UDC 632.951:631.347.3
DOI: 10.15587/1729-4061.2017.101080

IMPROVING THE DESIGN ELEMENTS OF SPRAYERS TO IMPROVE TECHNOLOGIES IN THE PROTECTION OF BLACK CURRANT AGAINST PESTS

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Застосування інсектицидів для захисту насаджень смородини чорної проти фітофагів залежить від ефективних обробок модернізованим обприскувачем ОП-2000 (Україна), що дає можливість забезпечити зниження заселеності рослин сисними шкідниками у 5,8 рази. Показані конструктивні особливості розробленого спеціалізованого рухомого складу, з використанням модернізованого обприскувача, для досягнення бажаного ефекту

Ключові слова: смородина чорна, фітофаги, модернізований обприскувач, інсектициди, спеціалізований рухомий склад, сисні шкідники

Применение инсектицидов для защиты насаждений смородины черной против фитофагов зависит от эффективных обработок модернизированным опрыскивателем ОП-2000 (Украина), что дает возможность обеспечить снижение заселенности растений сосущими вредителями в 5,8 раз. Показаны конструктивные особенности разработанного специализированного подвижного состава, с использованием модернизированного опрыскивателя, для достижения желаемого эффекта

Ключевые слова: смородина черная, фитофаги, модернизированный опрыскиватель, инсектициды, специализированный подвижной состав, сосущие вредители

1. Introduction

Mechanization, as well as in any technological process, in the technology of plant protection from harmful organisms is an important lever to improve labor productivity and product quality of black currant.

Black currant is one of the leading small fruit crops. The berries of this culture are a valuable raw material for food and processing industry, because, even after thermal treatment, they lose a very small percentage of ascorbic acid.

A problem in black currant cultivation technologies is significant losses of harvest productivity (30–40 %) from the sucking pests. Therefore, effective methods of plant protection of currant agrocenoses from phytophages is today's actual problem.

2. Literature review and problem statement

Efficient use of pesticides when growing crops in Ukraine is an important element of an integrated system of measures of protection, which provides saving potential yield with high quality of products [1].

Essential negative factors that directly affect the harvest of agricultural crops are pests [2]. One of the most effective ways to combat harmful organisms is a chemical method, which consists in spraying the large-scale industrial plantings [3].

The application of insecticides to protect plantings against the dominant groups of sucking pests and obtaining stable harvests depend primarily on the timely qualitative and effective treatment [4]. Chemical means for combating the harmful organisms require highly efficient equipment [5].

During the initial stages of biological development of phytophages, conducting prophylactic measures of protection provides the possibility to reduce their quantity with fewer norms for the consumption of preparations [6].

Sucking pests cause a great damage to agricultural crops, including the plantings of black currant [7].

Studies of scientists reveal that farms of different type of ownership use mainly standard sprinklers of the type OP-2000 (Ukraine) and others in the technologies of plant protection, which are relatively low-effective in protecting the currants from sucking phytophages [8].

Analysis of the scientific literature indicates that in order to prevent mass outbreaks of sucking phytophages it is necessary to monitor the phytosanitary condition of plantings [9].

According to statistical data of authors in [10], sucking insects live on the undersides of leaves during their feeding.

When using the standard sprayers, middle and lower tiers of bush habitus remain in a zone inaccessible for chemicals [11]. To solve this problem, the task was given to upgrade the rod sprayer OP-2000, with further development of specialized rolling stock based on it. In this case, there should be the possibility of lateral spraying of working fluid with the regulation of its dispersion to ensure the optimal zones of spraying. Lateral spraying of low-dispersed fractions provides for the formation of «light fog» that consistently covers the upper, middle and lower zones of bush with a volumetric effect of epidermis of each leaf.

3. The aim and tasks of research

The aim of present work is to reduce the population of sucking phytophages in black currant agrocenosis in the region of Polissya of Ukraine (Forest zone of Ukraine).

To accomplish the set aim, the following tasks had to be solved:

– to define optimal zones for spraying the insecticides on black currant bushes for further modernization of the sprayer OP-2000;

– to improve the units for spraying based on the modernized sprayer OP-2000 for use in the technologies of protection of currant from pests;

– to examine effectiveness of using the designed rolling stock with a modernized sprayer.

