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ANALYSIS OF THE EFFECT OF ULTRAVIOLET IRRADIATION ON VARROA MITE

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Представлені результати аналітичних досліджень впливу електромагнітних опромінювань оптичного спектру на біооб'єкти в УФ діапазоні (UVB, UVC). Отримані математичні вирази моделювання конструктивних характеристик захисних пристроїв від варроатозу. Запропоновано пристрій (льоткова приставка), який забезпечений світлодіодними модулями УФ випромінювання, що живляться від сонячних фотоелементів

Ключові слова: ультрафіолетове випромінювання, довжина хвилі, доза опромінення, кліщ Варроа, боротьба з варроатозом

Представлены результаты аналитических исследований воздействия электромагнитных излучений оптического спектра на биообъекты в УФ диапазоне (UVB, UVC). Получены математические зависимости моделирования конструктивных характеристик защитных устройств от варроатоза. Предложено устройство (летковая приставка), обеспеченное светодиодными модулями УФ излучения, питающимися от солнечных фотоэлементов

Ключевые слова: ультрафиолетовое излучение, длина волны, доза облучения, клещ Варроа, борьба с варроатозом

1. Introduction

An efficiency increase in the field of beekeeping is impossible without development and implementation of progressive resource-saving technologies and means of their implementation aimed at ensuring proper veterinary and sanitary conditions for maintenance, breeding and use of bee colonies. This fully applies to the development of means for prevention and treatment of bee diseases in active and passive periods of their life. Creation of the new beekeeping implements, which are capable of meeting the requirements of biosafety technologies, is an urgent problem for the design of technical means to control bee varroatosis with a use of UV irradiation. A promising development in mentioned area is creation of unified protective devices located outside nursing sockets. The devices are hive entrance attachment equipped with a module of UV radiation capable of performing several preventive and therapeutic functions simultaneously. In particular, it is formation of conditions for reduction of non-technological losses of the biopotential of a bee colony, preservation of its feeding stocks and possession of highly specialized characteristics, which ensure the reliable operation of a hive entrance attachment in the struggle with bee varroatosis [1, 2].

2. Literature review and problem statement

Varroatosis is an invasive disease of bee colonies, which causes significant material damage in the field of beekeeping and plant growing. It affects a level of food security of a country negatively. There are several types of known technologies to struggle with the disease: chemical, zootechnical, physical and combined. The aim of them all is inhibition or destruction of a causative agent of bee varroatosis – a Varroa-destructor mite. Chemical technologies imply processing of bees directly in a hive using artificially synthesized substances based on heavy (amitraz, fluvaline) or lighter (thymol) acaricides. A significant disadvantage of the use of acaricides is contamination of honey, perg, propolis and sotoramo by remnants of synthetic substances. They also do not promote preservation of the bio-potential of bee colonies and protection of their feeding stocks. In addition, mentioned technologies and means of their implementation complicate or make impossible to obtain environmentally friendly bee products [3, 4].

There are technologies based on the application of physical non-medicamentous methods to struggle with varroatosis. One of them involves processing bees in a heat chamber located outside a hive. In this case, there is a temperature of 46–48 °C in the operation volume of a heat chamber. Electric heaters and fans maintain the temperature throughout a period of bees staying in it. The technologies have greater effectiveness for controlling varroatosis due to the effect of high temperature on mites – most of them fall from bees and die. At the same time there is a risk associated with the emergence of a negative effect on future life of bees and bee queens due to overheating. This is the disadvantage of the heat treatment technology of bee colonies. In addition, to maintain a predetermined temperature in a heat chamber, there is a need in precise measurement equipment as a temperature comes near to critical acceptable temperature for bees. Increased energy consumption and labor intensity characterizes a process of heat processing of bee colonies. In addition, the technologies, despite the fact that a heat treatment process takes place outside a hive, cannot ensure preservation of feeding stocks and protection against non-technological losses of bees during their life.

