated to the normal distribution. In this case random errors of observations can be caused by both the errors of methodology and the random action of uncontrollable factors.
- dispersion of single observation of $\delta\varepsilon$ is caused by random errors ε and is constant in all experiments and does not depend on X1, X2, X3.

The matrices of planning for each of the stages of the experiment were done. And according to matrices data the experimental studies take place when the retry value is equal to three. It is necessary to build a regression model of both, the gathering coefficient and the coefficient of damage in the study. The models describe the dependence of kp and kwith from the coefficient of air depression pp, forced air supply pn and the speed of the unit Vas. To construct the model it is necessary to make the intermediate calculation, analyze of the significance of each of the factors, as well as multifactor interactions.

To create a mathematical model we have chosen a three-level plan of Box and Banking second-order design. Response variance is measured by the results of three experiments at zero point.

To reduce the impact of accidental external influences on the value of response function, the experiments were carried out in randomization order, in triple repetition. Levels and intervals of factor variation remain the same. The calculation of the regression coefficients was done with the help of the following formulae:

$$b_i = \frac{1}{8} \sum_{u=1}^{15} x_{iu} y_u \tag{23}$$

$$b_{ij} = \frac{1}{4} \sum_{u=1}^{15} x_{iu} x_{ju} y_u \tag{24}$$

$$b_{ii} = \frac{1}{4} \cdot \sum_{u=1}^{15} \left(x_{iu}\right)^2 \cdot y_u - \frac{1}{16} \cdot \sum_{j=1}^{15} \sum_{u=1}^{15} \left(x_{iu}\right)^2 \cdot y_u - \frac{1}{6} \cdot \sum_{u=1}^{3} y_{0u} \tag{25}$$

The value of the coefficient b $_0$ was calculated on the basis of three experiments at zero point according to the formula:

$$b_0 = \frac{1}{3} \cdot \sum_{u=1}^{3} y_{0i} = y_0 \tag{26}$$

It is known, that a full factorial experiment consists of the following stages: factor coding, matrix planning, re-conducting the experiment, implementation of the experiment, testing the adequacy of the model, and the significance of the regression coefficients [11, 20, 22].

It was important to find upper and lower levels for each factor, within which the value of the factor changes. The lower level of factor is offered to be marked as (-) and the top level is marked as (+) in the theory of experiment planning [11], [19].

The interval of factor changes was determined by the formula:

$$\varepsilon_i = \frac{x_s - x_{ect}}{2} \tag{27}$$

where εi is variation interval of the first factor;

xs is the top level of the first factor;

xetc. is the lower level of the first factor.

The Basic (zero) level was calculated by the formula:

$$x_{io} = \frac{x_s + x_{ect}}{2} \quad (28)$$

where xio is the value of the first factor at the zero level.

The value of star points was calculated according to the star shoulder that was α = 1.414 for a four-factor plan of the experiment [11].

To transform the natural factors into dimensionless quantities, in order to build an experiment matrix-plan, it is necessary to encode the factors [11]. The connection between the code and the natural values of the factors is identified according to the following dependence:

$$x_i = \frac{X_i - X_{io}}{\varepsilon_i} \quad (29)$$

where x_i, X_i are code and natural values of the first factor.

The plan matrix of the experiment was done on the basis of previous calculations. Then we substitute the value into the formulae and get the regression model:

$$\delta_{b0}^2 = \frac{1}{3}\delta_y^2 ;\ \delta_{bi}^2 = \frac{1}{8}\delta_y^2 ;\ \delta_{bij}^2 = \frac{1}{4}\delta_y^2 ;\ \delta_{bij}^2 = \frac{13}{48}\delta_y^2 \quad (30)$$

Where δ_y is a response variance.

$$\delta_y^2 = \frac{\sum_{i=1}^{m}\sum_{u=1}^{3}(y_{0_u} - y_0)^2}{3(m-1)} \quad (31)$$

where m is a retry value of one single experiment;

y0u is a value of the initial quantity in parallel experiments;

ý is an average number for zero points in terms of one experiment.