4. Materials and methods for examining the efficiency of application of specialized rolling stock in the system of protection of black currant against pests

The field research was conducted over 2010–2016 by the Department of Plant Protection at Zhytomyr National Agroecological University under agroecological conditions of SFG «Nadiya» in Chernyakhivsky region of Zhytomyr oblast (Ukraine).

The effectiveness of pesticides was studied by the method of spraying the plants of black currant against sucking phytophages. The study was conducted on the variety Vernisazh, 6 year in use, with a standard consumption of working fluid of 800 l/ha. Mother solution in this case was prepared directly before its introduction.

A survey of plantings of black currant and the account of its population of sucking phytophages was carried out according to techniques generally accepted in entomology. In order to determine the population of sucking phytophages on plants, we used a die-cut (of area 3.14 cm^2) from the examined leaves. By using a magnifier, we counted the number of individuals per such die-cut.

The degree of population of sucking phytophages on plants was determined using the 9-point scale, given in Table 1.

Table 1

Scale to determine the degree of population of sucking phytophages on plants

Point	Degree of population	Population	
		ind./leaf, sprout	%
1	Very weak	<3	<5
2–3	Weak	3–5	5–25
4–5	Medium	16–40	26–50
6–7	Strong	41–60	51–75
8–9	Very strong	>60	>75

Accounting starts when the first leaves emerge and continues throughout the entire growing season of plants.

Currant bud mite was calculated using the visual method by the number of damaged buds per bush. To determine the percentage of the populated buds, we counted the total number of buds and the number of buds populated with phytophage on five branches of each bush.

The average density of phytophages (ind./cm^2) was determined by formula (1):

$$X = \frac{\sum xi}{S \times n}, \tag{1}$$

where Σxi is the total number of calculated individuals of phytophages from all examined leaves, ind.; S is the area of the examined die-cut, cm^2; n is the number of the examined leaves, pcs.

Area of the die-cut (S), made with a pipe, was calculated by formula (2):

$$\pi R^2 = 3.14 \times R^2, \tag{2}$$

where R is the internal radius of the cutting pipe.

The account of population of ordinary spider mite on the plants of black currant started at stage IV of organogenesis (beginning of re-activation of wintering females) and periodically resumed over the summer period. Evaluation of the population of ordinary spider mite on the plants was performed using the 9-point scale given in Table 1.

Plant population of pests (percentage) was determined by formula (3):

$$P = \frac{100 \times n}{N}, \tag{3}$$

where n is the number of populated plants, pcs.; N is the total number of plants under examination, pcs.

Technical efficiency of preparations was assessed by the accounts of pest population and was computed by the Henderson-Tilton formula (4).

$$E = 1001\times\left(\frac{B\times a}{A\times b}\right), \quad (4)$$

where a is the pest density in a control before treatment; b is the pest density of in a control after treatment; A is the pest density before the treatment; B is the pest density after treatment.

Conducting an energy analysis in agriculture is required in order to develop and evaluate resource- and energy-saving technologies for the cultivation of agricultural crops. This approach provides a possibility to examine the appropriateness of using the fertilizers, biological and chemical crop protection products, growth stimulants and other activities that affect the formation of crop and its quality.

Energy analysis is the estimation of consumption of non-renewable energy for production compared with the volume of the received energy. In the energy evaluation, calculations are performed in common international units – kilocalories (kcal) or joules (J).

Calculation of consumption of non-renewable energy when cultivating different agricultural crops is conducted based on the developed technological cards. The level of energy consumption, associated with the use of fertilizers, fuel, pesticides, electricity, seeds, is calculated by multiplying the amount of this type of resource spent per hectare by its energy equivalent.

The indicator of energy evaluation of technologies in the application of pesticides is the coefficient of energy efficiency (K_{ce}), which is calculated by formula (5):

$$K_{ce} = \frac{E_y}{E_p} = \frac{A_p\times H\times K_d}{E_p}, \quad (5)$$

where E_y is the energy contained in the grown agricultural products, MJ/kg; E_a is the non-renewable energy spent on the formation of a crop, mJ/kg; A_p is the energy equivalent of the obtained products, mJ/kg; H_c is the harvest yield, kg/ha; K_d is the coefficient of content of dry substances; E_p is the total energy consumption for the production of products per 1 ha, mJ.