There are also works devoted to the study of an influence of optical irradiation of living organisms, including mites, which is a kind of non-medicamentous physical technology. They prove that irradiation with short-wavelength visible light kills eggs, larvae, pupae and adult Drosophila. Studies conducted in this direction showed that high-toxic wavelengths of visible light have different degrees of toxicity for certain types of insects [5].

There is a separate group of studies devoted to benefits of ultraviolet short-wave irradiation, which affects biopolymers destructively, including proteins and nucleic acids at the cellular level [6, 7]. Studies confirm the fact of death of spider mites from irradiation by electromagnetic radiation of UVB ultraviolet spectrum (280–315 nm) [8]. Thus, in paper [9], there is information on the practical application of intermittent ultraviolet irradiation of UVB spectrum of lower leaves of strawberry bushes at low temperatures at night for the treatment of Tetranychus urticae Koch mite in greenhouses. The data of scientific and technical literature indicate that peristalsis of intestines of mite females becomes sharply more activated under the influence of ultraviolet rays. One can observe mengeous movements and phosphorescence of chitinous cover. 100 % of Varroa mites died at irradiation under Q-400 lamp at a distance from an operation surface of 34.0–16.0 cm and exposure to 10 minutes in 17 hours [10].

The results presented in work [11] showed feasibility of the use of a hive entrance attachment equipped with a LED module of UV radiation for a struggle with Varroa mites. In particular, undiscovered data of scientific studies on the lethal effect of electromagnetic radiation with ultraviolet spectrum UVA and UVB (315–400 nm) on insects [12].

At the same time, the analysis of literary sources revealed a lack of a generalized methodology of physical methods and means of struggle with varroatosis, as well as a lack of an integrated approach to the creation of biosecurity electro technological installations based on high-performance sources of optical radiation (UV) range.

We should also note that there is no information on the design of protective devices, their geometric parameters and exposure to effectively struggle with the varroatosis of bees effectively in studies on the use of a spectrum of electromagnetic radiation in the area of a short-wave range for the control of pathogenic fauna.

3. The aim and objectives of the study

The aim of present study is to establish regularities in the formation of the effect of UV irradiation, which provides anti-varroatosis action of a hive entrance attachment.

We solved the following tasks to achieve the objective:

– determination of the effect of UV radiation on life processes of a Varroa mite and a bee;

– substantiation of geometrical parameters of a hive entrance attachment equipped with a module of UV irradiation of bees and mites;

– determination of the efficiency of the use of a hive entrance attachment equipped with a module of UV irradiation for the struggle with the varroatosis of bees.

4. Materials and methods of research

UV radiation causes specific reactions of a body of a bee and a Varroa mite. Nerve endings and humoral mechanisms transform the reactions by transferring generated active substances to hemolymph from a place of its formation into other insect organs. Such a property of UV radiation has large practical importance, as it shows the effectiveness of application and feasibility of not only general but also local radiation.

We propose a modular installation of UV irradiation to implement the assumption of effective control of bee varroatosis and preservation of bee potential. Electromagnetic radiation of UV spectrum of light emitting diodes affects a Varroa mite in this installation. LEDs are powered by photocells. The module for UV irradiation of bees and Varroa mites includes a hive entrance attachment, LEDs, a power supply for LEDs, a protective grid, a switching and control system. Fig. 1 shows the general view of the hive entrance attachment (HEA-1) equipped with UV irradiation module.