The table value of the Student’s criterion for degrees of freedom n = 2 is equal to 2,120.

Intervals of the regression coefficients were calculated according to the formula:

$$\Delta b = S\{b\}t_\alpha \quad (32)$$

The adequacy of the model was checked by F-test. Before that the variance of adequacy is calculated:

$$\delta_{a\partial} = \frac{\sum_{i=1}^{15}(y_{эi} - y_{pi})^2}{f} \quad (33)$$

where yèi is an experimental value of the initial value at the first point;

yri is the settlement value of the initial value at the first point;

f is the number of degrees of freedom.

In this case, the number of degrees of freedom:

$$f = N - k - (n - 1) \quad (34)$$

where n is the number of experiments at zero point.

The estimated values of the response function are found by substitution in the corresponding mathematical models. The calculation of the dispersion of adequacy allows us to calculate F-test (Fisher's criterion) and compare it with the table one, under the same level of significance.

CONCLUSIONS

1. The program of experimental research methodology has been developed.
2. To confirm the results of theoretical studies, and to carry out search and basic experiments, the laboratory and field experimental unit has been designed.
3. The attachment for laboratory and field study unit has been developed.
4. The additional equipment for research, as well as the devices for unit rating, has been created.
5. The information on the laboratory determination of physical and mechanical characteristics of pest insects is given.
6. The methodology of planning, conducting, and processing of the search and optimizing multifactor experiment results, along with theoretical investigations, enabling the comprehensive argumentation of parameters and modes of the pneumatic mechanical device, have been described.

The developed methods of experimental research and manufactured equipment have been covered by the author in referencing literature [4], [7], [8], [11], [20].

REFERENCES

1. Bendera, I.M., Hutsol, T.D.: Zbirennya kolorads′kykh zhukiv pnevmomekhanichnymy zasobamy // Zbirnyk naukovykh prats′ Podil′s′koyi derzhavnoyi ahrarno-tekhnichnoyi akademiyi. Vyp. 10. - Kam'yanets′-

Podil′s′kyy: "ABETKA", 238-240, (2002). http://188.190.33.56:7980/jspui/bitstream/123456789/525/1/Збирання%20колорадських%20жуків%20пневмомеханічними%20засобами.pdf

2. Brechko, E.V., Elisovetskaya, D.S., Nastas, T.N., Voitko, D.V., Yankovskaya, E.N.: Formation of phenotypic structure of populations of the Colorado potato beetle (Leptinotarsa decemlineata Say) under environmental stresses. Proceedings of the National Academy of Sciences of Belarus, agrarian series, no 4, 79–89, (2016).

3. Brechko, YE.V.: Yzmenchyvost′ fenotypychnoyi struktury populyatsiy koloradskoho zhuka (Leptinotarsa decemlineata Say) pid vplyvom insektytsydiv / E.V. Brechko, M.I. Zhukova // Zemlyarobstva i akhova raslin. №4, 56-60, (2010).

4. Gucol, T., Bendera, I., Nowak, J.: Zbieracz stonki // Rolniczy Przeglad Techniczny. - №5 (75). – P. 14, (2005).

5. Gutsol, T., Cherenkov, A.: Analysis of noise immunity and the electromagnetic environment in the areas of remote diagnostics of the state of animals with radiometric receiver / Bulletin of the Kharkiv National Technical University of Agriculture named after Petr Vasilenko. Technical sciences. Issue 186 "Problems of energy supply and energy saving in the agroindustrial complex of Ukraine". Kharkiv: KhNTUSG., 144-145, (2017).

6. Hare, J.D.: Impact of defoliation by the Colorado potato beetle on potato yields. Journal of Economic Entomology, 73(3): 369-373, (1980).

7. Hutsol, T.D.: Do pytannya formuvannya strumenyu povitrya nahnitayuchoyu nasadkoyu ustanovok dlya zbyrannya kolorads′kykh zhukiv // zbirnyk prats′ mizhnarodnoho sympoziumu "Mizhrehional′ni problemy ekolohichnoyi bezpeky" - Sumy: Sums′kyy NAU, 130-134, (2003).