Energy consumption is determined by formula (6):

$$E_c = E_e + E_p = \frac{E_l + E_m + E_h + E_{iv}}{P_e} + E_p, \quad (6)$$

where E_e is the direct consumption of energy, mJ/kg; E_p is the energy consumption for the production of fertilizers, pesticides, seeds and other substances, mJ/ha; E_l is the energy consumption of actual labor, mJ/h.; E_m, E_h are the energy intensity of machines, hitches and energy means per hour, mJ; E_{iv} is the energy intensity of a vehicle (car+trailer, tractor+trailer), mJ/ha; P_e is the performance efficiency of the unit per 1 hour, ha/h.

Direct energy consumption is determined by formula (7):

$$E = C_f\times H_f + C_e\times C_c + C_h\times C_d, \quad (7)$$

where C_f, C_e, C_h are the consumption of fuel (kg/ha), electricity (kW·h/ha) and heat (kcal/ha); Hf is the fuel heat capacity, mJ/kg; C_c=3.6 is the conversion coefficient from 1 kW·h to 1 mJ C_d=0.00419 is the conversion coefficient from 1 kcal up to 1 mJ.

Electricity consumption H_e per unit area (kW·h/ha) at harvest yield H_c (kg/ha) of this crop is determined by formula (8):

$$H_e = P_e\times H_c, \quad (8)$$

where P_e is the electricity consumption for processing the products, preparation of seeds to sowing, kW·h/kg.

Similarly determined is the consumption of thermal energy (H_T) per unit area, mJ/ha:

$$H_T = P_T\times Y, \quad (9)$$

where P_T is the thermal energy consumption for the processing of products, preparation of seeds, fertilizers and pesticides per unit weight, mJ/kg.

Materialized energy consumption E_p (mJ/ha) on fertilizers, pesticides, water and other substances used in the technology of production and harvesting of agricultural products is determined through the norms and validity of a substance:

$$E_p = \frac{A_p\times H_p}{V_s}, \quad (10)$$

where A_p is the energy equivalent (energy consumption for the production of unit of substance), mJ/kg; H_p is the application rate of a substance per unit area, kg/ha; V_s is the validity of a substance (fertilizers, pesticides – 1 year, organic fertilizers – 3 years).

The energy consumption of actual labor E_l (mJ/h) of staff involved in the technological process is determined based on norms that imply the grading of labor as very heavy, medium, light and very light.

$$E_l = \Pi_b\times A_b\times \Pi_e\times A_e, \quad (11)$$

where Π_b, Π_e are the number of basic (tractor and combine harvester drivers, etc.) and engaged (sowers, carriers, etc.) employees, persons; A_b, A_e are the respective energy equivalents of consumption of actual labor of the basic and involved employees, mJ/h.

Energy intensity of machines E_m hitches E_h tractors (ET) in mJ/h per 1 hour of labor is determined by formula (12):

$$E_m(E_h, E_t) = \frac{A_v\times M_m}{100}\left[\frac{F_r}{T_r} + \frac{F_c + F_m}{T_z}\right], \quad (12)$$

where A_v is the energy equivalent of a vehicle, mJ/kg; M_m is the weight of a vehicle, kg; F_r, F_c, F_m are the deductions for renovation, capital and current repairs of a vehicle (hitch, tractor), %; T_r and T_z are the rated and zonal employment of a vehicle, h/year. It is necessary to note that sophisticated machines and tractors are subject to major repair while hitches, simple machines and tools undergo only the current repair and maintenance.

Energy consumption of a vehicle (car+trailer) E_v (mJ/km) when transporting agricultural products is determined by formula (13):

$$E_v = \frac{A_a\times M_a\times D\times H(F_r + F_c + F_m)}{5\times 10^4\times L_c}, \quad (13)$$

where A_a is the energy coefficient of a vehicle, mJ/kg; M_a is the vehicle weight, kg; B is the distance of transporting a load; H is the harvest yield, kg/ha; F_r, F_c, F_m are the deductions on renovation, repair and depreciation per 1000 km, %; L_c is the load capacity of a vehicle, kg.

For a vehicle, fuel consumption F_c (kg/t) per unit mass of transported products is determined by formula (14):

$$F_c = \left(N_f + \frac{N_f \times K_r}{100} \right) \frac{2D_t \times D_f}{100 \times C_v}, \tag{14}$$

where N_f is the linear norm of fuel consumption per 100 km, l; K_r is the increase in the norm depending on the category of road or other factors, %; D_t is the distance of transporting the products, km; D_f is the fuel density (gasoline – G_n=0.72 kg/l, diesel fuel – D_d=0.82 kg/l); C_v is the load capacity of a vehicle, t.