We consider the Varroa mite as a specific radiative receiver in the study. It has a relative spectral sensitivity. A ratio of the minimum amount of irradiation at λ=297 nm to the intensity of irradiation with a given wavelength $\kappa(\lambda)$, which provides the same erythematous action, determines the sensitivity. Given this, the erythematous flow is defined as radiation. Such radiation is assessed by the ability of harmful effects on a Varroa mite (1).

$$P = \int_{\lambda_{\min}}^{\lambda_{\max}} \phi(\lambda)\kappa(\lambda)\,\mathrm{d}\lambda, \tag{1}$$

where $\kappa(\lambda)$ is the relative erythematous efficiency of radiation; $\phi(\lambda)$ is the magnitude of spectral intensity of the radiation flow,

$$\phi(\lambda)=\frac{dP}{d\lambda},\ \mathrm{W{\cdot}nm^{-1}}.$$

Fig. 1. HEA-1 hive entrance attachment

We developed a mathematical model to determine a power and a quantity of LEDs and to simulate parameters of the hive entrance attachment. Realization of the described model is the solution to a set of inequalities according to vector criterion (2)

$$D^b_{\min}\le D^b_j(\lambda,l,t,h)\le D^b_{\max},$$
$$D^b_i(\lambda,l,t,h)\ge D^b_{\max}, \tag{2}$$

if it is necessary to find the best value for a vector of variables that are calculated under constraints (3)

$$\lambda_{\min}\le\lambda\le\lambda_{\max},$$
$$l_{\min}\le l\le l_{\max},$$
$$t_1\le t\le t_2,$$
$$h_1\le h\le h_2, \tag{3}$$

here $D^b_{\min}$, $D^b_{\max}$ are the limit values of the interval of the dose of the erythematous flow, beyond which a bee and a Varroa mite do not survive (0.125; 0.667); λ is a wavelength, nm; l is the length of the hive entrance attachment, cm; h is the height of the hive entrance attachment, cm; t is the time of stay of bee and a Varroa mite in erythematous dose, s.

A vector of criteria $D^b_j(\lambda,l,t,h)$ and $D^b_i(\lambda,l,t,h)$ covers a space of the erythematous dose for a bee (j) and a mite (i) at UV irradiation with a wavelength λ at 265÷315 nm range. The mathematical representation of a space of the dose of the erythematous flow affecting a bee and a Varroa mite, meas·s·cm^{-2} (4).

$$D^b_{ji}(\lambda,l,t,h)=\int_{t_1}^{t_2}S_{ji}F_y(\lambda,l,h)t^{-1}\mathrm{d}t. \tag{4}$$

The total power of the UV installation, which operates on the area of the hive entrance attachment, with a height h=1 cm and a wavelength λ=297 nm, meas. (5)

$$F_{inst.}(l)=k_\Sigma\int_{l_{\min}}^{l_{\max}}l\cdot b\frac{A\cdot h^2\cdot k_{ef}\cdot\Phi}{2\cdot\tau\cdot h_n^2}\mathrm{d}l, \tag{5}$$

where k_{ef} is a coefficient of biological efficiency, which depends on a wavelength; k_Σ is a coefficient, which takes into account reflection, absorption, external conditions, a level of natural light; b is the width of the hive entrance attachment, cm; A is the dose of irradiation, a. u.; h is the height of the hive entrance attachment, cm; Φ is the threshold value of a light flow for one bio dose, meas·s·cm^{-2}; h_n is the normalized height of the installation of UV source for one bio dose, cm; τ is the operating time of the installation, s; S_{ji} is the estimated area of a surface of a bee and a Varro mite, cm^2.

We can estimate the adequacy of the mathematical model taking into account the following:

a) a bee and a mite located on it passes into a hive through the entrance attachment as a bio-object;

b) a length and a height of the hive entrance attachment affect a level of irradiation of a bio-object;

c) a time of irradiation of a bio object depends on a rate of passing a tunnel of the hive entrance attachment by a bee;

d) a dose of irradiation of a bee and a Varroa mite depends on an amount and power of UV radiation of the light emitting diodes;

e) we can consider irradiation as effective if a bio dosage, which affects a bee, does not exceed a threshold dose;

g) we can consider irradiation as effective if a bio dosage, which affects a Varroa mite, exceeds the threshold dose.

We consider a bee and a Varroa mite in a shape of a cylinder with average values of sizes. Such assumptions make possible to simplify a practical application of the model.