8. Hutsol, T.D.: Obgruntuvannya parametriv ta rezhymiv roboty prystroyu dlya mekhanichnoho zboru komakh-shkidnykiv prosapnykh sil′s′kohospodars′kykh kul′tur: avtoref. dys. ... kand. tekhn. nauk: 05.05.11 - "Mashyny ta zasoby mekhanizatsiyi sil′s′kohospodars′koho vyrobnytstva" / Taras Dmytrovych Hutsol. - L′viv, 2007. - 19 s. https://www.researchgate.net/publication/322158903_Grounding_parameters_and_modes_of_operations_of_mechanical_device_for_collecting_pests_of_agricultural_crops_OBGRUNTUVANNA_PARAMETRIV_TA_REZIMIV_ROBOTI_PRISTROU_DLA_MEHANICNOGO_ZBIRANNA_KOMAH-SKIDNIKI

9. Hutsol, T.D., Bendera, I.M., Bichyns′kyy, S.O.: Obgruntubannâ formi zabirnoï kameri pnevmomehaničhogo pristroű // "Ahrarnyy visnyk Prychornomor'ya" Zbirnyk naukovykh prats′ Odes′koho DAU. - Odesa: ODAU, - №28, 70-75, (2005).

10. Hutsol, T.D.: Ekolohichno chysta tekhnolohiya dohlyadu za roslynamy // Zb. dopovidey. t.1 - Donets′k .: DonNTU, DonNU, 194, (2003).

11. Hutsol, T.D.: Obgruntuvannya parametriv ta rezhymiv roboty mekhanichnoho prystroyu dlya zbyrannya komakh-shkidnykiv prosapnykh sil′s′kohospodars′kykh kul′tur. – Rukopys. Dysertatsiya na zdobuttya naukovoho stupenya kandydata tekhnichnykh nauk za spetsial′nistyu 05.05.11 – mashyny i zasoby mekhanizatsiyi sil′s′kohospodars′koho vyrobnytstva. – L′vivs′kyy derzhavnyy ahrarnyy universytet, L′viv, 2007.

12. Ivanyshyn, V., Hutsol, T.: The Ukrainian agricultural groups state and agromachinery rovision. Scientific achievements in agricultural engineering agronomy and veterinary medicine: Polish-Ukrainian

cooperation: monograph. State Agrarian and Engineering University in Podilya, Agriculture University in Krakow. Vol. I. Krakow: Traicon 1 (1), 5-18 (2017). https://www.researchgate.net/publication/321295222_THE_UKRAINIAN_AGRICULTURAL_GROUPS_STATE_AND_AGRO-MACHINERY_ROVISION

13. Kokhmanyuk, F.S. Modelʹ mykroévolyutsyy - koloradskyy zhuk / F.S. Kokhmanyuk, E.P. Klymets // Tez. dokl. III sʺezda BelOHyS. - Mynsk, 103, (1976).

14. Kokhmanyuk, F.S. Yzmenchyvostʹ fenetychnoyi struktury populyatsiy koloradsʹkoho zhuka v mezhakh arealu / F.S. Kokhmanyuk // Fenetyka populyatsiy. - M., 233, (1982).

15. Levytska, V., Mushynskyi, A., Hutsol, T.: Detection and Diagnosis of Encephalitozoonosis in Rabbits Under Ukraine-Specific Conditions. Scientific achievements in agricultural engineering, agronomy and veterinary medicine: Polish-Ukrainian cooperation : scientific monograph. State Agrarian and Engineering University in Podilya, Agricalture University in Kraków. Vol. I. Kraków : Traicon, 94-107, (2017).