Economic efficiency is directly dependent on the volume of the preserved crop (growth) and the cost of protective measures.

The main indicators that characterize economic efficiency of the application of pesticides are net profit, cost per unit of production and level of profitability.

Economic efficiency is determined by comparing the cost of the product obtained additionally, received by the application of a protective measure, to the costs associated with obtaining their growth.

Net profit N_p (UAH/ha) is the difference between the cost of the preserved products and the additional costs for obtaining them:

$$N_p = C_h \times P_p - (C_p + C_g + C_t), \tag{15}$$

where H is the volume of the preserved harvest, kg/ha; P_p is the price of product, UAH/kg; C_p is the cost of acquisition and use of a pesticide, UAH/ha; C_g is the cost of gathering the preserved harvest, UAH/ha; C_t is the cost of transporting the preserved harvest, UAH/ha.

Profitability level is the ratio of net income to expenses:

$$P = \frac{A_p \times 100}{T_p}, \tag{16}$$

where P is the profitability level, %; A_p is the additional net profit, UAH/ha; T_p are the total costs for preserving the harvest, UAH/ha.

Economic efficiency was calculated by the method of comparison of the cost of the products obtained additionally and total expenses for conducting protective measures and gathering berries.

5. Development of specialized rolling stock in the system of protection of black currant from sucking phytophages

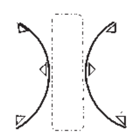
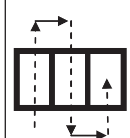
Agricultural machinery for the treatment of plantings of berry crops refers to mechanical recovery systems. Recovering the normal functioning of units for spraying depends not only on the level of maintainability of equipment, but also on the possibility of its technical re-equipment, the use of advanced methods of new technologies.

In order to develop effective system for the protection of plantings of black currant, we modernized the rod sprayer OP-2000 (Table 2) and designed a specialized rolling stock (SRS) by using it. Specialized rolling stock (Fig. 1) includes the power traction tractor MTZ-82 (Belarus), a connecting device that provides the maneuverability and flexibility of the system, and the modernized sprayer OP-2000.

Such model of SRS provides obtaining of optimal zones of spraying the bushes of currant, taking into account the lower, middle and upper tiers, reliably protecting the plants. The modernized design of the sprayer makes it possible to achieve uniform coverage with the preparation of all tiers of a black currant bush and effectively spray the working fluid with a fog-like effect.

Table 2

Operating modes of the modernized sprayer OP-2000 in black currant plantings

Bush height, m	Spraying norm, l/ha	Inter-row spacing width, m	Motion speed, km/h	Pressure in communication, kgf/cm²	Diameter of opening of slit sprayer, mm	Layout of arrangement of side sprayers on the sprayer	Schematic of unit motion
1.0–1.2	800	3.0	1.2–1.4	0.3-0.4	3.0		

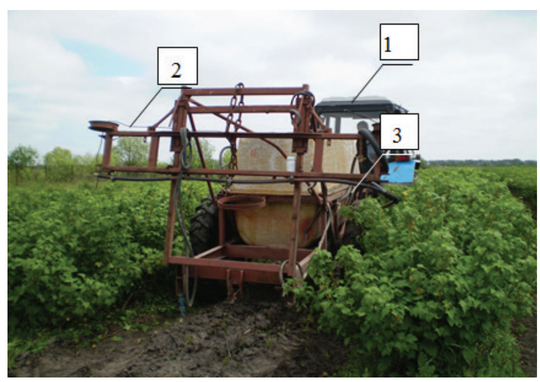


Fig. 1. General view of specialized rolling stock for spraying the black currant with pesticides:
1 – power traction unit; 2 – modernized sprayer;
3 – connecting device

The design features of the modernized sprayer include:

1. Symmetric installation from two sides of the sprayer OP-2000 of special arc brackets for mounting the pipelines with the original design of injectors (Fig. 2).

2. Calculated geometry of the arc-shaped brackets and the angles of inclination of injectors (Fig. 3) from the condition of receiving optimal zones of pulverization of the working fluid when spraying the plantings of currant.