We use the following input values to calculate parameters that create a process of interaction of a Varroa mite and electromagnetic UV radiation using the given mathematical model:

– a wavelength range of UV radiation 265÷315 nm with a change step $\Delta\lambda=5$ nm;

– a range of a change of a length of the hive entrance attachment 20÷2 cm with a change step $\Delta l=2$ cm;

– a range of a period of stay of bees and mites in an erythematous dose 2,5÷25 s with a step $\Delta t=2{,}5$ s;

– a range of a change in a height of the hive entrance attachment 1÷3 cm with a step $\Delta h=1$ cm;

– a range of an irradiation dose 0,2÷0,6 with a step ΔA=0,1, a.u.;

– an estimated average surface area of a bee S_j=1,1 cm^2, and a mite S_i=0,02 cm^2.

We obtained data according to formula (5). We constructed dependences of irradiation of installation $F_{\mathrm{inst.}}$ to a length of the hive entrance attachment at a wavelength λ=297 based on the obtained data. Fig. 2 shows the dependences.

Analysis of the dependences (Fig. 2) shows that the value of the irradiation of the installation should be increased at the increase in the length of the hive entrance attachment. At a length of the console tunnel l=8 cm and its height h=1 cm, the power consumed by the sources of the UV installation – (2.7·10^{-6}–9.1·10^{-7}) W at a change in the dose of radiation from 0.6 to 0.2.

Irradiation of the module depending on wavelength (6):

$$F_{inst}(\lambda)=$$
$$=0{,}5\cdot\int_{\lambda\min}^{\lambda\max}k_\Sigma\cdot l\cdot b\cdot A\cdot h^2\cdot h_n^{-2}\cdot k_{ef}(\lambda)\cdot\Phi\cdot\tau^{-1}\cdot\mathrm{d}\lambda, \tag{6}$$

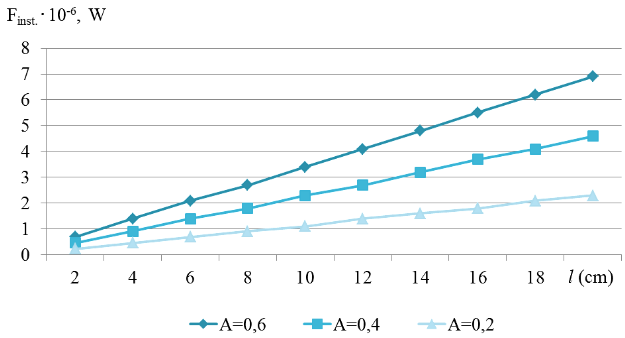

Fig. 2. Dependences of irradiation of the installation $F_{inst.}$ on the length of the hive entrance attachment with a dose of irradiation A=0.2; A=0.4; A=0.6 from a threshold value at a wavelength λ=297 nm and a height of the hive entrance attachment h_1=1 cm

We used the results of the determination of the irradiation of the installation depending on a wavelength with the dose A=0,6 from a threshold value of a bio dose and parameters of the hive entrance attachment: a length of a tunnel of the hive entrance attachment l=8 cm, its height h=1 cm and a width b=20 cm, to construct dependence in Fig. 3.

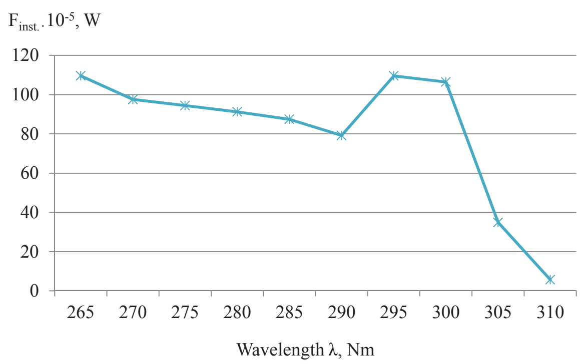

Fig. 3. Dependence of irradiation of the installation $F_{inst.}$ on wavelength λ at a dose change A=0.6 on a threshold value of bio doses