16. Nasadka prystroyiv dlya zboru vorsynok / V.A. Onopa, M.M. Petrenko ta inshi. Pat: № 20158 A Ukrayina.

17. Nowak, J., Bendera, I., Gucol, T.: Mechaniczne niszczenie stonki ziemniaczanej // Ziemniak Polski.– №4 (XVI), 30-33, (2006). http://agro.icm.edu.pl/agro/element/bwmeta1.element.agro-article-c276a5b1-c457-4650-9b1d-bc0c5e501017

18. Oleh Ovcharuk, Taras Hutsol, Vasyl Ovcharuk, Liudmyla Mykhailova, Nataliia Semenyshena, Barbara Dziedzic: Influence of Sowing Methods and Seeding Norms on Crop Production and Bean Harvest. Scientific achievements in agricultural engineering agronomy and veterinary medicine Polish - Ukrainian Cooperation Scientific Monograph Vol. II.. – Traicon SC, Krakow, 218–247, (2017).

19. Taras Gucol, Iwan Bendera, Janusz Nowak.: Ocena Mechanicznego Zwalczania Stonki Ziemniaczanej. Zarzadzanie Technika v Rolnictvie Zrovnovazonym. 35-37, (2006). https://www.researchgate.net/profile/Taras_Hutsol/publication/322397809_OCENA_MECHANICZNEGO_ZWALCZANIA_STONKI_ZIEMNIACZANEJ_EVALUATION_OF_MECHANICAL_POTATO-BEETLE_CONTROL/links/5a5765660f7e9bf2a537fefb/OCENA-MECHANICZNEGO-ZWALCZANIA-STONKI-ZIEMNIACZANEJ-EVALUATION-OF-MECHANICAL-POTATO-BEETLE-CONTROL.pdf

20. Volodymyr Ivanyshyn, Taras Hutsol, Komarnitsky Sergiy: Obgruntuvannya parametriv tekhnichnoho zabezpechennya proektiv zbyrannya rannikh zernovykh kulʹtur. Strategy of the balanced economy of economics, technology and resource potential of the territory. Compendium contains of science and education of the II international scientific and practical conference. Ternopil Krok, 27-30, (2016).

21. Zayats, E.V.: Do pytannya vyshukuvannya robochoho orhanu dlya zboru koloradsʹkykh zhukiv ta yikh lychynok / E.V. Zayats, S.A. Dubatovka // Uchni zapysky: materialy nauch.-prakt. konf / Hrodn. s.-kh. in-t; red .: A.D. Shatskyy [i dr.]. - Hrodno, - Vyp. 7. 83-85, (1997).

22. Gucol Taras, Bendera Iwan, Nowak Janusz: Grounding the parameters of pneumatic device for pests collecting. TEKA – Lublin: Polish academy of sciences branch in Lublin. Volyme 7 A, 35–40, (2007). http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.485.3574&rep=rep1&type=pdf

23. Ivanyshyn, V., Nedilska, U., Khomina, V., Klymyshena, R., Hryhoriev, V., Ovcharuk, O., Hutsol, T., Mudryk, K., Jewiarz, M., Wróbel, M., Dziedzic, K.: Prospects of Growing Miscanthus as Alternative Source of

Biofuel. Renewable Energy Sources: Engineering, Technology, Innovation: ICORES 2017, 801-812, (2018). DOI 10.1007/978-3-319-72371-6_78

24. Pantsyr, Y., Garasymchuk, I., Hutsol, T., Gordiychuk, I.: Energy Parameters' Calculation of a Hybrid Heat Supply System for a Private House in the Conditions of Western Part of Ukraine. Renewable Energy Sources: Engineering, Technology, Innovation: ICORES 2017, 765-780, (2018). DOI 10.1007/978-3-319-72371-6_75

25. Kozina, T., Ovcharuk, O., Trach, I., Levytska,V., Ovcharuk,O., Hutsol,T., Mudryk, K., Jewiarz,M., Wróbel, M., Dziedzic, K.: Spread Mustard and Prospects for Biofuels. Renewable Energy Sources: Engineering, Technology, Innovation: ICORES 2017, 791-799, (2018). 10.1007/978-3-319-72371-6_77