The arc-shaped brackets are installed on both sides of the sprayer that provides for the possibility of simultaneous one-sided treatment of two adjacent rows of plantings or, in other words, one inter-row spacing.

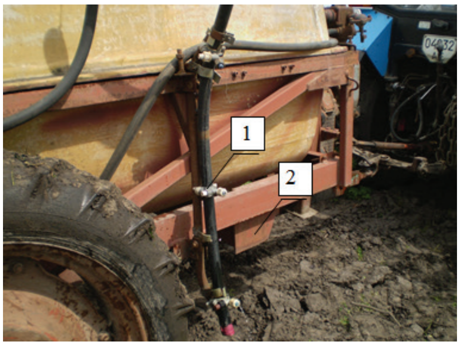


Fig. 2. General view of the modernized sprayer: 1 – arc brackets with specialized nozzles; 2 – chassis of semitrailer of the sprayer OP-2000

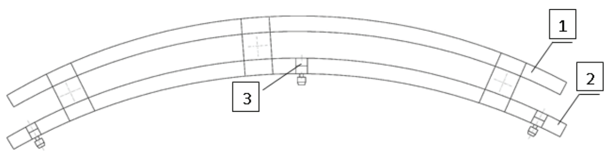


Fig. 3. Arc-shaped bracket: 1 – bracket; 2 – pipeline; 3 – specialized nozzle

In order to calculate geometric dimensions of the unit, we determined the following starting parameters: width of inter-row spacing – 3000 mm, width of a specialized unit – 1500 mm, currant bush height – 1200 mm and its extent (habitus) is 1200 mm.

The length of arc of the brackets (1250 mm) was determined constructively, based on the mean size of a black currant bush.

When a specialized unit moves in the process of spraying the black currant planting, the following is provided:

– by the upper nozzle of the modernized sprayer – optimal spraying of the upper zone of bushes on one side of the row;

– by the middle nozzle – the middle part of bush habitus;

– by the lower nozzle – the bottom area of leaf crown, with the largest population of pests, according to the schematic (Fig. 4).

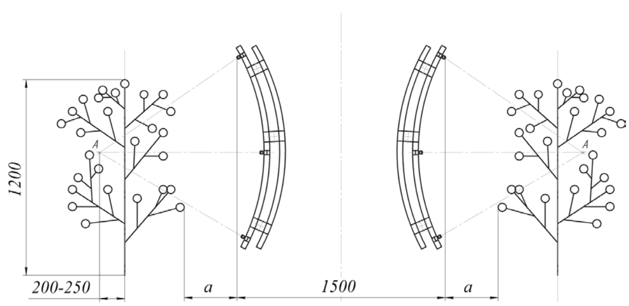


Fig. 4. Schematic of treating a black currant inter-row spacing

Point A (Fig. 4) of convergence of disperse dust flow of pesticides should be approximately at a distance of 200–250 mm from the middle of the bush to achieve the effect of overlapping the zones of spraying. Given these considerations, we determined geometrical parameters of arranging the nozzles by calculation scheme (Fig. 5).

In Fig. 5, the distance of the outer nozzles to the edge of the bush (a) is determined by the difference in width of inter-row spacing along the axis of bushes and the width of the unit. This difference is divided into two, and a number of 600 mm (half the width of the bush) is subtracted from the resulting value. In the given case, the estimated value a=150 mm.

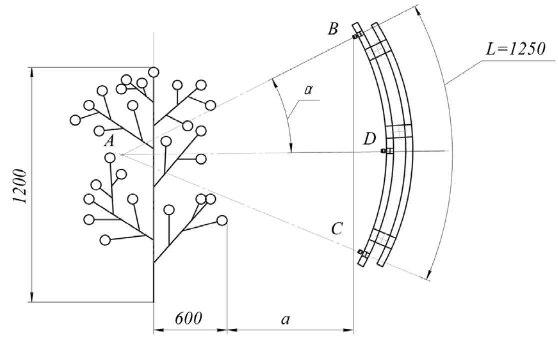


Fig. 5. Calculation scheme of geometric parameters of arrangement of the nozzles on the arm relative to a currant bush

In triangle ABC, AD is the height calculated as the sum of the numbers of the overlap (200 mm), half the width of the bush (600 mm) and a distance from the nozzles to the edge of the bush (a=150 mm). Estimated value AD=950 mm. Considering one of the triangles (ABD or ADC), we shall determine the angle α of inclination of the nozzle axis relative to a horizontal line that is perpendicular to the axis of symmetry of the specialized unit.

$$\alpha = \mathrm{arctg}\frac{BD}{AD}. \tag{17}$$

Assuming that BD is approximately equal to half the arc L, we shall receive angle α=33.3°.