We analyzed graphical dependence in Fig. 3 and can state that the total erythematous flow of the installation reaches a maximum at a wavelength of 265 nm and 295 nm and is 109.59·10^{-5} units. We need four light emitting diodes with a power of 0.08 W (LED with a power of 0.08 W and a diameter of 5.9 mm=29.3·10^{-5} units) to provide such irradiation. A minimum value of the total erythematous flow of the installation at the same dose and wavelength of 305 nm and 310 nm is 34.85·10^{-5} units and 5.7·10^{-5} units.

A bio dose received by a mite and a bee during passing through the hive entrance attachment equipped with a UV radiation module, a.u. (7):

$$D_{bij} = k_{sj} \cdot F_{inst.}(\lambda) \cdot t \cdot k_s^{-1} \cdot S_{ij}^{-1} \cdot \Phi_t^{-1}, \qquad (7)$$

where k_{aj} is a coefficient of account of bee hair-covering; k_s is a coefficient of a stock; t is the period of staying of a bee and a mite in the erythema's dose, s; S_{ij} is the estimated area of a surface of a Varroa mite and a bee, cm^2; Φ_t is the threshold dose of a light flow of UV irradiation at an altitude of 1 cm, unit·s·cm^{-2}.

As a result of calculations according to paper (7), we obtained values of bio doses acting on a bee at a given wavelength of irradiation with A dose, which varies in the range from 0.2 to 0.6 threshold value. Table 1 shows calculation data for the hive entrance attachment with a length of the tunnel l=8 cm and a height h=1 cm and t_1=5 s. The obtained values of bio doses do not act on bees destructively.

Table 1

Bio doses, which act on a bee at doses A=0.6, A=0.5; A=0.4; A=0.3; A=0.2 of a threshold value and irradiation wavelength

h=1 cm, l=8 cm, t_1=5 s									
A=0.2		A=0.3		A=0.4		A=0.5		A=0.6	
λ, nm	D_b, a.u.	λ, nm	D_b, a.u.	λ, nm	D_b, a.u.	λ, nm	D_b, a.u.	λ, nm	D_b, a.u.
270	0.0269	270	0.04	270	0.054	270	0.067	270	0.081
275	0.026	275	0.039	275	0.052	275	0.065	275	0.078
280	0.0251	280	0.0377	280	0.05	280	0.063	280	0.075
285	0.0241	285	0.0362	285	0.048	285	0.06	285	0.072
290	0.0218	290	0.0328	290	0.044	290	0.055	290	0.066
297	0.03	297	0.045	297	0.06	297	0.075	297	0.09
300	0.029	300	0.044	300	0.058	300	0.073	300	0.088
305	0.0096	305	0.0145	305	0.019	305	0.024	305	0.029
310	0.0016	310	0.0024	310	0.003	310	0.004	310	0.005
315	0.0003	315	0.0006	315	0.001	315	0.001	315	0.001

According to formula (6), we obtained a total power of UV irradiation, which affects the area of the hive entrance attachment, at a wavelength of irradiation from 265 nm to 315 nm with a dose A=0.2 from a threshold value of a bio dose. We calculated a bio dose of a bee and a mite for a time they pass through the hive entrance attachment by the formula (7). We took into account parameters of the hive entrance attachment h=1 cm, l=8 cm, b=20 cm. Table 2 gives results of calculations.