The radius of arc R of the brackets for mounting the pipes and nozzles of a sprayer is determined by the size of sides AB=8AC=R=1137 mm from triangle ABC.

By using the side sprayers with regulating nozzles (layout is given in Table 2), the sprayer creates a finely-dispersed fog-like medium that enables the treatment of one inter-row spacing of plantings in one pass of the unit.

An important point in the technology of treatment is to ensure, when using the designed SRS, alignment between the intensity of spraying and the motion speed of the unit. We practically established that the optimal treatment of black currant plantings with insecticides is provided in the speed interval of 1.2–1.4 km/h (4–4.6 m/s) when using as a part of the specialized unit the tractor MTZ-82 in accordance with the rated working fluid consumption by the modernized sprayer of 800 l/ha.

6. Discussion of results of reducing the population of sucking phytophages in the plantings of black currant under agroecological conditions of the Ukrainian Polissya

Analytical and statistical research methods were employed. Studies were conducted at stages VI, VIII, X of black currant organogenesis under agroecological conditions of SFG «Nadiya» in Zhytomyr oblast (Ukraine). Comparison of the effectiveness of spraying was performed for the rod and modernized sprayer with results given in Table 3.

Table 3

Technical efficiency of using the modernized sprayer OP-2000 on black currant (SFG «Nadiya», Chernyakhivsky region, Zhytomyr oblast, Ukraine, 2010–2016)

No. of entry	Variants	Tier	Pest density by tier, colonies										ΣCp
			BCA		RGA		GA		CBM		OCM		
			colon./bush	Cp	colon./bush	Cp	colon./bush	Cp	bud/bush	Cp	ind./bush	Cp	
1	Control – without spraying	1	27.3	1.0	29.1	1.0	32	1.0	44	1.0	55	1.0	5.0
		2	17.5	0.64	18.0	0.62	16.9	0.53	28	0.64	36	0.65	3.08
		3	9.7	0.35	12.1	0.42	10.2	0.32	13	0.30	23	0.42	1.81
2	OP-2000 (rod)	1	18.3	0.67	21.1	0.72	21	0.66	32	0.73	38	0.69	3.47
		2	10.5	0.38	13.5	0.46	13.4	0.42	16	0.36	22	0.40	2.02
		3	7.6	0.28	8.8	0.30	8.5	0.26	8	0.18	12	0.22	1.24
3	OP-2000 (modernized)	1	5.3	0.19	6.3	0.22	6.9	0.22	10	0.23	11	0.20	1.06
		2	2.2	0.08	3.3	0.11	2.0	0.06	5	0.11	4	0.07	0.43
		3	1.1	0.04	2.1	0.07	0.5	0.02	2	0.04	2	0.04	0.21

Notes: 1 – upper tier; 2 – middle tier; 3 – lower tier; BCA – big currant aphid; RGA – red currant gall aphid; GA – gooseberry aphid; CBM – currant bud mite; OCM – ordinary spider mite; Cp – coefficient of population; ΣCp – total coefficient of population

It follows from data in Table 3 that depending on the variants of examining protection of black currant plantings from sucking phytophages, the value of total coefficient of population ΣCp varies. By comparing this parameter by its average values for the variants of protection indicated in Table 3, we may draw the following conclusions:

1. Reduction in pest density by the total coefficient of population ΣCp is 1.5 times when using the rod sprayer OP-2000.

2. Using the modernized sprayer reduces the number of pests by 5.8 times by ΣCp which is 3.9 times better than when using a not modernized one.

Reduction in the number of sucking phytophages and the stimulation of plant growth and development positively influences the structure of the harvest yield of black currant berries, as evidenced by data in Table 4.

Data in Table 4 show that for different experiment variant, the weight of berries from a black currant cluster varies in the following way:

1. The minimum magnitudes of berry weight in the range of 1.3–2.1 g are yielded by the variant without spraying.

2. Dimensions of berries in the intervals of 1.7–2.4 g and 1.9–3.0 g are provided when using the rod and the modernized sprayers, respectively.