Table 2

Value of a total power of the UV installation with a dose A=0.2 from a threshold value and a number of LEDs

A=0.2 a.u., h=1 cm, l=8 cm, t_1=5 s				
λ	$F_{inst.}$	n	D_{bj}	D_{bj}
nm	measure	units	a.u.	a.u.
265	$36.53 \cdot 10^{-5}$	2	0.03	1.96
270	$32.52 \cdot 10^{-5}$	1	0.0269	1.741
275	$31.47 \cdot 10^{-5}$	1	0.026	1.684
280	$30.41 \cdot 10^{-5}$	1	0.0251	1.628
285	$29.15 \cdot 10^{-5}$	1	0.0241	1.56
290	$26.4 \cdot 10^{-5}$	1	0.0218	1.413
297	$36.53 \cdot 10^{-5}$	2	0.03	1.98
300	$35.48 \cdot 10^{-5}$	2	0.029	1.9
305	$11.61 \cdot 10^{-5}$	1	0.0096	0.6217
310	$1.9 \cdot 10^{-5}$	1	0.0016	0.1017
315	$0.42 \cdot 10^{-5}$	1	0.0003	0.0226

The obtained values (Table 2) make it possible to conclude that a bio dose, which a mite and bee receives, depends on irradiation of the istallation $F_{inst.}$ A mite gets a maximum value of a bio dose at a wavelength of 265 nm and 297 nm. A magnitude of such a bio dose is fatal to a mite. Mites and bees are exposed at the same time, but the levels of bio doses are different.

5. Results of study into existence of mites on bees using a hive entrance attachment

We carried out experiment from April 15, 2014 to September 30, 2016 in the beekeeping sector of "Charunka" Scientific and Technical Center, Pervukhinka settlement, Bogodukhivsky region of Kharkiv oblast (Ukraine) to study effectiveness of the proposed hive entrance attachment as a measure against mites. We conducted the experiment under field conditions, objects of the experiment were Carpathian bee kinds affected by Varroa destructive mites.

We found that the experimental bee colonies number 2 and number 3 had the same – high – level of mite presence. The degree of mite presence of the bee colony number 2 was 5–7 %, the degree of mite presence of the bee colony number 3 was 6 %. The mentioned bee colonies could be used as control and test bee colonies, respectively, for the further stages of field experiment on using the proposed HEA-1 hive entrance attachment to struggle with varroatosis directly on an apiary when LEDs were powered by a solar cell. In the experiment, we used UV radiation sources with the following technical characteristics: a wavelength interval of 305÷265 nm, an interval of erythematous flow $35\cdot10^{-5}\div110\cdot10^{-5}$ units, voltage of power supply was 4 V, supply current was 20÷30 mA. Table 3 gives the type and specifications of power supply.

Table 3

Type and specifications of LEDs

Number	Parameters	Wave-length, nm	Voltage, V	Current, A	Capacity, mW
2	SMD 5050	265	7–8.5	20	0.2–0.5
3	Deep UV	280	4.8–7	20	0.5–1
4	CUD1 AF1C	310	6	20	1.3
5	CUD 8AF1C	275	6	20	1.9
6	TW-UVP8D	285	6	25	–
7	High Power-TO39	290	5.8–7	30	–
8	High Power UVB LED	305	4.5–6.5	20	–
9	TO39 UV LED	300	5.5–7.5	20	–
10	Ball Len TO39	295	5.5–7.5	20	–

The next stage of the experiment was control weighing of hives of 20 breeding frames with control and experimental bee colonies. The total weight of the control hive with a bee colony was 43 kg on April 15, 2014, the test one – 45 kg. We left both the test and the control hives on scales until the end of the experiment (September 30, 2016).

Next, we equipped an entrance of the test hive with the attachment with a module of sources of UV irradiation with a photocell attached (the total weight of the connected structure was 950 grams). Fig. 4 shows the setup.

We determined effectiveness of the use of a hive entrance attachment by formula (8):

$$E_{he} = (P_{BB} - (P_{BA} - K_e))100 / P_{BB}, \quad (8)$$

where P_{BB} is a degree of presence of mites in a bee colony before the use of a hive entrance attachment, %; P_{BA} is a degree of presence of mites in a bee colony after the use of a hive entrance attachment, %; K_E are the mites exterminated by auxiliary means against varroatosis, %.

Table 4 gives results of the determination of effectiveness of the hive entrance attachment with an irradiated module of the UV spectrum, as a tool to fight against varroatosis.

Fig. 4. Design of the hive entrance attachment with a solar collector

Table 4

Results of effectiveness of the use of a hive entrance attachment with an irradiated module of UV spectrum for fighting against varroatosis

Year of the study	Presence of mites in a control bee colony, %	Presence of mites in a test bee colony, %	Auxiliary means against varroatosis, %	Effectiveness, %
2014	7	1.43	0.3	83.86
2015	5	1.84	0.2	67.2
2016	6	1.92	0.5	76.33

In addition, the use of the proposed hive entrance attachment with an irradiated module of the UV spectrum gives possibility to reduce labor costs for a process of healing of bees from varroatosis.

The use of such resource-saving technology as irradiation of bees by ultraviolet radiation also demonstrated the following effects under conditions of integrated protection of a bee colony:

– prevention of penetration of bee-villains, wasps, hornets to a hive;

– prevention of infection of bees by elimination of possibility of penetration of sick bee-villains into a hive;

– prevention of a decrease in a number of bees as a result of an attack of tomtits, jays, woodpeckers and other enemies of bee colonies due to a limited space formed around a hive entrance by the installed entrance attachment.

6. Discussion of results of the productivity improvement of bee colonies

A number of external and internal factors affects productivity of a bee colony as a single bio organism. If we assume that external factors influence on biology and physiology of any bee colony equally, a scale of an influence of internal factors on the production of bee products will correlate. Diseases belong to internal factors for which we determine a number of bee products. One of the major invasive diseases is the varroatosis. Therefore, nominal productivity of a bee colony depends on the effectiveness of counteraction to distribution of diseases and effectiveness of devices, which struggle with varroatosis. Creation of a new beekeeper equipment based on bio-safe electrotechnology to control varroatosis of bees using UV irradiation, as shown by analytical experimental and calculation data, can significantly increase productivity of bee colonies. At the same time, promising development in this area is creation of unified protective devices located outside a nursing socket and thus do not violate a natural rhythm of operation of bee colonies. It has a positive effect on improvement of their productivity. Such protective devices are the developed hive entrance attachments, which are additionally equipped with a LED module of UV radiation capable of simultaneously performing several functions (therapeutic and prophylactic).

The advantage of the proposed solutions is possibility to create conditions for reduce in non-technological losses of the biopotential of a bee colony, preserving its feeding stocks during a production cycle, and ensuring the sustained operation of a hive entrance attachment in fighting varroatosis.

Justification of geometrical parameters of a hive entrance attachment and UV characteristics of UV radiation provide its effective work to increase productivity of a bee colony.

The disadvantage of studies includes difficulties caused by the cost of indicators of UV radiation and their shortage in the retail network.

The development of the study can be continued in terms of determination of an effect of UV radiation on pathogenic microflora and fauna, as pathogens of infectious disease of bees (mould, mycoses, etc.).

7. Conclusions

1. We established that a bio dose obtained by a bee and a Varroa mite depends on the power of UV installation. A mite and a bee get the maximum value of a bio dose at a wavelength of 265 nm and 297 nm with a power of $36.53 \cdot 10^{-5}$ units. This value corresponds to 1.98 a.u. for a mite and 0.03 a.u. for a bee. Such parameters of a bio dose can heal bees from varroatosis.

2. Analytical studies made possible to substantiate approaches to determination of characteristic geometric parameters of a hive entrance attachment. A recommended length of a tunnel is l=8±0.1 cm, height h=1±0.1 cm, the number of LEDs – 1–4 pieces with a power of 0.08 W and a voltage of 4–7 V taking into account an irradiation dose and a wavelength.

3. We established that effectiveness of the use of a hive entrance attachment equipped with a UV radiation module when fighting bee varroatosis was 83.86 % in 2014, 67.2 % in 2015, 76.33 % in 2016.

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