3. When using the modernized sprayer OP-2000, the weight of berries per bush increases from 1.418 to 1.598 kg.

Improvement of elements in the structure of harvest yield of black currant berries provides a significant increase in the weight of berries, as evidenced by data in Table 5.

It follows from data in Table 5 that the use of the modernized sprayer, instead of the rod sprayer, provides a possibility to improve the harvest yield of berries from 1.6 up to 2.4 t/ha.

Analytical calculations of forecasting the data on crop confirm reliability of the research results as the smallest significant difference (HIP_{05}) is significantly lower than the increase in harvest.

Calculations of energy and economic efficiency are given in Table 6.

Table 4

Structure of the harvest yield of berries when using different sprayers on black currant (SFG «Nadiya», Chernyakhivsky region, Zhytomyr oblast, Ukraine, 2010–2016)

Research variant	Weight of berries per cluster, g			Weight of 100 g of berries, g	Weight of berries per bush, kg
	small	medium	large		
Control – without spraying	1.3	1.8	2.1	172	1.058
OP-2000 (rod)	1.7	2.1	2.4	228	1.418
OP-2000 (modernized)	1.9	2.7	3.0	253	1.598

Table 5

Economic efficiency when using different sprayers on black currant (SFG «Nadiya», Chernyakhivsky region, Zhytomyr oblast, Ukraine, 2010–2016)

No. of entry	Research variant	Harvest yield by years, t/ha								
		2010	2011	2012	2013	2014	2015	2016	mean	± to control
1	Control – without spraying	4.6	4.9	4.5	5.0	5.1	4.6	4.2	4.7	–
2	OP-2000 (rod)	6.8	6.2	5.9	6.0	6.8	6.1	6.3	6.3	1.6
3	OP-2000 (modernized)	7.2	6.9	7.0	6.8	7.2	7.1	7.5	7.1	2.4
4	HIP_{05}	0.11	0.15	0.09	0.13	0.14	1.10	0.12	–	–

Note: HIP_{05} is the smallest significant difference that is calculated with an accuracy of 0.5 t/ha

Table 6

Effectiveness of using the modernized sprayer while protecting black currant (SFG «Nadiya», Chernyakhivsky region, Zhytomyr oblast, Ukraine, 2010–2016)

No. of entry	Research variant	Harvest yield, t/ha	Energy efficiency mJ /ha				Economic efficiency			
			energy, accumulated in the harvest uncrease	energy consumptiong for receiving the harvest	obtained pure energy	Cee	price of harvest, UAH/ha	cost of harvest, UAH/ha	net income, UAH/ha	harvest profitability, %
1	Control – without spraying	4.7	12901	11280	1621	1.14	56400	13307	43093	324
2	OP-2000 (rod)	6.3	17293	14534	2759	1.19	75600	16109	59491	369
3	OP-2000 (modernized)	7.1	19489	15336	4153	1.27	85200	17534	67666	386

The data given in Table 6 indicate that when applying the modernized sprayer instead of the rod sprayer OP-2000, coefficient of energy efficiency increases from 1.19 to 1.27 units. When spraying black currant with the modernized sprayer, the net profit increased from UAH/ha 1646 to 2584 with a change in payback of costs from 3.2 to 3.9 times.

The benefits of using specialized rolling stock with the modernized sprayer follow the conclusions about economic efficiency. Studies resolve to a certain extent the actual problem of reducing the losses in harvest from sucking pests and might be used under conditions of the Ukrainian Polissya. Present research can be continued with further improvement in design of the systems of protection from pests.

6. Conclusions

1. In order to ensure optimal working fluid spraying zones, we calculated geometric parameters (length of bracket arcs L=1250 and angles of inclination α of nozzles) of special brackets for the modernization of rod sprayer OP-2000).

2. Based on the modernized sprayer, we made an arrangment of specialized rolling stock for effective spraying of black currant in the system of protection against sucking pests.

3. A study into effectiveness of applying the designed specialized rolling stock revealed the following main results:

a) reduction in the population of sucking pests by 3.9 times in comparison with the variant of applying the non-modernized sprayer due to enlarging the zones of deciduous cover of bush that the insecticides can reach;

b) increase in the harvest yield of black currant berries from 1.6 up to 2.4 t/ha by reducing the losses from sucking pests, which increases the net profit from UAH/t 1646 to 2584.

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